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ECONOMICS AND BUSINESS MANAGEMENT

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THE IMPACT OF THE TAXATION SYSTEM ON THE FINANCIAL STABILITY OF ENTERPRISES IN THE CONTEXT OF DIGITALIZATION OF THE ECONOMY

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Key words:
taxes, tax systems, taxation of enterprises, financial stability, profitability, digitalization of the economy, digital technologies.

The variability of legislation, the instability of the economy, the growth of rates for certain types of taxes, the increase in the level of tax burden can lead to a decrease in the financial stability of enterprises in various fields of activity. It is determined that a decrease in the financial stability of enterprises can lead to a reduction in the volume of production and sales of products, a decrease in the amount of net income from the sale of products (goods, works, services), gross profit, financial result from operating activities, financial result before taxation and as a result of a reduction in the amount of tax deductions. The article studies changes in legislation relating to the work of enterprises operating on both the general and the simplified tax system. In particular, such changes in tax legislation relate to tax rates, tax conditions, provision of benefits, deadlines for paying taxes, filing tax returns, etc. The importance of taking into account changes in tax legislation in order to timely fulfill tax obligations, submit tax reports and tax returns, as well as avoid the accrual of fines, has been proven. The dynamics of payment of taxes of enterprises in the form of tax revenues to the state budget is analyzed, which confirmed the important role of taxes in the formation of the revenue component of the budget. Cases of violation of tax legislation, which are reflected in the indicators of the tax burden, are considered. The importance of conducting business inspections by the State Tax Service of Ukraine through the use of digital technologies, which is an important tool for preventing cases of tax evasion, has been established. The conditions of functioning of enterprises that significantly influenced the financial stability and the amount of taxes are considered. Directions of influence of taxes on financial stability of enterprises in conditions of digitalization are characterized. Recommendations for improving the taxation system and improving the financial stability of enterprises in the context of digitalization of the economy have been formed.

ВПЛИВ СИСТЕМИ ОПОДАТКУВАННЯ НА ФІНАНСОВУ СТАБІЛЬНІСТЬ ПІДПРИЄМСТВ В УМОВАХ ЦИФРОВІЗАЦІЇ ЕКОНОМІКИ

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Ключові слова:
податки, податкова системи, оподаткування підприємств, фінансова стабільність, прибутковість, цифровізація економіки, цифрові технології.

Змінність законодавства, нестабільність економіки, зростання ставок за окремими видами податків, підвищення рівня податкового навантаження можуть призвести до зниження фінансової стабільності підприємств різних сфер діяльності. Визначено, що зниження фінансової стабільності підприємств може призвести до скорочення обсягів виробництва та збуту продукції, зменшення суми чистого доходу від реалізації продукції (товарів, робіт, послуг), валового прибутку, фінансового результату від операційної діяльності, фінансового результату до оподаткування та як результат скорочення суми податкових відрахувань. У статті досліджено зміни законодавства, що стосуються роботи підприємств, які функціонують як на загальній, так і на спрощеній системі оподаткування. Зокрема, такі зміни податкового законодавства стосуються податкових ставок, умов оподаткування, надання пільг, термінів сплати

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податків, подання податкових декларація та ін. Доведено важливість врахування змін податкового законодавства з метою своєчасного виконання податкових зобов'язань, подання податкової звітності і податкових декларацій, а також уникнення нарахування штрафів. Проаналізовано динаміку сплати податків підприємств у вигляді податкових надходжень до державного бюджету, що підтвердило важливу роль податків у формуванні дохідної складової бюджету. Розглянуто випадки порушення податкового законодавства, які відображаються у показниках податкового бору. Встановлено важливість проведення Державною податковою службою України перевірок бізнесу шляхом використання цифрових технологій, що є важливим інструментом попередження випадків ухилення від сплати податків. Розглянуто умови функціонування підприємств, які значно вплинули на фінансову стабільність та розмір сплати податків. Охарактеризовано напрямки впливу податків на фінансову стабільність підприємств в умовах цифровізації. Сформовано рекомендації до вдосконалення системи оподаткування та покращення фінансової стабільності підприємств в умовах цифровізації економіки.

Statement of the problem

In conditions of instability, the tax system is a significant factor influencing the results of financial and economic activities, the level of profitability of enterprises, which is carried out through an increase in the tax burden. The growth of rates for certain types of taxes leads to an increase in the burden on the work of enterprises, which accordingly affects financial stability and can lead to a decrease in profitability. Therefore, the actual issue is the study of the degree of influence of the tax system on the activities of enterprises in order to formulate recommendations for improving the taxation system.

Analysis of recent studies and publications

As part of the study, it was found that many scholars have studied the tax burden on enterprises, the formation of an effective tax policy as a prerequisite for their financial stability, the introduction of digital technologies to automate the payment of taxes. In particular, it should be noted such scientists: Bezkrovnyi O. V., Doroshenko O. O. [2]; Doroshenko A., Doroshenko O., Teliatnyk V. [7]; Doroshenko O., Troian M. [8]; Drobotia Ya. A., Doroshenko O. O. [9]; Ohrenych Yu. O. [1; 10]; Pankova O. V., Kasperovych O. Yu. [12]; Cherep A., Dashko I., Ohrenych Yu. [16].

Objectives of the article

The article is aimed at studying the impact of the taxation system on the financial stability of enterprises in the context of digitalization of the economy, the formation of directions for optimizing the tax burden and improving the financial stability of enterprises.

Presentation of the main material

Enterprises operate in rather difficult conditions and are exposed to environmental factors. One of the factors that has a significant impact on the financial stability of enterprises is the state of the tax system, the variability of tax legislation and tax policy of the state. An increase in the level of tax burden leads to a decrease in the profitability of enterprises and a deterioration in financial capabilities. An important task is to optimize the tax burden, the use of digital technologies for reporting, control over the payment of taxes, inspections of business entities. Along with this, at enterprises it is advisable to form their own tax policy, to determine the directions of reducing the tax burden, observing the norms of tax legislation.

The study of the chronology of tax reforms in Ukraine allows us to note the stage of adaptation of the tax system to economic conditions and challenges, such as European integration, pandemic, martial law. On the one hand, reforms and changes in tax legislation are aimed at reducing the burden on business, but on the other hand, at ensuring the growth of tax revenues to the budget.

During 2015 amendments were made to the Tax Code of Ukraine, which concerned reducing the number of taxes from 22 to 9, and a unified approach to the administration of taxes and fees was formed. Since January 1, 2015 there was a reduction in the number of taxes and fees, which made it possible to abolish ineffective fees, combine individual taxes, reform local taxes, and introduce UST. This was the catalyst for an increase in the number of registered enterprises in 2016-2017 (Table 1) [4]. In addition, such drastic changes to the Tax Code of Ukraine ensured a reduction in the tax burden on enterprises, which contributed to the growth of their profits, and also created conditions for the opening and development of small businesses.

In 2020 introduced mandatory registrars of settlement transactions for certain categories of small businesses. The introduction of cash registers was aimed at increasing the transparency of financial transactions and ensured an increase in tax revenues. However, in some regions the number of registered individual entrepreneurs for 2021 has decreased due to the mandatory use of cash registers.

During 2020-2021 due to the economic crisis caused by COVID-19, the government introduced tax incentives in the direction of exemption from single tax for private entrepreneurs of the first group and deferral of tax liabilities. Such decisions contributed to the resumption of work and the growth of the number of registered businesses [6].

With the beginning of hostilities in 2022 a simplified regime for small businesses was introduced, which

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allowed fins of groups 1 and 2 under the simplified taxation system not to pay a single tax, as well as 3 groups of individual entrepreneurs to pay a single tax at a rate of 2%. Such actions allowed to support small businesses, which contributed to the resumption of their work [6].

Taking into account the analyzed chronology of changes to the Tax Code of Ukraine, the dynamics of the number of individual entrepreneurs in 2019-2024 has been studied (Fig. 1). We can note that the number of individual entrepreneurs is slowly decreasing, because we have the following changes: in 2023, compared to 2022, the share of open business increased by 41.65% and closed by 20.55%; in 2024, compared to 2023, the share of open business decreased by 2.60%, closed business increased by 0.37%. Full-scale invasion in 2022 part of the business entities was forced to close their activities: in 2022 – 199673 units, in 2023 – 240699 units, in 2024 their activities ceased 241583 units, in 01.03.2025 – 84140 units. The analyzed changes indicate the impact of tax reforms on the adaptation of companies to crisis conditions, and also confirm the importance of the balance between tax policy and support for enterprises.

In order to study the impact of tax policy on the financial performance of enterprises, it is necessary to consider the existing tax systems, the dynamics of tax revenues, to establish the feasibility of using preferential tax regimes, to analyze the impact of taxes on financial indicators. According to the Tax Code of Ukraine, two forms of taxation are defined, in particular, a general and simplified system for business of different categories (Table 2) [13].

The introduction of a simplified taxation system allowed to reduce the tax burden on small businesses, to simplify the mechanism of calculation between the budget and payers. It should be noted that a feature of the simplified taxation system is that each group of taxpayers differs in a set of criteria: entity; single tax rates; rates of military collection; amount of income; number of employees; tax period; types of economic activity. For example, for 1 group of taxpayers under the simplified tax system, the following criteria are provided: entity – only individuals; the single tax rate is 10% (normal) of the subsistence minimum and 15% for individual entrepreneurs (increased); the rate of military duty is 10% of the minimum wage; single social contribution rate – 22% of the minimum wage; the amount of income should not exceed 167 minimum wages per year; employees – absent; tax period – year; type of economic activity – retail [13]. As for the general system of taxation, these criteria do not apply and, accordingly, there are no restrictions on the amount of income, the number of employees, types of economic activity, but a single income tax rate is used for enterprises, that is, there is no progressive approach.

It should be noted that the tax system has shortcomings, that is, the unequal distribution of the tax burden between the payer from different sectors of the economy, the variability of legislation. For a more detailed consideration of the state of the tax system, we will analyze tax revenues in the revenue structure of the consolidated budget of Ukraine during 2020-2024 (Fig. 2). From the analyzed data, it should be noted that in 2024 tax revenues amounted to 58.2% in the structure of consolidated budget revenues and the largest share by share was occupied by personal income tax (16.3%), value added tax (20.5%), corporate income tax (8.3%), excise tax (6.6%). At the same time, it should be noted that for 2024 compared to 2023 tax revenues increased by 27.5%. There is a positive dynamics of taxes paid by enterprises operating on a common taxation system. Along with this, for 2024 the single tax in the structure of tax revenues is 1.9% and relative to 2023 grew by 23.9%, which also confirms the important role of small businesses in filling the budget.

During the studied period, there is a variable dynamics of tax revenues and taking into account the data for 2019-2024 forecast for 2025-2026 has been made. (Fig. 3). In particular, according to forecast data for 2026. provides for an increase in tax revenues, namely personal income tax and levy, corporate income tax, value added tax, single tax. The growth of tax revenues will help stabilize the economic situation and indicate the resumption of work of large and medium-sized businesses. Consequently, the

Table 1 –The impact of tax reforms on business

Year	Number of registered businesses	Reform	Business impact
2016-2017	+15%	reduction of taxes	growth in the number of enterprises
2020	-5% individual entrepreneurs	introduction of a payment transaction registrar	some enterprises have suspended operations
2021	stable	benefits during COVID-19	reduction of bankruptcies and stabilization
2022-2023	+ 5% individual entrepreneurs in the rear regions	simplification for small businesses	small business support

Source: compiled based on [4]

Table 2 –Comparison of the general and simplified taxation systems

Indicator	General taxation system	Simplified taxation system
Taxes	Corporate income tax (rate 18%), value added tax (rate 20%)	Single tax (group 1 – rate 10% of the subsistence minimum and increased by 15%, group 2 – rate 20% of the minimum wage and increased by 15%, group 3 – 3% or 5% of income and increased by 6% or 10%, group 4 – rates determined in the Tax Code of Ukraine)
Accounting	Detailed accounting	Simplified accounting

Source: compiled based on [13]

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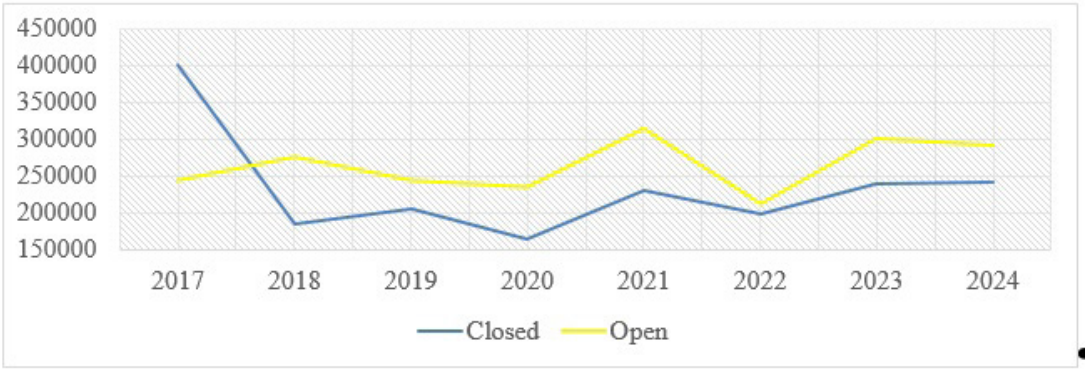

Fig. 1. – Dynamics of the number of individual entrepreneurs in 2019-2024
Source: compiled based on [3; 15]

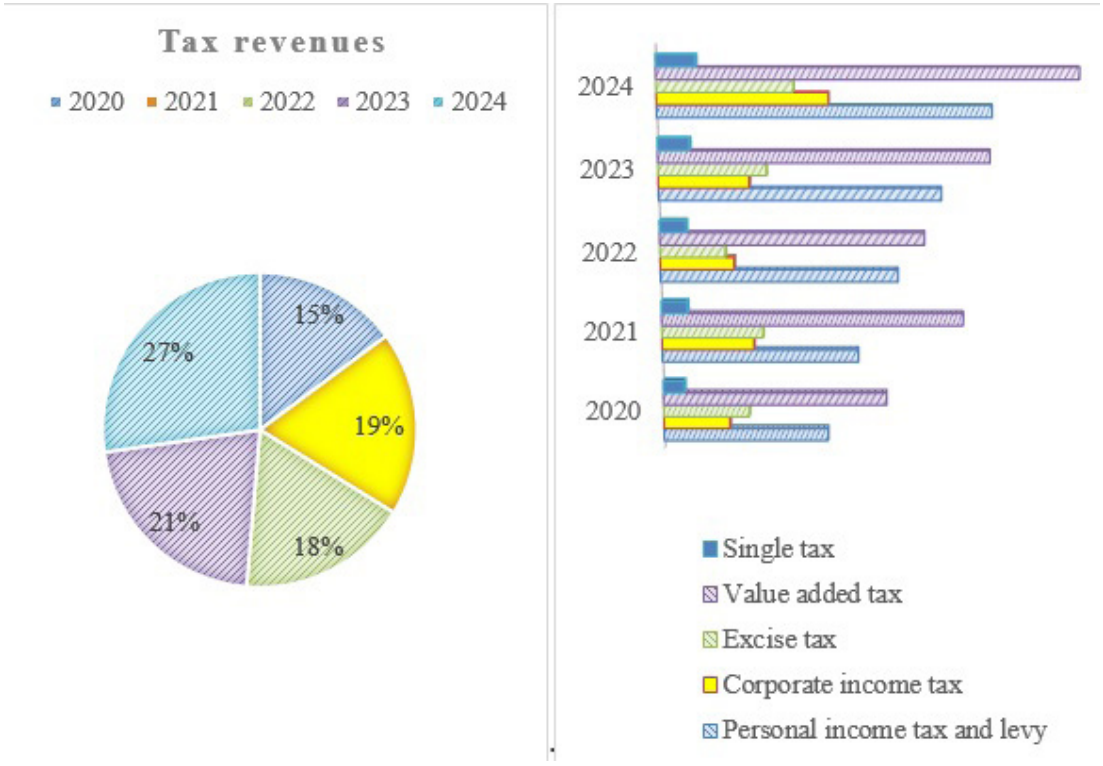

Fig. 2. – Dynamics of tax revenues to the consolidated budget of Ukraine for 2019-2024 (billion UAH)
Source: compiled based on [3]

growth of the taxes considered allows us to note an increase in the wages of employees, the profitability of enterprises. Positive dynamics is observed for a single tax, which in 2026 compared to 2024 will grow by 11.92%, that is, the work of small businesses is activated and deductions in the form of taxes are growing.

Further, it should be established the appropriateness of the use of preferential tax regimes and it should be noted that for a long period the benefits were provided to enterprises of leading industries. In Ukraine, there is a large number of benefits for each type of tax, which leads to the development of various schemes of tax evasion and shortfall in tax deductions to the local and state budgets, increasing the tax burden on business entities. At the same time, it should be noted the positive impact of tax incentives on the preservation of the financial stability of small businesses through the exemption from paying a single tax.

In recent years, the positive dynamics of tax revenues is due to the improvement of tax administration, increasing the efficiency of the tax system, the work of the State Tax Service (STS), which carries out constant inspections in order to combat tax evasion. In recent years, tax legislation has undergone simplifications to support business, as some taxes were reduced or temporarily abolished, which allowed businesses to work legally and avoid a significant tax burden.

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In addition, all these changes affect the financial stability of enterprises through the improvement of the tax system.

Factors such as COVID-19, martial law in Ukraine during 2019-2022 negatively affected the solvency of taxpayers, which made it impossible to pay tax liabilities in a timely manner and led to an increase in tax debt (Fig. 4). In particular, during 2020-2022 there is an increase in tax debt, but in 2023 relative to 2022 there was a 4% reduction. The growing tax burden on businesses, correspondingly affecting their financial stability, led to an increase in tax debt at the end of 2024.

Taking into account the dynamics of tax debt, it is necessary to consider the main violations that occur in the field of taxation in Ukraine and are related to the shadow economy, tax schemes, abuse of benefits, namely: fictitious entrepreneurship and optimization schemes, which leads to tax evasion, such as income tax, personal income tax; illegal refund of value added tax or overstatement of tax credit amounts; unofficial employment, i.e., the postponement of an employment contract, which reduces the budget revenues from personal income tax, military duty, and single social contribution; unregistered entrepreneurial activity, which leads to concealment of income and non-payment of taxes to the budget; use of tax benefits for other purposes, which leads to a reduction in tax liabilities; understatement of the tax base; submission of false reports by including false data; sale of goods, provision of services without the use of registers.

The study identified the risks of failure to fulfill the plan of tax revenues to the state and local budgets (Table 3). These risks lead to a reduction in tax revenues, which may lead to a decrease in financing of the expenditure side of the budget.

The prerequisite for reducing tax debt, preventing cases of tax evasion, risks of non-fulfillment of the tax revenue plan is conducting control and verification work by the State Tax Service of Ukraine. Conducting tax audits allows to maintain transparency of financial transactions of enterprises. Before the war, the STS regularly conducted scheduled and unscheduled business inspections, which allowed maintaining fiscal discipline. However, with the introduction of martial law, a moratorium on inspections was temporarily imposed, in particular in 2022. there was an actual suspension of most planned inspections in order to reduce administrative pressure on entrepreneurs. Since December 2023 the moratorium on inspections was lifted. Results of GFS control and check operation are given in Table 4. According to the data given during 31.12.2024 compared to 2023 the structure of planned inspections of

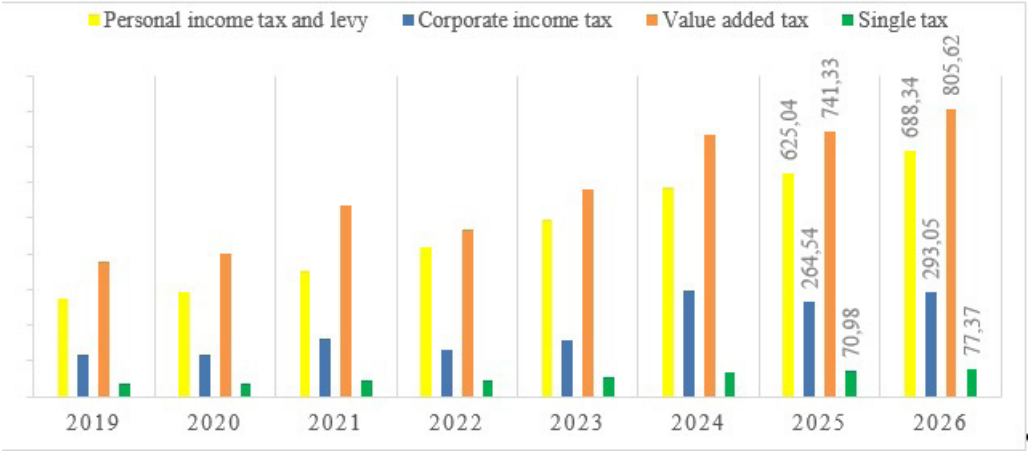

Fig. 3. – Dynamics of tax revenues in 2019-2024 and forecast for 2025-2026 (bn UAH)
Source: compiled based on [3]

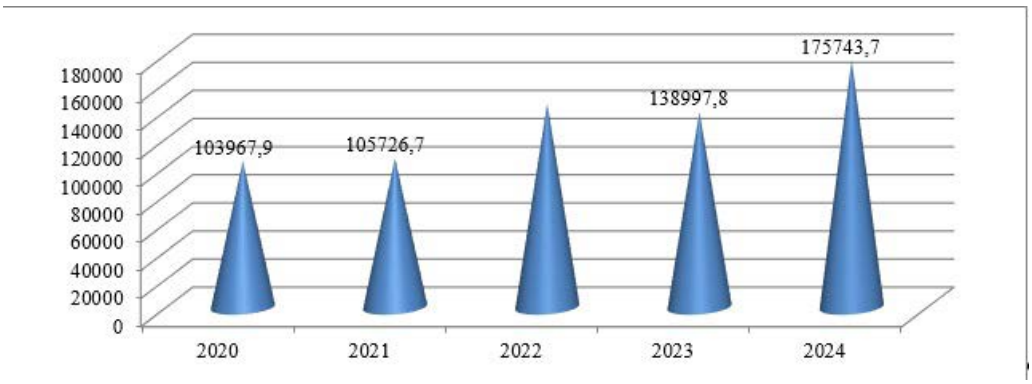

Fig. 4. – Dynamics of tax debt in Ukraine in 2020-2024 (million UAH)
Source: compiled based on [4]

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the STS has the following changes: the number of planned inspections of legal entities on the general tax system has increased by 3.03 times; the number of planned inspections of legal entities in the simplified taxation system increased by 9.10 times. As for unscheduled inspections, their number for legal entities on the general tax system decreased by 17.16% and for legal entities on the simplified tax system decreased by 5.43% during 2024. compared to 2023.

In conditions of complication of doing business, variability of tax legislation, instability of the economic situation, the indicators of financial activity of enterprises worsen. In particular, 32% of entrepreneurs say that they face obstacles from regulatory authorities, and 26% complain about high taxes [12]. Accordingly, the growing tax burden is the reason for the decline in profitability of enterprises.

Among the areas of influence of taxes on the financial stability of enterprises in the context of digitalization, which have a negative impact, it should be noted:

1. tax reporting and financial discipline. At the beginning of martial law, many enterprises had problems with the submission of financial and tax reports due to hostilities, loss of documents;

2. tax burden can reduce the solvency of enterprises by directing part of the profits to pay taxes. For enterprises operating on a common taxation system, tax rates were not reduced during martial law, which reduces their solvency;

3. reduction of the financial result after taxation, that is, the growing level of tax burden on enterprises is the basis for a decrease in net profits, which negatively affects financial capabilities and development;

4. slowing down investment attraction. Frequent changes in tax legislation, the complexity of the tax system, the lack of clear rules and conditions of taxation creates uncertainty for potential investors, which caused the outflow of foreign investment;

5. impact on the labor market. A decrease in household income causes a decrease in purchasing power, which is the reason for a decrease in net income from the sale of products of enterprises;

6. the risk of tax information leakage in the context of digitalization and the threat of cyber attacks;

7. variability of tax legislation creates difficulties for enterprises and their non-accounting can lead to the accrual of fines.

Along with this, in the era of digitalization, taxes affect financial stability and can form opportunities: the use of digital technologies in order to improve the tax payment management process; introduction of tax incentives for IT-companies reduces the tax burden and increases financial stability; Reduce the cost of administering taxes and fees the use of registrars of settlement transactions increases the transparency of doing business, minimizes the possibility of tax evasion; digitalization of State Tax Service contributes to better interaction with business, advising on changes in legislation, increases data transparency, which prevents the accrual of fines; the use of software products for E-audit, the definition of tax risk allows you to include in the audit plans those entities that have the risk of non-payment of taxes and prevent the case of tax evasion.

In order to study the impact of taxes on financial stability, the financial indicators of the enterprise Jysk Ukraine LLC were analyzed (Fig. 5). During the period under review, there was a 5% increase in net sales revenue in 2024 compared to 2023, which ensured a further increase in tax payments. It should be noted that in 2024, compared to the previous period, the financial result before tax decreased by 2.23%, net profit decreased by 13.09%, income tax expenses increased by 1.24 times, but in 2022 compared to 2021 decreased by 95%. The dynamics of the income tax indicator during 2022 was analyzed. explained by the fact that the company was a single tax payer for the third group for 01.04.2022-31.07.2023 years.

Table 3 – Risks of not fulfilling the tax revenue plan

Risk	Description
Social risks	The decline in household income will result in lower payments of personal income tax, value added tax, and excise taxes.
Economic risks	The shadow economy and tax evasion significantly reduce tax revenues, which affects the government's ability to form the expenditure side and finance budget programs.
Administrative risks	Reduced control of tax authorities over taxpayer registration, tax reporting, and tax payments will lead to a decline in tax revenues; corruption in tax and customs authorities reduces public confidence.
Technical risks	Outdated software, malfunctions in the electronic systems of tax authorities, and cyber attacks on information systems can lead to complications in taxpayer accounting and a decrease in tax revenues.

Source: compiled based on [11]

Table 4 – Indicators of control and inspection work of legal entities by the State Tax Service in 2021-2024 (units)

Type of inspection	2021	30.11.2022	2023	2024
	Scheduled inspections of the State Tax Service			
Legal entities	2 305	597	445	1 917
On the general taxation system	2 094	546	425	1 715
On the simplified taxation system	211	51	20	202
	Off-site inspections of the State Tax Service			
Legal entities	9 010	4 953	13 288	11 118
On the general taxation system	8 372	4 574	12 348	10 229
On the simplified taxation system	638	379	940	889

Source: compiled based on [5]

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To summarize, the chosen taxation system and, accordingly, the payment of taxes affect the financial stability of enterprises. The growing tax burden, constant changes in tax legislation, existing problems with the system of electronic administration of value added tax, fuel sales, and submission of reports through the taxpayer's electronic office create risks of penalties, which affects financial performance. An important task is to reduce the tax burden, improve the work of the State Tax Service, and improve the work of the taxpayer's electronic office, which will allow taxpayers to take into account changes in legislation in a timely manner, pay taxes and function effectively.

In order to improve the taxation system in terms of digitalization of the economy, the following recommendations have been formed: improving the work of the STS, minimizing corruption, which will ensure the establishment of communication with taxpayers and increase their confidence in the tax authorities; improving the work of the taxpayer's electronic cabinet, electronic document management system, which will contribute to the automation of filing tax reports, processing documents, increasing transparency in financial transactions; adjustment of the list of tax benefits and their expansion for large businesses will reduce the tax burden, increase financial stability; transparency of the tax system by introducing the experience of EU countries towards digitalization; expansion of electronic services for calculating tax amounts (for example, personal income tax, value added tax, income tax, single tax); introduction of tax holidays or reduction of tax rates for enterprises; automation of the tax control system for taxpayers in order to prevent cases of tax evasion.

To improve the financial stability of enterprises, measures have been formed: the introduction of digital technologies at enterprises will automate the filing of reports, tax returns, prevent cases of violation of tax deadlines; training of employees at enterprises in the direction of accrual, payment of taxes, reporting by using the online training resource of the STS; attracting investments in digital technologies for financial management, reporting, registration of tax returns at enterprises; implementation of cost management programs that will optimize them; use of state support programs as a source of raising funds; expanding the range of products and adjusting prices in accordance with the capabilities of consumers; implementation of ERP systems for financial management, forecasting of performance indicators, use of software products for digitalization of accounting and tax accounting; monitoring the list of tax benefits and their use.

In the context of digitalization, improving the tax system will ensure not only an increase in the amount of tax revenues to various budgets, but will contribute to the growth of performance indicators of enterprises, strengthen their financial stability, and expand sales markets. At the same time, an important task is to increase the efficiency, transparency of the tax system, improve tax policy at the state level, which will contribute to the development of the economy and stabilize the situation in the country.

Conclusions

It is established that enterprises pay a lot of different taxes, which forms a significant amount of tax revenues. In addition, the level of tax burden is constantly growing, which affects the financial stability of enterprises. The introduction of the established recommendations will improve the taxation system and improve the performance of enterprises. In addition, an important issue is the introduction of digital technologies at the state level to automate the submission of reports and tax returns, control over the payment of taxes, inspections of business entities, and the formation of a tax rating. All this will help to avoid cases of tax evasion, transparency of doing business, increase the profitability of enterprises, increase tax deductions, which in turn will ensure the development of the country's economy.

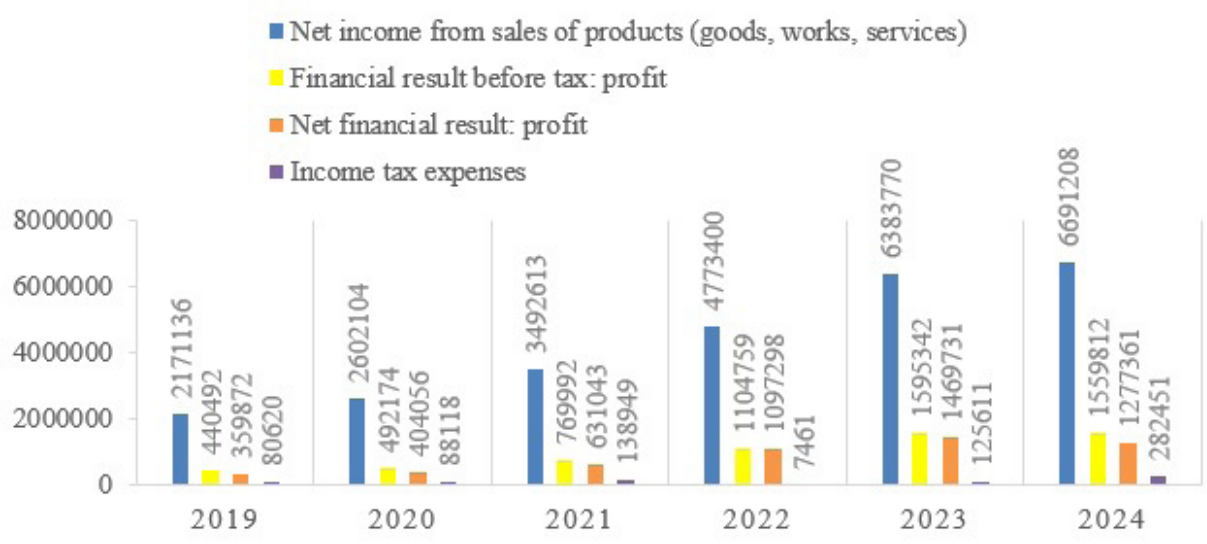

Fig. 5. – Financial indicators of Jysk Ukraine LLC in 2019-2024 (UAH)

Source: compiled based on [14]

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STRATEGIC APPROACHES TO THE DIGITAL TOOLS APPLICATION BY ENTERPRISES IN INDUSTRY 4.0 ENVIRONMENT

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Key words:
Industry 4.0, digital strategy, digital transformation, digital tools, business processes, automation, artificial intelligence, innovation.

Strategic approaches to the implementation of digital tools by enterprises in the context of Industry 4.0 are investigated in this paper. The authors substantiate the importance of digital transformation as a comprehensive process including intellectualization, automation, integration of artificial intelligence, the Internet of Things, Big Data, cloud technologies and digital platforms.
The evolution of scientific approaches to the formation of digital strategy, its role in increasing the competitiveness of enterprises and adaptation to the dynamic digital environment are considered. The concept, essence, purpose, main objectives and main tools for implementing the digital strategy of enterprises are investigated. The main tools of digital transformation such as: digital marketing, digitalization of business processes, online presence, e-commerce, and busines- flexibility management are identified
Particular attention is paid to the analysis of successful digitalization examples among Ukrainian companies, including PrJSC «Ternopil Dairy Plant», LLC «Agroprod-service», LLC «Nova Poshta» and LLC «Leoni Wiring Systems UA GmbH», which indicates the ability of Ukrainian enterprises to adapt to the challenges of the digital economy. The strategic application of digital tools is considered not only as a technological innovation, but as an integrated management concept that ensures increased efficiency of business processes, flexibility to changes in the external environment, and the formation of long-term competitive advantages.
The model for implementing the digital strategy is proposed. This model includes five key stages: assessment of the digital readiness of the enterprise, strategic vision formation, development and implementation of digital solutions, their integration into operational activities, monitoring and adjustment of the strategy.
It is emphasized in this paper that the formation and implementation of the digital strategy should be considered as systemic and interdisciplinary process that covers not only technological, but also economic, organizational, social, and personnel aspects of enterprise development in the digital era.

СТРАТЕГІЧНІ ПІДХОДИ ДО ВИКОРИСТАННЯ ЦИФРОВИХ ІНСТРУМЕНТІВ ПІДПРИЄМСТВАМИ В УМОВАХ ІНДУСТРІЇ 4.0

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Ключові слова:
Індустрія 4.0, цифрова стратегія, цифрова трансформація, цифрові інструменти, бізнес-процеси, автоматизація, штучний інтелект, інновації.

У статті досліджено стратегічні підходи до впровадження цифрових інструментів підприємствами в умовах Індустрії 4.0. Автори обґрунтовують важливість цифрової трансформації як комплексного процесу, що охоплює інтелектуалізацію, автоматизацію, інтеграцію штучного інтелекту, інтернету речей, великих даних, хмарних технологій та цифрових платформ.
Розглянуто еволюцію наукових підходів до формування цифрової стратегії, її роль у підвищенні конкурентоспроможності підприємств та адаптації до динамічного цифрового середовища. Досліджено поняття, сутність, мету, основні цілі та основні інструменти реалізації цифрової стратегії підприємств.

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Визначено основні інструменти цифрової трансформації: цифровий маркетинг, діджиталізація бізнес-процесів, присутність в Інтернеті, e-commerce та управління бізнес-гнучкістю.
Особливу увагу приділено аналізу прикладів успішної цифровізації українських компаній, серед яких ПрАТ «Тернопільський молокозавод», ТОВ «Агропрод-сервіс», ТОВ «Нова пошта» та ТОВ «Леоні Ваерінг Системс УА ГмбХ», що свідчить про здатність українських підприємств адаптуватися до викликів цифрової економіки. Стратегічне використання цифрових інструментів розглядається не лише як технологічна інновація, а як інтегрована управлінська концепція, що забезпечує підвищення ефективності бізнес-процесів, гнучкість до змін зовнішнього середовища та формування довгострокових конкурентних переваг.
Запропоновано модель реалізації цифрової стратегії, що включає п'ять ключових етапів: оцінка цифрової готовності підприємства, формування стратегічного бачення, розробка й впровадження цифрових рішень, їх інтеграція в операційну діяльність, моніторинг та коригування стратегії.
У статті підкреслено, що формування та реалізація цифрової стратегії має розглядатися як системний та міждисциплінарний процес, який охоплює не тільки технологічні, а й економічні, організаційні, соціальні та кадрові аспекти розвитку підприємства в умовах цифрової епохи.

Statement of the problem

Under modern conditions of dynamic development of the global economic space and growing competition between business entities in the world market, the formation of effective strategic approaches to the implementation of digital technologies is of particular importance. This is due to the transformational processes caused by the Fourth Industrial Revolution – Industry 4.0, which significantly changes the paradigm of the enterprise operation, reorienting their activities towards intellectualization, automation, digitalization of business processes and the use of cyber-physical systems.

In the context of the rapid development of innovative technologies, particularly artificial intelligence, the Internet of Things (IoT), cloud computing, Big Data, machine learning, and blockchain technologies, there is an urgent need for comprehensive understanding of the strategic principles of digital transformation. These principles should take into account not only technological, but also organizational, economic, social, and legal aspects of implementing digital tools in the production and management activities of enterprises in various industries.

The relevance of this investigation is caused by the need of national business to adapt to the new challenges of the digital era, optimize management decisions in the digital environment, increase the level of competitiveness and innovative capacity of enterprises by developing effective strategic guidelines and application of modern digital tools as a key factor in ensuring sustainable development in the context of Industry 4.0.

Analysis of available researches and publications

A number of scientists have studied the strategic guidelines for the application of digital tools by enterprises in the context of Industry 4.0. It is necessary to note among them the works by Ostrovska H.Y., Ostrovskyi O.T. [1], Klevtsevych N.A. [2], Melnyk L.H., Karintseva O.I., Kalinichenko L.L., Kharchenko M.O., Tarasenko S.V. [3], Chernikov D.I., Hryshko S.V. [4], Zubkov A., Maigurova D., Misiunia R. [5], Shynkovych A.V., Vasylieva N.B., Romanenko O.V. [6] and others. Each of the above mentioned scientists presented their own scientific research on defining strategic approaches to the application of digital tools by enterprises. In particular, Ostrovska H.Y. and Ostrovskyi O.T. [1] note the specifics of digital transformation in modern conditions, emphasizing its key features, including: new wave of technological development, growing demand for digital technologies, shortening the life cycle of technologies, new impulses of digitalization due to the consequences of the COVID-19 pandemic, the growing importance of knowledge culture as well as technological and social risks.

The authors of the study emphasize that in the future, the priority areas of technological development that will attract significant attention from the industrial sector will be neurotechnology, artificial intelligence, innovative wireless communication tools, advanced manufacturing technologies, as well as virtual and augmented reality technologies. In the context of these trends, the digital transformation of industry will gradually evolve towards the development of flexible, highly adaptive, efficient and decentralized networked production, based on digital platforms capable of integrating all participants in the value chain into a single functional ecosystem.

Scientist N.A. Klevtsevych [2] investigated the evolution of modern approaches to business process management in the context of digitalization, focusing on their classification according to the level of change radicality – from gradual to innovative. She substantiated that the key competitive advantages of the enterprise are ensured by integrated management of resources and business processes based on digital technologies.

The team of scientists [3] carried out comprehensive investigation of the digital transformation of business processes in the Ukrainian economy, focusing on the adaptation of Ukrainian and foreign enterprises to the latest technological changes. They analyzed key strategies, tools, and stages of implementing digital innovations in various industries, taking into account industry specifics

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and the needs of business models. The main challenges of digitalization are outlined and the role of the state and stakeholders in creating favorable environment for sustainable digital business development in the future is defined.

Chernikov D.I. and Hryshko S.V. [4] studied the specifics of implementing Industry 4.0 and Industry 5.0 technologies, focusing on the development of the system of strategic risks that arise during the implementation of digitalization projects at enterprises of the key sectors of the Ukrainian economy. Within their study, they analyzed the key factors in the development of both concepts and proposed the approach to systematizing strategic risks, covering eight classes of such risks. An important result of the study is the identification of the characteristics of each type of risk, including technological, financial, brand-related, personnel, and hybrid impact risks, which makes it possible for enterprises to manage threats during the digital transformation process more effectively.

Zubkova A., Maigurova D., and Misiunia R. [5] carried out a comprehensive scientific research dedicated to the comparative analysis of the key characteristics of Industry 4.0 and Industry 5.0 focusing on technological tools enabling the digital transformation of international enterprises. In their research, the authors identified common and distinctive features between two industrial concepts, described the possibilities of using innovative software in various industries, and analyzed modern challenges associated with the implementation of the latest technologies. Special attention in the research is paid to the integration of artificial intelligence, automation, and human-machine interaction as defining components of Industry 5.0, which opens new prospects for incresing the efficiency and flexibility of manufacturing processes in the global business environment.

Researchers – scientists Shynkovych A. V., Vasilieva N. B. and Romanenko O. V. [6] carried out thorough research of innovative approaches to enterprise management in the context of digital transformation, focusing on strategies for adapting business to dynamic technological changes. In their research, the authors analyzed the impact of digital technologies – such as artificial intelligence, the Internet of Things, automation, and Big Data – on the formation of modern business models, the optimization of operational processes, and the enhancement of enterprises' digital resilience. They proved that the integration of innovation strategies focused on digitalization contributes to enhancing business competitiveness and creates the foundation for its long-term development in the context of external environmental challenges.

Summarizing the main researches and publications on the investigated topic, it should be noted that scientists pay significant attention to the analysis of the enterprise digital transformation, investigation of Industry 4.0 and 5.0 features, as well as determination of strategic directions for the application of digital technologies in business process management.

The researches cover a wide range of aspects: from the classification and evaluation of business models to risk management, from the industry-specific features of digitalization to the creation of adaptive organizational environment. Carried out analyses indicate the presence of various scientific approaches to understanding the essence of digital transformations, in particular through the prism of innovative development, technological integration, and strategic management. The emphasis is placed on the importance of implementing digital platforms, artificial intelligence, the Internet of Things, automation, and data analytics as key tools for increasing enterprise efficiency in the digital age.

At the same time, problems related to the practical implementation of strategic approaches to the use of digital tools by enterprises in the context of Industry 4.0 remain insufficiently developed. In particular, the problems of integrating digital solutions into business processes, taking into account industry specifics, organizational culture, and the level of digital maturity of enterprises, require further consideration. It is also important to carry out in-depth investigation of the mechanisms for developing, implementing, and evaluating the effectiveness of digital strategies in conditions of high external environment turbulence, which requires systemic approach and interdisciplinary analysis.

The objective of the scientific investigation is comprehensive justification and development of strategic approaches to the application of digital tools in the context of Industry 4.0, taking into account the latest technological trends, challenges of digital transformation, and the needs of enterprises to improve the efficiency of production, management, and communication processes. This will contribute to the formation of innovation-oriented development model, ensure business flexibility, increase competitiveness at the national and international levels, and create the foundation for sustainable economic growth in the digital economy.

Statement of the task

In order tj achieve the objective set in the scientific research, the following tasks were identified, in particular: determining the essence and content of the digital strategy of the enterprise; studying the purpose, goals and tools used in the formation of the digital strategy of enterprises; determining the specifics of the digital strategy toolkit; presenting examples and features of the use of digital tools in the practice of Ukrainian enterprises; developing a sequence of stages for implementing the digital transformation strategy at the enterprise; determining the advantages of using the model for implementing the digital transformation strategy at the enterprise.

The following methods were used to present the main results of this scientific study: grouping, generalization, comparison, synthesis and analysis, planning, and forecasting.

Presentation of the main research material

In the current context of technological shifts driven by the transition to the Industry 4.0 concept, the strategic use of digital tools is becoming crucial for ensuring the competitiveness of enterprises. Digitalization of business processes, automation of production, integration

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of artificial intelligence, Big Data and the Internet of Things are radically changing approaches to resource management, interaction with consumers and the formation of value chains. In this context, strategic approaches to the implementation of digital technologies should be comprehensive, flexible, and adaptive to the challenges of the dynamic digital environment.

In scientific literature, the term "digital strategy" is distinguished as the basis for implementing digital transformations in the long term.

The research of scientific approaches to the concept of "digital strategy" indicates a variety of interpretations that reflect different aspects of its formation and implementation in the activities of enterprises. Let us consider each of the presented approaches and give our own assessment of their significance.

According to the definition of Matt S., Hess T., and Benlian A., digital strategy is understood as the identification of future business opportunities through the integration of new digital technologies. This approach emphasizes the role of technology as a key driver of enterprise transformation, enabling the development of long-term competitive advantages. In our opinion, the presented approach is fundamental, as it defines digital strategy as the basis of innovative development. However, it should be supplemented with analysis of the impact of digital changes on organizational processes and the human factor.

Ismail M., Khater M., and Zaki M. consider digital strategy as transforming the enterprise into digital organization with personalized approach to customers and data-driven decision-making. This approach focuses on digital interaction and business adaptability to changes in the external and internal environment. The presented approach reflects current trends in customer-centric and analytics-driven business and is relevant for enterprises striving for flexibility and competitiveness.

Voskoboieva O., Romashchenko O., Kirzhetska M., and Kirzhetskyi Yu. interpret digital strategy as a component of corporate strategy that is integrated into the operational and functional strategies of the enterprise. This approach emphasizes the need to align digital initiatives with the overall business strategy to ensure synergy. Such integration is critically important for the integrity of strategic management, as it avoids fragmentation and ensures the comprehensive development of the organization.

The approach by Panchuk A.S. and Malkova K.O. considers the digital strategy of the enterprise as the process of coordinating the digitalization of key areas of activity – business models, customer experience and operational processes carried out taking into account the overall strategic direction. The main aim of this approach is to create or increase the value of products, services and solutions in the context of the digital economy. This approach has comprehensive and systemic nature, as it recognizes that digital transformation is not limited to the implementation of individual technologies, but is coordinated change in all key areas of an enterprise activities. Special attention is paid to customer experience, which meets modern market requirements, where individualization and quality of interaction with the customer determine competitiveness.

Summarizing the approaches of the scientist, it should be noted that digital strategy is comprehensive approach to planning and implementing digital technologies and tools aimed at achieving the strategic goals of the enterprise, optimizing business processes, and increasing its competitiveness in the conditions of digital market transformation. Digital strategy encompasses the selection of technological solutions, organizational changes, and management practices that enable more effective adaptation to the rapidly changing technological environment and maximize value creation for all stakeholders.

The goal of implementing the digital strategy is to ensure the enterprise competitiveness through the comprehensive digital transformation of its business models, operational processes, and customer experience, taking into account modern technological trends and the requirements of the digital economy. All above mentioned involves not only the implementation of the latest digital tools, but also the optimization of the company activities to create added value and increase efficiency.

At the same time, the main goals of ensuring the implementation of the digital strategy at Ukrainian enterprises are:

– increase of the operational flexibility and adaptability of the enterprise to the external environment changes;

– integration of digital technologies into key business processes for automation and optimization of operations;

– improvement of customer experience by personalization of products and services, as well as the development of digital interaction channels;

– creation of new income sources due to innovative digital products and services;

– strengthening market positions by improving the quality, speed and transparency of business processes;

– ensuring digital security and managing risks associated with digital transformation.

The goals of digital strategy for small business enterprise will be achieved due to its key tools (Fig. 1) [10, pp. 12–13]: digital marketing; digitalization of business processes; online presence; e-commerce; and business agility management.

Let us consider the features of using each of the tools in the digital strategy of enterprises in detail. In particular, digital marketing involves the use of various digital channels and technologies to attract the target audience, build a positive image, and increase sales. The peculiarity of digital marketing is the ability to target consumers precisely and make optimal use of the marketing budget.

Digitalization of business processes includes the implementation of information technologies to automate, optimize, and increase the transparency of an enterprise internal operations. It contributes to the increase of operational efficiency, costs reduction, and improvement of management decisions.

Online presence is necessary condition for ensuring communication with customers and partners, increasing brand awareness, and expanding market opportunities; at

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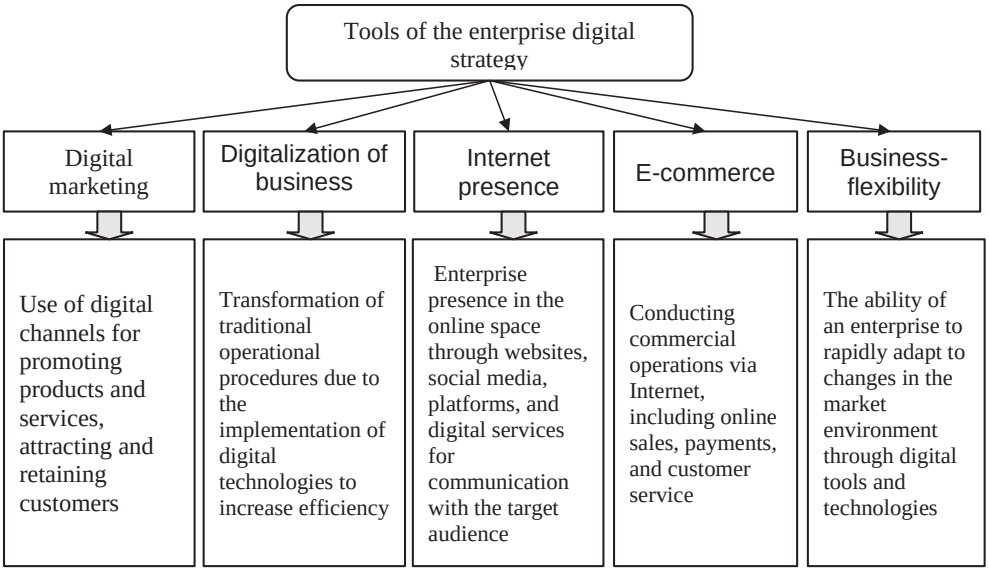

Fig. 1. Types of enterprise digital strategy tools [10, p. 13]

the same time it includes website development, activity on social networks, and the use of other digital platforms.

E-commerce involves organization of the sale of goods and services through Internet channels, which contributes to the expansion of the customer base and optimization of the sales processes. An important component is the selection of appropriate digital platforms and services for payment processing and logistics.

Business agility management involves creation of the digital environment that enables rapid adaptation to changes in both external and internal conditions due to the digital integration of business models, processes, and offerings, thereby ensuring the stability of the enterprise in of market instability conditions.

Accordingly, the application of the above mentioned digitalization tools is a decisive factor for the successful operation and development of various enterprises in the modern conditions of Industry 4.0.

Positive examples of implementing digital strategy using digitalization tools are already actively applied in the activities of Ukrainian enterprises and indicate gradual transition of businesses toward the innovative development model. Thus, the well-known Ukrainian PrJSC "Ternopil Dairy Plant" [12] implemented an ERP system, automated quality control and CRM, making it possible to improve control over production processes, increase product quality and the efficiency of interaction with customers. The use of IoT for monitoring the quality of dairy products has become particularly important.

LLC "Agroprod-Service" [13] implemented precision farming, the use of Big Data for agroanalytics, and automation of document management, thereby optimizing production costs and significantly increasing crop yields.

One of the leaders in digital transformation in the service sector is LLC "Nova Poshta" [14], which has implemented ERP system, mobile application, automated sorting terminals, and digital addresses. This has significantly increased the speed of parcel processing, minimized errors, and ensured a high level of service for customers.

The logistics aspects of digitalization were highlighted at "Leoni Wiring Systems UA GmbH" [15], where the implementation of automated lines, digitization of warehouses and logistics, as well as the use of AI analytics, optimized costs and minimized production delays.

The given examples demonstrate that the strategic implementation of digital technologies not only enhances the internal efficiency of enterprises but also creates long-term competitive advantages for these companies in the market.

To stimulate the development of digital strategy in Ukrainian enterprises, it is necessary to create comprehensive mechanism that provides gradual, step-by-step implementation of digital transformations, taking into account industry specifics, the level of digital maturity, available technical infrastructure, human resources, and the financial capacity of the business entity. Such approach will not only minimize the risks associated with technological upgrades but also ensure the effective use of digital tools at each stage of strategy implementation. The defining stages of implementing the enterprise digital transformation strategy are presented in Fig. 2.

At the first stage, the initial assessment of the company's readiness for digital transformation is carried out. It includes diagnosing existing business processes, IT infrastructure, digital resources, and personnel competencies. The goal of this stage is to identify strengths and weaknesses, barriers, and potential for implementing digital technologies. Analysis of the internal environment of the enterprise is carried out, the degree of process automation, the level of digital tools use, and the availability of the necessary personnel are determined.

At the second stage, strategic vision for the enterprise digital development is formed. It is based on the in-depth analysis of the market, consumer expectations, competitor behavior, and current industry trends. At the same time, key

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areas of digital development are developed, strategic goals, priorities, and performance indicators are determined. It is important that the digitalization strategy aligns with the overall mission and long-term development goals of the enterprise.

At the third stage, specific digital solutions are developed and implemented in order to optimize processes and enhance competitiveness. Such solutions may include enterprise resource planning (ERP) systems, customer relationship management (CRM), e-commerce platforms, cloud services, Big Data analytics, Internet of Things (IoT), artificial intelligence, etc. The choice of tools depends on the specifics of the company activities and available resources.

The fourth stage involves the integration of digital tools into the daily activity of the enterprise. This requires changes of the internal procedures, adaptation of the organizational structure, and the development of employees' digital skills. Special attention is paid to employee training and professional development, as well as to changing corporate culture in favor of openness to innovation, flexibility and creativity. Digitalization tools should become an integral part of operational activities.

At the final, fifth stage, monitoring and evaluation of the results of digital transformation are carried out. The achieved indicators are regularly monitored, the effectiveness of the implemented solutions is analyzed, and areas for further improvement are identified. If necessary, the digital development strategy is adjusted according to changes in the external environment, market conditions, or internal challenges. Continuous monitoring ensures the adaptability of the digital strategy and its sustainability in the long term.

Such logic for digital strategy development provides a number of key advantages for enterprises implementing digital transformation processes, among which the following should be highlighted:

– formation of holistic and phased management model makes it possible to optimize the resource distribution, ensuring more effective investment in the implementation of digital technologies and to minimize the risks of financial losses;

– systematic approach to digital transformation promotes increased flexibility and adaptability of the enterprise to rapidly changing market conditions and technological trends, and is critically important for maintaining competitiveness;

– integration of modern digital tools into business processes improves the quality of management decision-making due to access to up-to-date analytical data and automation of routine operations, and as a result contributes to increased productivity and reduced operating costs;

– consistent implementation of the stages of the digital strategy ensures systematic staff training, forming digital competence culture, and serves as the foundation for the introduction of innovations and further development of the enterprise;

– such management model contributes to the formation of long-term partnerships with customers, suppliers and other stakeholders, due to the transparency of business processes and the increase in the level of service, which significantly increases the reputation and trust of the company in the market.

Accordingly, the implementation of the structured strategic model of digital transformation is strategically important factor in ensuring sustainable development, innovation, and stable growth of Ukrainian enterprises.

Conclusions

Summarizing the results of the investigation, it should be noted that in modern conditions digital strategy is

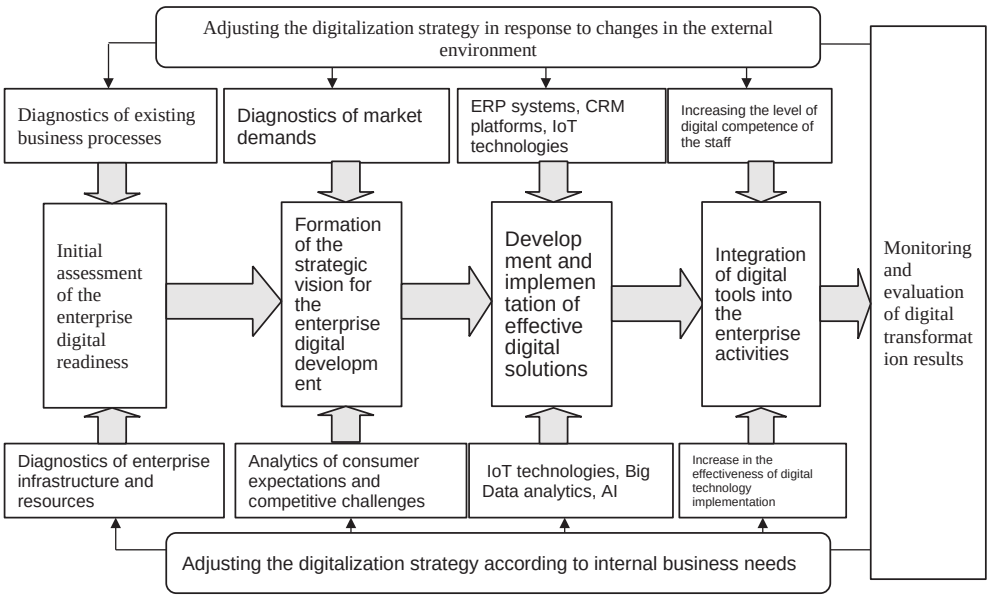

Fig. 2. Main stages of implementing the digital transformation strategy at the enterprise [author's own development]

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considered not only as the implementation of individual technological innovations, but as an integrated system of transformational process management, which ensures the creation of new value for all stakeholders. Successful implementation of digital strategy involves phased approach, which includes: initial assessment of the digital readiness of the enterprise; formation of strategic vision of digital development; development and implementation of appropriate solutions; their integration into operational activities; as well as constant monitoring and adjustment in accordance with internal and external changes.

Five main tools for implementing the digital strategy have been identified: digital marketing, digitalization of business processes, online presence, e-commerce and business agility management. Their application contributes to process automation, cost optimization, improvement of customer service quality, creation of new sales channels and increased flexibility of the enterprise.

Practical examples of the implementation of digital strategies in the activities of Ukrainian companies (PrJSC "Ternopil Dairy Plant", LLC 'Agroprod-service", LLC "Nova Poshta", LLC "Leoni Wiring Systems UA GmbH") confirm the effectiveness of digital transformation in the context of increased productivity, improved product and service quality, strengthened market positions and reduced operational risks.

To stimulate the development of digital strategy, mechanism and sequence of its implementation are proposed. This implementation includes several stages: initial assessment of the enterprise's readiness for digital transformation, formation of strategic vision for the enterprise's digital development, development and implementation of effective digital solutions, integration of digital tools into the enterprise's activities, monitoring and evaluation of the results of digital transformation. This sequence of stages makes it possible to ensure systematic and consistent approach to digital transformation, minimize organizational and technological risks, optimize the use of resources, and achieve consistency between the enterprise's strategic goals and implemented digital solutions. Each stage serves as logical component of the single process that contributes to the formation of adaptive, innovative business environment capable to respond effectively to the challenges of digital economy and to ensure sustainable growth of the enterprise in the long term.

In general, the development and implementation of digital strategy is an integral part of modern strategic management and should be considered as a long-term investment in increasing the innovative potential, efficiency and sustainable enterprise development in the digital economy.

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ECONOMIC AND MATHEMATICAL MODELING AND INFORMATION TECHNOLOGIES IN ECONOMICS

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CONCEPTUAL MODEL FOR FORECASTING THE DYNAMICS OF ELECTRIC VEHICLE SALES VOLUMES ON THE GLOBAL MARKET

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Key words:
sales forecasting, time series, causal models, non-causal models, neural networks, clustering.

The modern electric vehicle market is characterized by rapid development and significant fluctuations driven by technological, economic, and political factors. Forecasting sales dynamics is critically important for the strategic planning of manufacturers, investors, and government institutions. However, existing forecasting methods often lack accuracy due to data heterogeneity, insufficient consideration of market-specific features, and influencing factors.
This paper proposes a conceptual model for forecasting electric vehicle sales dynamics in the global market. The model incorporates market clustering, time series analysis, and both causal and non-causal forecasting models. The model includes the following stages: data collection, clustering of markets based on dynamic characteristics, construction of causal (regression model using an MLP neural network) and non-causal (ARIMA, RNN, hybrid model) forecasting models, as well as evaluation of forecast quality and selection of the most relevant model.
The scientific novelty of the research lies in a comprehensive approach that combines modern forecasting methods, enabling improved prediction outcomes in an emergent economy. The proposed model demonstrates potential due to its use of hybrid methods and the integration of neural networks alongside traditional statistical approaches.
The research results may be valuable for manufacturers, investors, and government bodies in planning infrastructure projects, developing support policies, and assessing market trends. The model also opens up opportunities for further research in the field of forecasting dynamic markets.

КОНЦЕПТУАЛЬНА МОДЕЛЬ ПРОГНОЗУВАННЯ ДИНАМІКИ ОБСЯГІВ ПРОДАЖІВ ЕЛЕКТРОМОБІЛІВ НА СВІТОВОМУ РИНКУ

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Ключові слова:
прогнозування продажів, часові ряди, каузальні моделі, некаузальні моделі, нейронні мережі, кластеризація.

Сучасний ринок електромобілів характеризується стрімким розвитком та значними коливаннями, зумовленими технологічними, економічними та політичними факторами. Прогнозування динаміки продажів є критично важливим для стратегічного планування виробників, інвесторів та державних установ. Однак існуючі методи прогнозування часто мають обмежену точність через неоднорідність даних, недостатнє врахування специфіки окремих ринків та факторів що на них впливають.
У цій статті запропоновано концептуальну модель прогнозування динаміки обсягів продажів електромобілів на світовому ринку, яка включає кластеризацію ринків, аналіз часових рядів, каузальні та некаузальні моделі прогнозування. Модель включає такі етапи: збір даних, кластеризацію ринків за характером динаміки, побудову каузальних (регресійна модель за допомогою нейронної мережі MLP) та некаузальних (ARIMA, RNN, гібридна модель) моделей, а також оцінку якості отриманих прогнозів та вибір найбільш релевантної моделі.

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Наукова новизна дослідження полягає в комплексному підході, який поєдную сучасні методи прогнозування, що дозволить покращити результати прогнозів в умовах емерджентної економіки. Запропонована модель має потенціал завдяки використанню гібридних методів та використанню нейронних мереж наряду із традиційними статистичними підходами.
Результати дослідження можуть бути корисними для виробників, інвесторів та державних органів при плануванні інфраструктурних проектів, розробці політик підтримки та оцінці ринкових тенденцій. Модель також відкриває перспективи для подальших досліджень у галузі прогнозування динамічних ринків.

Statement of the problem

The modern world is undergoing an active transition to environmentally friendly technologies, among which electric vehicles hold a special place. The growing popularity of electric vehicles is driven by their environmental benefits, cost-effectiveness in operation, and support from governments across various countries. However, the global electric vehicle market is marked by significant differences in sales volume dynamics between countries. These differences depend on a range of factors such as government policy, the level of economic development, electricity and fuel prices, and the deployment of charging infrastructure.

Forecasting the sales dynamics of electric vehicles in the global market is an important tool for strategic planning, the development of effective public policies, and business decision-making. However, the accuracy of forecasts is often limited due to data heterogeneity, the unpredictability of changes in regulatory mechanisms, and the rapid pace of technological advancement. Therefore, there is a need to create adaptive models that consider both global and local factors influencing the market.

Currently, a significant portion of existing forecasting research focuses either on causal models, which account for specific influencing factors, or on non-causal models, which analyze time series. However, these methods are typically used separately and little attention is paid to integrating these approaches into a comprehensive forecasting framework to improve prediction accuracy. Additionally, the issue of clustering markets based on their dynamic characteristics is underexplored in the literature, despite its potential to significantly enhance forecast quality for each specific market group.

Thus, the development of a forecasting model for electric vehicle sales dynamics in the global market – one that combines time series analysis with factor analysis and takes into account the specific characteristics of different national markets – is a relevant and pressing task.

Analysis of recent studies and publications

Forecasting sales dynamics is one of the key tasks in the field of economic analysis and management. In modern scientific literature, various forecasting methods are widely covered, including time series analysis, causal models, machine learning, and combined approaches.

Among classical approaches for forecasting non-stationary time series, ARIMA models are widely used and thoroughly described in [1]. These models allow for predictions based on historical data; however, their limitations include the requirement of stationarity and dependence on a fixed model structure. Furthermore, studies [2, 3] explore extensions of classical models through the use of seasonal integration and adaptive filters.

Causal models focus on identifying and quantifying the factors that influence the variables being forecasted. Research [4] highlights the importance of analyzing correlations between economic, social, and infrastructural indicators for predicting sales volumes. In particular, factors such as government subsidies, fuel prices, and the availability of charging infrastructure play a decisive role in determining the dynamics of electric vehicle sales. Studies [5, 6] demonstrate that regression models can be effective in accounting for these factors, though they are limited by their assumption of linear relationships.

Recent research has devoted considerable attention to the use of machine learning methods for forecasting sales dynamics. Neural networks – especially recurrent neural networks (RNN) and multilayer perceptrons (MLP) – have proven to be effective tools for modeling nonlinear dependencies and handling large datasets. Studies [7, 8, 9] show that hybrid models combining neural networks with traditional time series analysis methods deliver higher forecasting accuracy compared to either approach used independently.

Another promising direction is the clustering of markets based on the similarity of their development dynamics. In works [10, 11], clustering algorithms are proposed that group economic agents in electric vehicle markets to build specialized models and analyze the resulting information. This enhances forecast accuracy and enables model adaptation to local conditions.

Despite significant progress in the field, several unresolved issues remain. In particular, there is insufficient research on the integration of market clustering methods with both causal and non-causal forecasting models. Additionally, further study is needed on the adaptation of hybrid models to the rapidly changing environment characteristic of the electric vehicle market.

Therefore, there is a need to develop a model that incorporates market clustering based on sales dynamics, factor analysis, and modern modeling methods to improve the accuracy of forecasts for electric vehicle sales dynamics.

Objectives of the article

The aim of this study is to develop a conceptual model for forecasting the dynamics of electric vehicle sales in the global market, which will enhance forecast accuracy through a multi-stage process structure. This structure integrates the

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following components: market clustering based on dynamic characteristics, time series analysis, factor analysis, and the application of various forecasting methods.

The model is designed to serve as a universal forecasting tool that enables adaptation to the specific features of different national markets. It aims to ensure effective use in both the private and public sectors for planning purposes in the context of the rapidly evolving electric vehicle market.

The main material of the research

To forecast the dynamics of electric vehicle sales in the global market, a conceptual model will be developed based on the following key stages:

a) Market clustering – to account for the specific characteristics of sales volume dynamics in different electric vehicle markets;

b) Development and use of causal models – to identify the impact of defined factors on sales dynamics;

c) Development and use of non-causal models – to capture the nature and characteristics of time series, enabling faster results based on historical data without delving into cause-and-effect relationships, particularly for datasets with strong temporal patterns;

d) Forecast generation using the developed models;

e) Comparative analysis of forecast accuracy and determination of the most effective forecasting method for different market clusters.

The structure of the model is illustrated in the diagram (Fig. 1). Each stage of the model plays a key role in the forecasting process.

Let us take a closer look at the main stages of forecast construction using the proposed model:

Stage 1. Data collection on electric vehicle sales volumes

At this initial stage, data is collected on the dynamics of electric vehicle sales across various countries. It is advisable to consider sources such as: official reports from electric vehicle manufacturers, statistical data from government agencies, and information from open databases such as EV Volumes [12], IEA [13], among others.

Additional variables should also be included, such as data on charging infrastructure development, subsidy levels, demographic and economic indicators, as well as electricity prices.

Stage 2. Market clustering based on sales dynamics

Once the data is collected, markets are clustered based on their sales dynamics. It is recommended to use the Pearson correlation metric for this purpose, as it allows grouping countries into clusters that show the highest correlation in their sales dynamics. This metric is calculated using the following formula [14]:

$$K(x,y)=\frac{\sum_{i=1}^{N}x_i y_i}{\sqrt{\sum_{i=1}^{N}x_i^2\sum_{i=1}^{N}y_i^2}} \quad (1)$$

Stage 3. Modeling the Dynamics of Sales Volumes

The application of causal (cause-and-effect) and non-causal (statistical) models in forecasting the dynamics of sales volumes is appropriate, as each of these approaches has its own advantages and limitations. Using both approaches in parallel makes it possible to compensate for the shortcomings of individual methods and to improve forecasting accuracy.

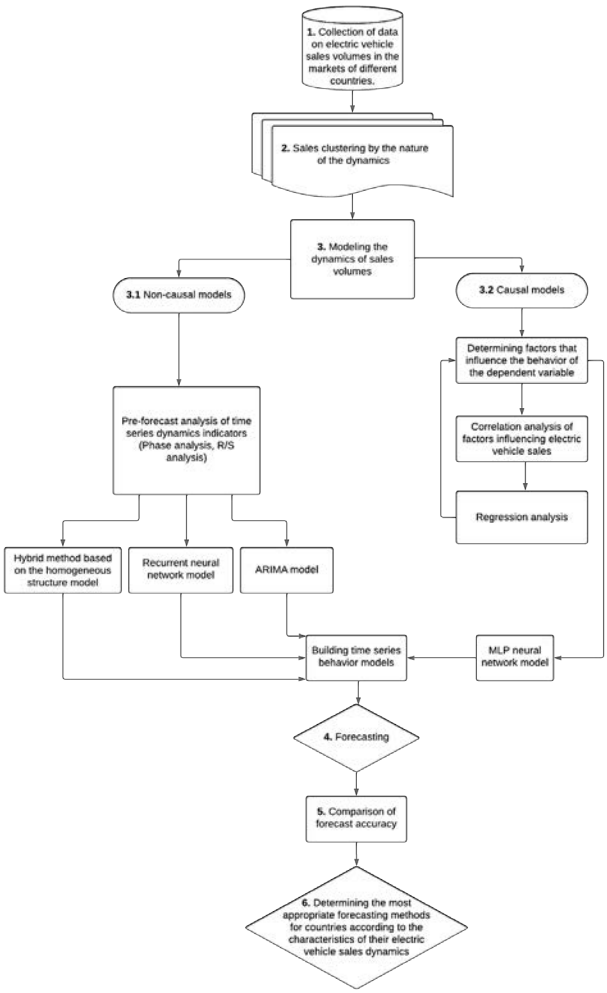

Fig. 1 – Scheme of the conceptual model of forecast construction

Non-causal models, such as ARIMA, recurrent neural network (RNN) models, or hybrid methods, are effective in detecting time dependencies, trends, and seasonality. However, they do not take into account external influencing factors. Conversely, causal models, such as regression analysis or multifactor neural network models, allow for the assessment of the impact of marketing, economic, or social factors, but may underestimate complex nonlinear relationships hidden in historical data.

The combined use of both approaches provides more stable and interpretable forecasts. This enables the generation of the most accurate results, especially under conditions of structural shifts or market instability.

3.1. Non-Causal Models

At this stage, the dynamic characteristics of time series are analyzed, followed by the forecasting of future values of sales volumes.

The following approaches are proposed for forecasting: ARIMA models, recurrent neural networks (RNN), and a hybrid method based on a homogeneous structure.

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The construction of the proposed non-causal models requires pre-forecast analysis to identify the characteristics of the time series. Various time series analysis methods are used to detect nonlinear (chaotic) behavior in economic data [15].

In our opinion, for the proposed forecasting methods, it is advisable to use the following tools for studying nonlinear dynamics, namely: traditional R/S analysis (Rescaled Range Analysis) – Hurst exponent method, phase analysis, and recurrence analysis.

To obtain an overall assessment of the fractal properties of the time series (TS), we will apply the Hurst rescaled range algorithm [16].

It is known [16] that if a system produces a Hurst statistic H over a sufficiently long period, this indicates the result of interdependent events. The measure of such interdependence, as is well known, is the correlation coefficient. The influence of the present on the future can be expressed through the following correlation relationship:

$$C = 2^{2H-1} - 1, \quad (2)$$

where C is the correlation measure, H is the Hurst exponent.

The range of values of the Hurst exponent H is the interval [0;1]. The value of the exponent H allows us to divide (classify) all TS into three groups: 1) $H = 0,5$, 2) $0 \le H < 0,5$ and 3) $0,5 < H \le 1$.

Value $H = 0,5$ indicates a random TS: events are random and uncorrelated (in accordance $C = 0$). The present does not affect the future.

If $H \in (0,5;1]$, then the considered TS is persistent, or trend-resistant and is characterized by the effect of long-term memory. Events are more correlated, the closer the value of H is to unity (respectively, C also approaches unity or 100% correlation according to (2)).

Values of H within the interval $H \in [0;0,5)$ correspond to antipersistent time series. In a loose definition, antipersistence means a tendency to revert to the mean or, in other terms, frequent reversal (alternation of positive and negative increments) more often than in a random process. Thus, the Hurst exponent H is a key indicator for diagnosing the nature of the development of a system or process.

To test the validity of the results regarding the presence of long-term memory based on the value of the Hurst H index, we propose to use the test for random mixing of the levels of the TS.

Phase analysis is one of the effective methods for obtaining information about the nature of the dynamics of the system under consideration [17]. For a time series $X = \left(x(t), t = \overline{1,n}\right)$, this representation method is used to return from the observed state of the system to its previous state. This "return" is implemented by the method of time delays and is carried out by constructing a phase trajectory (phase portrait) of dimension ρ:

$$\Phi_\rho(X) = \left\{\left(x(t), x(t+1), ..., x(t+\rho-1)\right)\right\}, \quad t = \overline{1,n}, \quad (3)$$

which represents a set of points called "M-history" ($\rho \equiv M$). For any time series (TS), the set of all its M-histories defines the corresponding set of points in the pseudo-phase (or lag) space. In this case, when using the terms "phase portrait" or "phase trajectory," it is implied that neighboring points of set (2) are visually connected by straight or curved line segments for clarity.

A graphical representation of a system on the phase plane (or in phase space), where the coordinate axes correspond to the values of the system's variables (levels of the time series), is called the phase portrait of the system. The behavior of phase points over time, described by the phase trajectory, and the collection of such phase trajectories for any initial conditions form the phase portrait. The phase portrait is a mathematical method for representing the system's behavior and a geometric depiction of individual motions. It also reflects equilibrium states, periodic and chaotic motion of the phase point, the logic of the system's behavior, and its dependence on external and internal influences.

Objective information about the nature of the behavior of a dynamic process can be obtained through the observation of the time series X, based on Takens' theorem [18]: if the system generating the time series is m-dimensional and the inequality $\rho \ge 2m + 1$, then, in the general case, the phase trajectories will reproduce the dynamics of the studied system. There exists a diffeomorphism between the phase trajectories and the true data generated by the system. This result allows making conclusions about the behavior of the system based on observational data and, moreover, obtaining information for forecasting this behavior.

Analysis of the phase portrait allows us to determine the type and characteristic features of the dynamics of a particular system.

To determine the embedding dimension of a time series, the false nearest neighbor method is applied, as described in [19]. This method is based on the assumption that, with successive iterations, neighboring points of the phase trajectory remain sufficiently close. However, if the nearest points move away from each other, they are considered false nearest neighbors. The goal of the method is to select such an embedding dimension ρ for the time series at which the proportion of points with false neighbors is minimized.

Based on the calculated embedding dimension and lag parameters, recurrence plots of the time series are constructed.

The analysis of statistical characteristics of the recurrence plot allows determining measures of the complexity of the recurrence structure [20], namely:

recurrence rate (%REC),

determinism measure (DET),

average (ADL) and maximum (MDL) diagonal line lengths of the recurrence plot.

Based on the analysis of these statistical characteristics, it is possible to identify the presence of homogeneous processes with independent random values; processes with slowly varying parameters; periodic or oscillatory processes corresponding to nonlinear systems. Thus, the analysis of the recurrence surface enables the assessment of the characteristics of a nonlinear object using relatively short time series, facilitating prompt decision-making in the management of the object.

3.2 Causal Models. Preparation for forecasting using a causal model involves several key stages aimed

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at identifying and assessing factors that influence the dependent variable, as well as building a mathematical model of the relationships. The main stages of this process include determining the factors affecting the behavior of the dependent variable, correlation analysis, and regression analysis of these factors.

At the first stage, factors that may affect sales volumes are identified. Both theoretical approaches (economic models, expert assessments) and empirical methods (analysis of historical data, market trends) are used. Factors can be internal (prices, product assortment) or external (consumer income levels, social factors, competition, macroeconomic conditions). It is important at this stage to formulate hypotheses about the influence of each factor on the dependent variable and to determine potential interrelationships.

After identifying the factors, correlation analysis is conducted to evaluate the strength and direction of the relationship between each factor and the dependent variable. Correlation analysis is performed using either the Pearson correlation coefficient [21] or Spearman's rank correlation coefficient [22], depending on the nature of the data.

Speaking of the Pearson correlation, let us explain how it is calculated. Let *a* and *b* be two real random variables; then the Pearson correlation coefficient (PCC) is defined as [21]:

$$\rho(a,b) = \frac{E(a,\ b)}{\sigma_a \sigma_b} \tag{4}$$

where E(a, b) is the cross-correlation (covariance) between a and b, and $\sigma_a = E\left(a^2\right)$ і $\sigma_b = E\left(b^2\right)$ dispersions of signals *a* and *b*, respectively. Ultimately, it will be more convenient to work with the squared Pearson correlation coefficient (SPCC):

$$\rho^2(a,b) = \frac{E^2(a,\ b)}{\sigma_a^2 \sigma_b^2} \tag{5}$$

One of the most important properties of SPCC is that

$$0 \le \rho^2(a,b) \le 1 \tag{6}$$

SPCC indicates the strength of the linear relationship between two random variables *a* and *b*. If $p^2\ (a,\ b) = 0$, then *a* and *b* are uncorrelated. The closer the value of $p^2\ (a,\ b)$ is to *1*, the stronger the correlation between the two variables. If the two variables are independent, then $p^2\ (a,\ b) = 0$. However, the reverse is not true, since the PCC only detects linear dependencies between the two variables *a* and *b*. For nonlinear dependencies, the PCC may be zero.

The general classification and interpretation of correlations is as follows[24]:

– strong, or dense, with a correlation coefficient of $\rho > 0{,}70$;

– average at $0{,}50 < \rho < 0{,}69$;

– moderate at $0{,}30 < \rho < 0{,}49$;

– weak at $0{,}20 < \rho < 0{,}29$;

– very weak at $\rho < 0{,}19$.

That is, factors with moderate correlation and below clearly cannot be used for further model construction.

We know that simple linear correlation describes the relationship between two variables or phenomena; that is, when one of the variables changes, it causes a change in the other, whether an increase or a decrease. When both variables increase or decrease together, their relationship is positive. Conversely, when one variable decreases while the other increases, their relationship is negative.

A simplified definition of the Spearman rank correlation coefficient can be given as follows: it is a coefficient that expresses the strength and direction of the relationship between two phenomena. This relationship can be either positive or negative, and weak or strong. Spearman's correlation is used for rank correlation, where variable *A* has rank R_A and variable *B* has rank R_B. Assuming *d* represents the difference between the two ranks, i.e. $d = R_A - R_B$, then Spearman's correlation coefficient ρ is calculated by the following formula:

$$\rho = 1 - \frac{6 \sum d_i^2}{n\left(n^2 - 1\right)} \tag{7}$$

where *n* is the number of ordered pairs of observations.

The next step is to conduct regression analysis [23] to quantitatively assess the impact of independent variables on the dependent variable. Most often, the method of multiple linear regression is used, which allows estimating the contribution of each factor to the change in the predicted value. To build the regression model, regression coefficients are determined, which show how much the dependent variable changes with a change in each independent factor. Additionally, the statistical significance of the model is evaluated (F-test, coefficient of determination R^2) as well as the significance of individual factors (t-test, p-value).

For assessing the goodness of fit in multiple linear regression, the coefficient of determination or R^2 is a very straightforward tool and is most commonly used in practice. Although it is not recommended as the final tool for model selection, it provides an indication of how well the chosen explanatory variables predict the response [25]. However, besides statistical significance, it is necessary to confirm how the selected independent variable affects the dependent variable.

In the context of classical multiple linear regression, the coefficient takes values between 0 and 1. It is generally accepted that the closer the coefficient is to 1, the better the model. The coefficient of determination increases with the inclusion of predictors (independent variables) in the model. However, this does not necessarily mean that a model with more predictors is better than a model with fewer predictors. Therefore, the coefficient of determination should be used only as one of the metrics for evaluating the validity of the model.

The coefficient of determination is defined as follows [26]:

$$R^2 = 1 - \frac{V(y|x)}{V(y)} = 1 - \frac{\sigma^2}{\sigma_y^2}\ , \tag{8}$$

where $V(y) = \sigma_y^2$ – variance of a random variable *y*, $V(y|x) = \sigma^2$ – conditional variance of the dependent variable (variance of the model error).

To calculate the sample coefficient of determination, sample estimates of the values of the corresponding variances are used:

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$$R^2 = 1 - \frac{\hat{\sigma}^2}{\hat{\sigma}_y^2} = 1 - \frac{RSS/n}{TSS/n} = 1 - \frac{RSS}{TSS}, \quad (9)$$

where $\sum_{t=1}^{n} e_t^2 = \sum_{t=1}^{n} (y_t - \hat{y}_t)^2$

– sum of squares of regression residuals, y_t, $\hat{y}_t$ – actual and estimated values of the explanatory (dependent) variable.

$TSS = \sum_{t=1}^{n} (y_t - \bar{y})^2 = n\hat{\sigma}_y^2$ – total sum of squares.

$\bar{y} = \frac{1}{n}\sum_{t=1}^{n} y_t$ – average value of observed (actual) data.

In the case of classical linear multiple regression (regression with a constant):

$TSS = RSS + ESS$, де $ESS = \sum_{t=1}^{n} (\hat{y}_t - \bar{y})^2$ – sum of squares explained. And as a result:

$$R^2 = \frac{ESS}{TSS} \quad (10)$$

As a result of data analysis and preparation, a causal model is formed that explains the influence of key factors on sales volumes and can be used to forecast future values of the dependent variable under certain conditions.

The construction of a causal model using regression based on neural networks can be performed using ready-made software products that have proven effective in similar studies [27, 28, 29, 30]. One example of such a product is Statistica 13. The multilayer perceptrons (MLP) used in this software are among the most popular neural network architectures today.

In this architecture, each neuron computes a weighted sum of its input data and passes it through a transfer function *f* to produce the output. For each neural layer in the MLP, there is also a bias term. The bias is a neuron whose activation function is constantly set to 1. Like other neurons, the bias connects to neurons in the upper layer through a weight often called the threshold. Neurons and biases are arranged in a layered feedforward topology. Thus, the network can be simply interpreted as an input-output model with weights and thresholds as free (adjustable) model parameters. Such networks can model functions of almost arbitrary complexity, with the number of layers and units in each layer defining the complexity of the function [31].

A schematic diagram of the MLP neural network [32] is shown in Fig. 2.

In this architecture, each neuron computes a weighted sum of its input data and passes it through a transfer function to generate the output. This method allows building a model that describes target (dependent) variables based on independent ones. In other words, when constructing this model, the interdependence of variables is taken into account, revealing the causal nature of the model. Such networks enable the creation of process (dynamic) models of almost arbitrary complexity, with the number of layers and units in each layer determined by the complexity of these processes [31].

Thus, the simultaneous application of causal and non-causal models is a promising approach in sales forecasting, as the final result benefits from the strengths of each model in its respective use case. This is especially relevant in a dynamic business environment, where underestimating external or internal factors can lead to significant forecasting errors.

Stage 4. Forecast Construction

At the forecasting stage, predictions are generated according to each model. However, the common steps in the forecasting process are as follows:

– splitting the data into training (80-90%) and testing (10-20%) sets;
– determining the model parameters;
– training the model (parameter optimization);
– forecasting future values;
– determining confidence intervals;
– comparing the forecast with actual data.

Stage 5. Comparison of Forecast Quality Results

At this stage, the accuracy of the obtained forecasts is evaluated, for example, using MAPE (Mean Absolute Percentage Error). Models are compared based on their performance within each cluster. The Mean Absolute Percentage Error (MAPE) is a measure of forecasting accuracy in statistics. It typically expresses accuracy as a ratio defined by the formula:

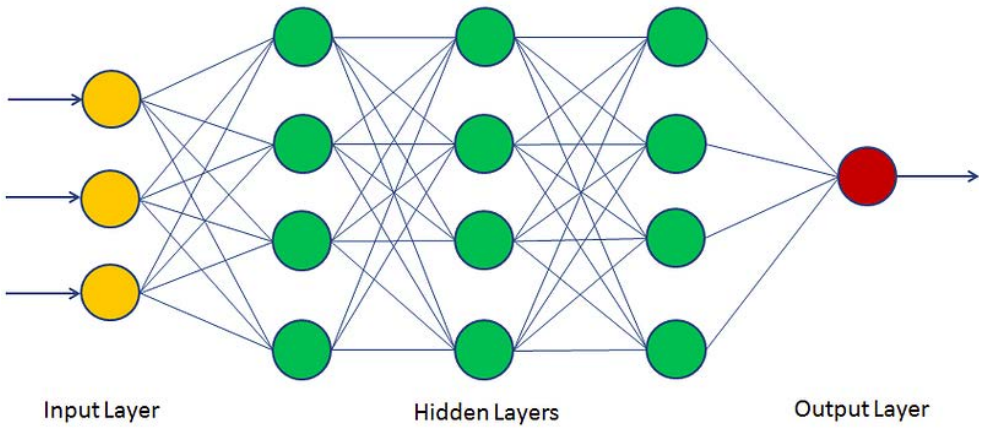

Fig. 2 – Diagram of an MLP neural network [32]

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$$MAPE = 100 \frac{1}{n} \sum_{t=1}^{n} \left| \frac{A_t - F_t}{A_t} \right|, \quad (11)$$

where A_t is the actual value, and F_t is the forecasted value. Their difference is divided by the actual value A_t. The absolute value of this ratio is summed over each forecasted time point and divided by the number of observations *n*.

Stage 6. Selection of the Best Forecasting Method Based on the evaluation results of forecast accuracy, the forecasting method that demonstrates the highest accuracy is selected. This method is considered the best fit for the specific market characteristics of the given cluster.

Conclusions

In the course of this research, a conceptual model for forecasting the dynamics of electric vehicle sales volumes in the global market was developed. The model incorporates market clustering, time series analysis, and both causal and non-causal forecasting approaches. The proposed model allows for consideration of the specific characteristics of different markets, which is a key factor in ensuring high forecast accuracy in a rapidly changing environment. Thus, the scientific novelty of this study lies in the integrated approach to forecasting that combines the aforementioned tools.

The relevance of the research is driven by the rapid development of the electric vehicle market, which is a crucial segment of the global automotive industry. The growing demand for electric vehicles is accompanied by significant fluctuations caused by technological, economic, and political factors. Accurate forecasting of sales dynamics is critically important for manufacturers, investors, governments, and other stakeholders to enable effective planning and decision-making.

The proposed model also demonstrates innovation through the use of modern techniques such as neural networks and hybrid forecasting methods, allowing for a substantial improvement in accuracy compared to traditional models.

The obtained results can be applied for strategic planning at the level of investors, governmental support programs, and infrastructure projects. Furthermore, the proposed model lays the groundwork for further scientific research in forecasting under dynamic market conditions.

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MODELING THE IMPACT OF THE LEVEL OF TECHNOLOGICAL DEVELOPMENT ON INTERNATIONAL LOGISTICS PROCESSES IN UKRAINE USING FUZZY LOGIC

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Key words:
fuzzy logic, international logistics, automation, information technology, environmental technologies, transport infrastructure, efficiency of logistics processes.

The article is dedicated to the development of a fuzzy model for assessing the impact of technological development on the efficiency level of international logistics processes. Key factors influencing the efficiency level of international logistics processes are identified: automation level, information technologies, environmental technologies, and transport infrastructure development. The study formulates 60 fuzzy rules that define the relationships between technological variables and the efficiency of logistics processes. The membership functions of the variables are chosen according to their characteristics: trapezoidal, triangular, Gaussian, and sigmoid. The modeling results show that the efficiency level of international logistics processes is at an average level (6.3 out of 10), with automation and digitalization of logistics operations having the greatest impact on its improvement. In addition, it is established that environmental technologies and the development of transport infrastructure also play an important role in increasing logistics efficiency, but their impact is less pronounced compared to digital technologies. A high level of automation combined with environmental innovations will provide an optimal result, emphasizing the importance of not only technological but also environmental development in the field of international logistics. The proposed model can be used for strategic planning and improvement of international logistics processes in the context of digital transformation. Its application allows companies and government bodies to assess the current state of technological development and identify areas for further improvement of logistics activities. The research results can be useful for logistics operators seeking to optimize their processes, increase competitiveness, and reduce the environmental impact of transportation.

МОДЕЛЮВАННЯ ВПЛИВУ РІВНЯ ТЕХНОЛОГІЧНОГО РОЗВИТКУ НА МІЖНАРОДНІ ЛОГІСТИЧНІ ПРОЦЕСИ В УКРАЇНІ З ВИКОРИСТАННЯМ НЕЧІТКОЇ ЛОГІКИ

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Ключові слова:
нечітка логіка, міжнародна логістика, автоматизація, інформаційні технології, екологічні технології, транспортна інфраструктура, ефективність логістичних процесів.

Стаття присвячена розробці нечіткої моделі оцінки впливу технологічного розвитку на рівень ефективності міжнародних логістичних процесів. Визначено ключові фактори, що впливають на рівень ефективності міжнародних логістичних процесів: рівень автоматизації, інформаційні технології, екологічні технології та розвиток транспортної інфраструктури. У межах дослідження сформовано 60 нечітких правил, які визначають взаємозв'язки між технологічними змінними та ефективністю логістичних процесів. Функції приналежності змінних обрано відповідно до їхніх характеристик: трапеціїподібна, трикутна, гаусова та сигмоїдна. Результати моделювання показали, що рівень ефективності міжнародних логістичних процесів знаходиться на середньому рівні (6,3 бала з 10), а найбільший вплив на його підвищення мають автоматизація та цифровізація логістичних операцій. Крім того, встановлено, що екологічні технології та розвиток транспортної інфраструктури також відіграють важливу роль у підвищенні ефективності логістики, проте їхній вплив є менш вираженим порівняно з цифровими технологіями. Високий рівень автоматизації в поєднанні з екологічними інноваціями забезпечить оптимальний результат, що підкреслює важливість не тільки технологічного, а й екологічного розвитку в сфері міжнародної логістики. Запропонована модель може бути використана для стратегічного планування та вдосконалення міжнародних логістичних процесів у контексті цифрової трансформації. Її застосування дозволяє компаніям і державним органам оцінювати поточний стан технологічного розвитку та визначати напрями для подальшого вдосконалення логістичної діяльності. Результати дослідження можуть бути корисними для логістичних операторів, що прагнуть оптимізувати свої процеси, підвищити конкурентоспроможність і знизити екологічний вплив транспортних перевезень.

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Statement of the problem

Modern international logistics is significantly influenced by technological innovations that are transforming traditional supply chains. The introduction of the Internet of Things, blockchain, artificial intelligence, and automation is changing logistics processes, increasing their efficiency, transparency, and adaptability to market changes. However, assessing the real impact of these technologies is complicated by the lack of universal methodologies capable of accounting for uncertainty and subjective factors, such as management quality, the level of digital readiness of a company, or the impact of the external environment. Fuzzy logic allows for the formalization of such vague criteria and provides a quantitative assessment of their impact, making it an ideal tool for analysis in a dynamically changing business environment.

Analysis of recent studies and publications

The relevance and importance of implementing innovative technologies in international logistics is undeniable, which is confirmed by active research on this issue both among scientists studying theoretical aspects and practitioners directly facing the need to optimize logistics processes in various sectors of the economy. In particular, Bokovets V., Davydiuk L., and Pyliavoz T. in their work [1] investigated the introduction of innovative technologies (information, technological, managerial, and environmental, including IoT, AI, blockchain, and automation) in international logistics and their impact on process optimization, cost reduction, and efficiency improvement, and also identified obstacles to their implementation. Shatska Z.Ya. and Stuzhny O.S. [2] determined that logistics is at the sixth stage of development – "logistics of the future," where an integrated flow management system is being formed, actively adapting to new conditions through areas such as Logistics 4.0 and green logistics. Mogilevska O.Yu., Slobodyanyk A.M., and Sidak I.V. [3] proved that artificial intelligence significantly simplifies the processing of large volumes of data and increases productivity, which has a significant impact on the economy, including logistics processes, and contributes to GDP growth and business process optimization. Hrynko I.M. [4] investigated the impact of the latest blockchain technology on the development of international trade between countries, particularly on supply chains, and identified the main obstacles to the implementation of blockchain. Nakonechna T.V. and Gryniv N.T. [5] examined the importance of innovative technologies in logistics, determined their impact on supply chains and enterprise efficiency, and described key modern technologies, their advantages, implementation features, and the effects obtained for participants in the logistics chain. Khmelovsky O.V. [6] considered the features, trends, and challenges of the development of international logistics in the context of globalization, and also characterized the levels of its globalization and the conditions for their achievement. Malashchuk D.V. and Hrynchak N.A. [7] analyzed the current state of the global logistics services market, identified key trends and factors of its differentiation, studied the dynamics of development, and developed a forecast for its further growth. Makedon V.V. [8] investigated the impact of digital technologies on international logistics, developed a model for their integration into logistics processes, and provided recommendations for improving the efficiency of logistics operations.

Objectives of the article

The purpose of the article is to develop a model for assessing the impact of technological development on the efficiency level of international logistics processes in Ukraine using fuzzy logic tools.

The main material of the research

To model the impact of technological development on international logistics processes in Ukraine, the authors believe it is appropriate to use fuzzy logic. Since fuzzy logic allows modeling complex systems where parameters and conditions can be defined imprecisely, within certain ranges, or with fuzzy gradations. In general, the mechanism of logical inference includes four stages: fuzzification, fuzzy inference, composition, and defuzzification. The authors propose an algorithm for modeling the impact of the level of technological development on international logistics processes in Ukraine, presented in Fig. 1.

According to the proposed methodology, the first stage formulates the task, which is to determine the impact of technological development on the efficiency level of international logistics processes (ELP) in Ukraine. The second stage identifies the tuple of input variables and the output variable. Based on the analysis of scientific research, the following factors of technological development are selected:

– automation level (RA), the degree of implementation of automated systems in logistics processes, such as robots, automated warehouses, drones, etc.;

– information technologies (IT), the degree of development and implementation of modern information technologies, such as the Internet of Things (IoT), Big Data, and blockchain, for tracking, managing, and analyzing logistics processes;

– environmental technologies (ET), the implementation of technologies aimed at reducing the environmental impact of logistics processes (e.g., electric trucks, energy-efficient warehouses, reduction of CO2 emissions, etc.);

– development of transport infrastructure (TI), the degree of development of transport infrastructure, including roads, ports, airports, railway networks, etc., and their compliance with the latest technologies.

Thus, the tuple of input linguistic variables of the fuzzy model is: $< RA, IT, ET, TI >$, and the output parameter is the efficiency level of international logistics processes (ELP). At the third stage of constructing the fuzzy model, implemented in the Fuzzy Logic Toolbox of Matlab, the linguistic representation of the variables is defined. The terms of the specified input and output linguistic variables are defined as fuzzy sets [9]:

$$T_i = \left\{\left(x, \mu_{Ti}(x)\right) : x \in X, \mu_{Ti}(x) \in [0, 1]\right\},$$

where $\mu_{Ti}(x)$ – is the membership function of the corresponding fuzzy set.

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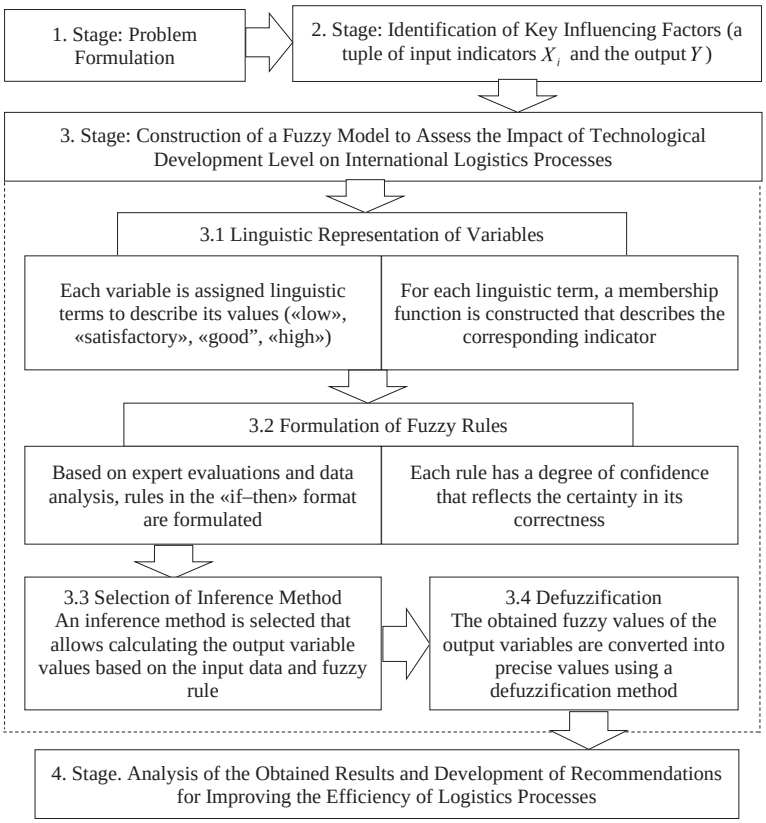

Fig. 1. – Algorithm for modeling the impact of the level of technological development on international logistics processes

Source: developed by the authors

The efficiency level of international logistics processes is studied under conditions of uncertainty, therefore, the following range of term definitions is accepted:

$$RA = \begin{cases} \text{low} \in [0;\ 0{,}25] \\ \text{satisfactory} \in [020;\ 0{,}50] \\ \text{good} \in [0{,}45;\ 0{,}75] \\ \text{high} \in [0{,}70;\ 1] \end{cases} \qquad ET = \begin{cases} \text{low} \in [0;\ 0{,}25] \\ \text{satisfactory} \in [020;\ 0{,}50] \\ \text{good} \in [0{,}45;\ 0{,}75] \\ \text{high} \in [0{,}70;\ 1] \end{cases}$$

$$IT = \begin{cases} \text{low} \in [0;\ 0{,}25] \\ \text{satisfactory} \in [020;\ 0{,}50] \\ \text{good} \in [0{,}45;\ 0{,}75] \\ \text{high} \in [0{,}70;\ 1] \end{cases} \qquad TI = \begin{cases} \text{low} \in [0;\ 0{,}25] \\ \text{satisfactory} \in [020;\ 0{,}50] \\ \text{good} \in [0{,}45;\ 0{,}75] \\ \text{high} \in [0{,}70;\ 1] \end{cases}$$

Output term definition range:

$$ELP = \begin{cases} \text{low} \in [0;\ 0{,}25] \\ \text{satisfactory} \in [020;\ 0{,}50] \\ \text{good} \in [0{,}45;\ 0{,}75] \\ \text{high} \in [0{,}70;\ 1] \end{cases}.$$

If the efficiency level of international logistics processes is low, this indicates serious problems in supply chain management, which can lead to losses and a loss of competitiveness at the international level. Satisfactory – logistics processes can function quite effectively but require improvement to achieve better performance in international trade. Good – logistics processes operate efficiently, ensuring stable and reliable deliveries with minimal costs, which allows for successful competition in the international market. High efficiency means that a company or country has significant advantages in international trade, ensuring fast, reliable, and economical deliveries with minimal environmental impact.

Input terms are evaluated on a 10-point scale, where 0 means no development at all, and 10 means a high level of technology development. The value of the membership function lies in the range from 0 to 1, where 1 is a complete correspondence to the truth of the statement, and 0 is its complete absence.

A trapezoidal membership function is used to describe the variable «Automation Level», which effectively models clearly defined levels (low, satisfactory, good, high) with gradual transitions between them. This function allows for a more accurate representation of intermediate states of automation, which is typical for complex production and logistics systems. The variable «Information Technologies» is described by a triangular membership function, which provides clear intersection points between levels of technology development. A Gaussian membership function is used for the variable «Environmental Technologies». It provides a smooth and continuous transition between levels, which is especially important for processes with gradual but constant changes. The use of this function is justified by the fact that

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environmental technologies usually develop without sharp jumps, and their implementation has a long-term and predictable nature. The development of transport infrastructure is modeled by a sigmoid membership function, which well reflects processes with abrupt changes. In the real world, infrastructural development often goes through periods of rapid growth after reaching a certain critical level. The sigmoid function allows for a correct description of these features, providing a realistic modeling of the transition from a low level to a high level. Fig. 2 shows the membership functions for the input variables.

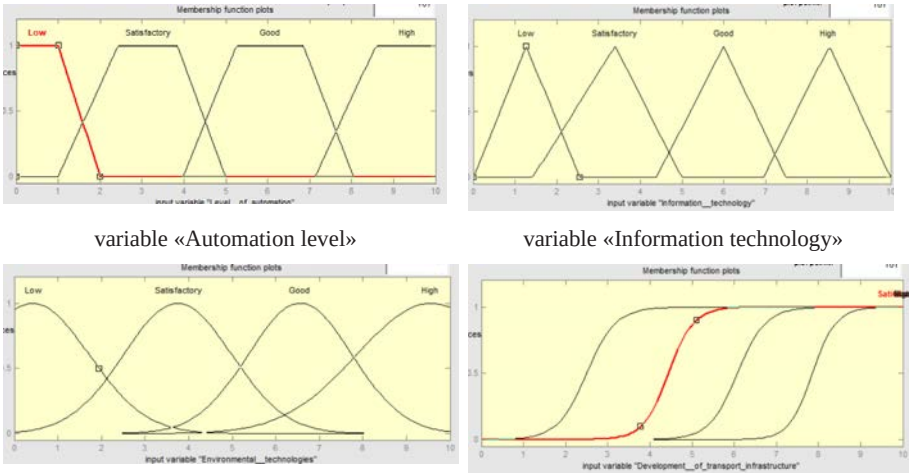
A trapezoidal membership function is used to describe the output variable «Efficiency of International Logistics Processes» (Fig. 3). After all, this type of function makes it possible to well describe situations where efficiency remains at a certain level for some time interval and allows for describing a wide range of efficiency with clearly defined high and low levels. This allows for considering the possibility of a stable high level of efficiency within a certain range and a gradual decrease to lower levels.

The next step of the third stage is to select the inference method; the Mamdani and Sugeno algorithms are most commonly used. The authors chose the Mamdani algorithm because it allows for effective modeling of complex relationships between influencing factors, takes into account expert assessments, and provides an intuitively understandable output result in the form of fuzzy assessments of the impact level of technological development on international logistics. The Sugeno algorithm is more suitable for accurate forecasting when it is necessary to obtain a numerical value, for example, for optimizing logistics costs.

The Mamdani fuzzy inference algorithm is based on the formation of a rule base of the following type [9, 10]:

$$IF\left(x_1\ IS\ X_1^{(i)}\ AND\ x_2\ IS\ X_2^{(i)}\ AND\ \ldots\ AND\ x_n\ IS\ X_n^{(i)}\right)$$
$$THEN\ I_{ELP} = Y_k^{(i)},\ i = 1,\ldots,\ I,$$

where $X_1^{(i)}, X_2^{(i)}, \ldots, X_n^{(i)}, Y_k^{(i)}$ – are the values from the term set corresponding to the *-i* rule.



variable «Automation level» | variable «Information technology»

variable «Environmental technologies» | variable «Development of transport infrastructure»

Fig. 2. – Membership functions of the model's linguistic variables

Source: developed by the authors

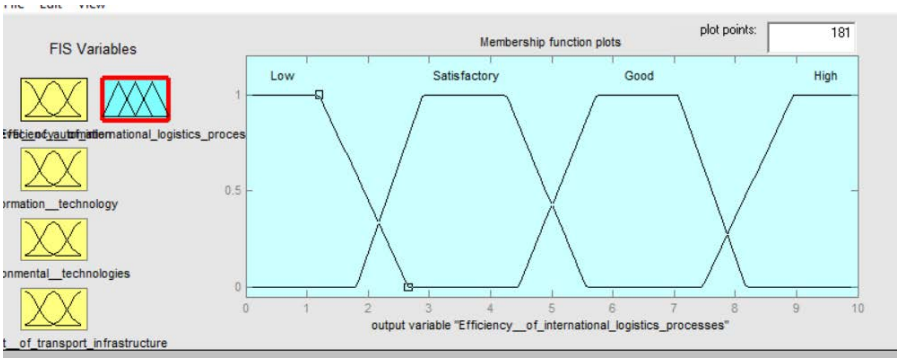


Fig. 3. – Trapezoidal membership function of the variable «Efficiency of International Logistics Processes»

Source: developed by the authors

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At the next step of the third stage, defuzzification of the fuzzy sets of the output variables is performed. Defuzzification according to the Mamdani algorithm is determined by the centroid method, which consists of finding the average value in the area under the graph of the membership function. This is the most commonly used method, where the defuzzification result is determined as the center of mass for the graph of the membership function [11]:

$$y_k = \frac{\int_{\min}^{\max} y \cdot \mu_k(Y_k)\, dy}{\int_{\min}^{\max} \mu_k(Y_k)\, dy},$$

where y_k – is the defuzzified value of the k-th fuzzy set of the output variable; $\mu_k(Y_k)$ – is the membership function of the fuzzy set of the output variable Y_k, I_{ELP} are the boundaries of the universe of the variable I_{us}.

Then, the impact of technological development on the efficiency level of international logistics processes according to the Mamdani fuzzy inference algorithm is determined by the formula:

$$I_{ELP} = \frac{\sum_{k=1}^{m} y_k \mu_k(Y_k)}{\sum_{k=1}^{m} \mu_k(Y_k)},$$

where m is the number of fuzzy sets (elements of the term set) of the output variable I_{ELP}.

Considering the number of variables and possible terms, 60 fuzzy rules were formed, based on expert assessments in this field. Each rule considers different combinations of input variables (RA, IT, ET, TI) and determines the corresponding efficiency level. The formed rules provide an understanding of the relationships between different technological factors and their impact on the efficiency of international logistics processes.

In the process of defuzzification, which involves converting fuzzy results obtained based on the rules into a specific numerical value, an assessment of the impact of technological development on the efficiency of international logistics processes in Ukraine was carried out. Assessing the level of development of automation, information technologies, environmental technologies, and the development of transport infrastructure in Ukraine is a complex task, as these indicators vary depending on the industry, region, and other factors:

– the level of automation is satisfactory, as the level of automation in industry and manufacturing in Ukraine is growing, but it remains at an average level compared to developed countries. There are sectors, especially in large cities and modern enterprises, where automation is well developed, but many enterprises still use old technologies;

– the development of information technology is at a high level. The IT sector in Ukraine is developing rapidly and is one of the strongest in the economy. Ukraine is known as a center for software outsourcing and has a developed IT infrastructure, which contributes to a high level of IT integration into business processes. The IT sector is one of the strengths of the Ukrainian economy;

– the level of environmental friendliness of technologies is low, but closer to average (satisfactory). The adoption of environmental technologies in Ukraine is only gaining momentum. Although there are initiatives and individual projects, the overall level of use of environmentally friendly technologies and standards remains low to medium. More and more attention is being paid to this topic, but significant improvements are still needed;

– the development of transport infrastructure is satisfactory. Ukraine's transportation infrastructure is not uniformly developed. Large cities have relatively well-developed infrastructure, but the overall condition of roads, railways, airports, and ports often requires modernization. Despite some progress, there are still many infrastructure problems, especially in rural and remote areas. Given the current situation in the country and the damage that Russia is doing to Ukraine's infrastructure, infrastructure development requires significant investment and modernization to reach a higher level.

The results of the fuzzy model implementation are shown in Fig. 4.

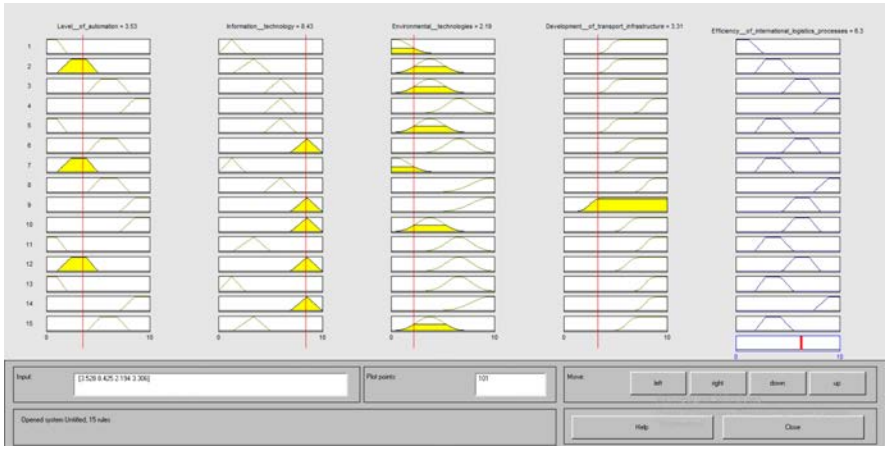

Fig. 4. – Results of implementing a fuzzy model for assessing the impact of technological development on the efficiency of international logistics processes in Ukraine

Source: built by the authors

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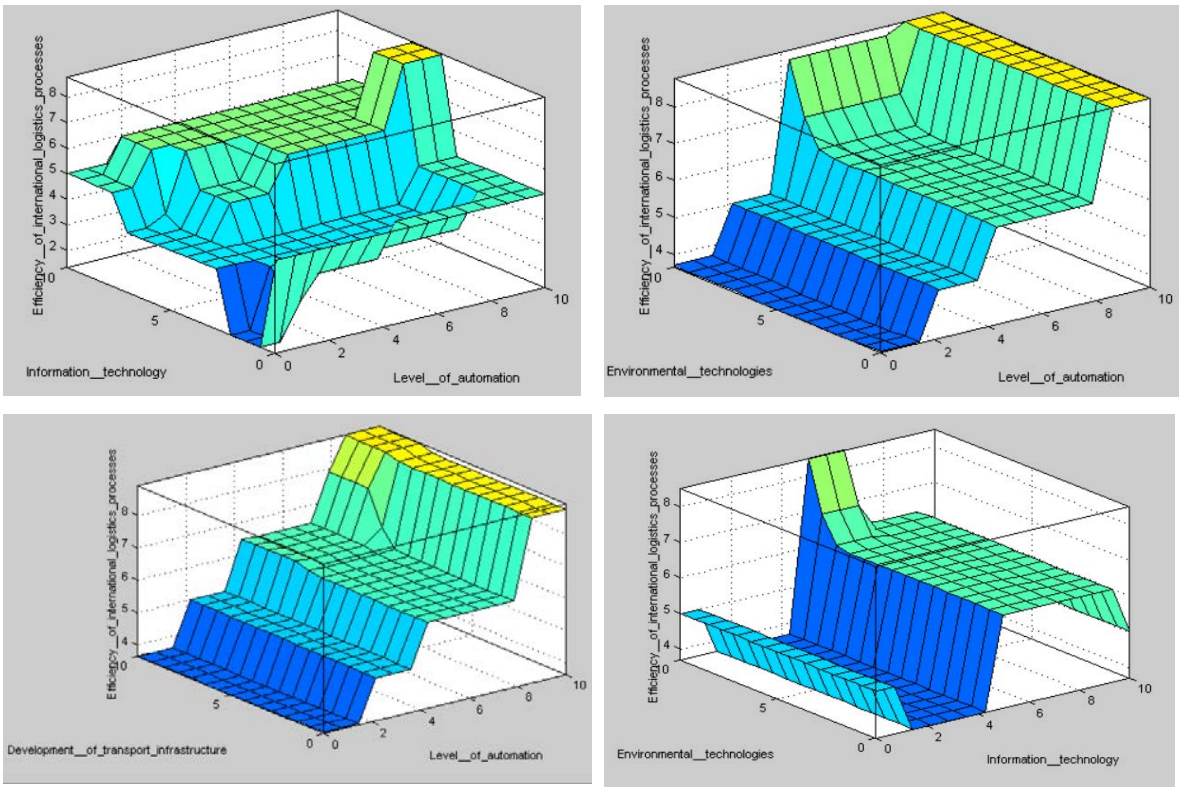

Fig. 5. – Surface of fuzzy inference of the level of efficiency of international logistics processes
Source: built by the authors

At the fourth stage of the proposed algorithm (Fig. 1), we analyzed the results and found that the level of efficiency of international logistics processes is 6.3 points on a 10-point scale, indicating an average level of development of the industry. This indicates that key technological factors such as automation, use of information technology, implementation of environmental solutions, and development of transport infrastructure have a significant positive impact, but their potential is not fully realized. To achieve a higher level of efficiency, it is necessary to focus on further integration of innovative technologies, process optimization, and environmental sustainability, as well as on improving the infrastructure that supports the international circulation of goods. Such measures will not only improve the quality and speed of logistics operations but also reduce their cost, which will help strengthen international competitiveness.

A visual representation of the impact of technological development on the level of efficiency of international logistics processes is shown in Fig. 5.

Analyzing the results presented in Fig. 5, we can conclude that the efficiency of international logistics processes largely depends on the level of automation and the introduction of information technology. High values of these factors contribute to maximum efficiency, while low values of automation and information technology lead to a significant decrease in efficiency. This emphasizes the need for a comprehensive approach to the introduction of technology into logistics processes, where the lack of development in both areas significantly limits efficiency. To maximize efficiency, it is important to integrate automation with environmental technologies. Their interaction yields significantly better results than the separate implementation of each factor. A high level of automation combined with environmental innovations provides an optimal result, which emphasizes the importance of not only technological but also environmental development in the field of international logistics. The analysis of Fig. 5 confirms that the efficiency of international logistics processes also largely depends on the development of transport infrastructure. The best way to achieve the maximum level of efficiency is to simultaneously improve both technological solutions and infrastructure. The gradual improvement of each factor allows for consistently high efficiency, but at certain stages of development, saturation may occur, which indicates the need for a comprehensive approach to investment in all aspects of the logistics system.

Conclusions

The results of the study showed that a high level of automation and information technology contributes to efficiency growth, while insufficient development of these factors limits the possibilities for increasing productivity. The analysis of the situation in Ukraine showed an average level of technology development in logistics, in particular, the level of automation and environmental technologies requires significant improvements, while information technology and the development of transport infrastructure are at a satisfactory level. In order to achieve a higher level of efficiency in international logistics processes, it is necessary to focus on further development of automation,

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integration of modern information technologies, introduction of environmental technologies, and improvement of transport infrastructure. An integrated approach to the development of technological and infrastructure components will help reduce costs, increase competitiveness, and strengthen positions in the international market.

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CONCEPTUAL MODEL OF ARTIFICIAL INTELLIGENCE APPLICATION IN VIDEO GAME DEVELOPMENT PROJECT MANAGEMENT

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Key words:
artificial intelligence, project management, video game development, automated testing, data analysis, feedback, procedural content generation, conceptual model, game industry.

The article focuses on developing a conceptual model for artificial intelligence application in video game development project management. It examines the complex relationships between game product creation stages and corresponding AI tools that optimize production processes. The research substantiates the relevance of this issue through growing competition in the video game market, dynamic technological changes, and continuously evolving user needs.

The paper identifies and analyzes in detail three fundamental principles of artificial intelligence integration: automation of routine processes through automated testing and data analysis tools; strategic planning and resource management to forecast project needs and optimize task distribution; and improving user interaction through real-time feedback collection and analysis.

The conceptual framework presented by the authors demonstrates the step-by-step integration of specific artificial intelligence tools, including ChatGPT, DALL-E, Unity ML Agents, IBM Watson, Nvidia DLSS, GameAnalytics and others, into development blocks – from idea generation and initial planning to testing, release, and user feedback analysis.

Special attention is paid to mechanisms of testing process automation, resource planning optimization, market trend forecasting, and analysis of player behavioral patterns. The paper describes AI application at each stage of the production cycle, noting specific benefits that development teams receive through the implementation of these technologies.

Research results confirm that systematic AI implementation contributes significantly to improving development efficiency, end product quality, risk reduction, and resource cost optimization. The developed conceptual model can serve as a theoretical foundation for creating methodological recommendations on AI integration into video game development project management processes, opening new opportunities for enhancing product competitiveness in this dynamic industry.

КОНЦЕПТУАЛЬНА МОДЕЛЬ ЗАСТОСУВАННЯ ШТУЧНОГО ІНТЕЛЕКТУ В УПРАВЛІННЯ ПРОЄКТАМИ РОЗРОБКИ ВІДЕОІГОР

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Ключові слова:
штучний інтелект, управління проєктами, розробка відеоігор, автоматизоване тестування, аналіз даних, зворотний зв'язок, процедурна генерація контенту, концептуальна модель, ігрова індустрія.

Стаття присвячена розробці концептуальної моделі застосування штучного інтелекту в управлінні проєктами розробки відеоігор. Досліджено комплексні взаємозв'язки між етапами створення ігрових продуктів та відповідними інструментами ШІ, що дозволяють оптимізувати виробничі процеси. У дослідженні обґрунтовано актуальність проблематики зростаючою конкуренцією на ринку відеоігор, динамічними змінами технологій та постійно еволюціонуючими потребами користувачів.

У роботі визначено та детально проаналізовано три фундаментальні положення інтеграції штучного інтелекту: автоматизація рутинних процесів через інструменти автоматизованого тестування та аналізу даних; стратегічне планування та управління ресурсами з метою прогнозування потреб проєкту та оптимізації розподілу завдань; покращення взаємодії з користувачами через збирання та аналіз зворотного зв'язку в режимі реального часу.

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Стаття присвячена розробці концептуальної моделі застосування штучного інтелекту в управлінні проєктами розробки відеоігор. Досліджено комплексні взаємозв'язки між етапами створення ігрових продуктів та відповідними інструментами ШІ, що дозволяють оптимізувати виробничі процеси. У дослідженні обґрунтовано актуальність проблематики зростаючою конкуренцією на ринку відеоігор, динамічними змінами технологій та постійно еволюціонуючими потребами користувачів.
У роботі визначено та детально проаналізовано три фундаментальні положення інтеграції штучного інтелекту: автоматизація рутинних процесів через інструменти автоматизованого тестування та аналізу даних; стратегічне планування та управління ресурсами з метою прогнозування потреб проєкту та оптимізації розподілу завдань; покращення взаємодії з користувачами через збирання та аналіз зворотного зв'язку в режимі реального часу.

Statement of the problem

Effective management of video game development projects requires a comprehensive understanding of complex production processes that encompass both technical and creative aspects of creating a game product. Growing competition in the video game market, rapid technological development, and constantly changing user needs create the necessity to search for new approaches to optimize development processes and implement innovative project management tools. One of the promising directions for improving management processes is the integration of artificial intelligence into various stages of video game development.

Developing a system of models for applying artificial intelligence in video game development project management allows for improved planning and coordination of work, optimized resource utilization, reduced costs, enhanced quality of the final product, and securing competitive advantages in the market. Furthermore, considering the analytical capabilities of artificial intelligence is important in the context of developing modern game development technologies, such as procedural content generation, automated testing, adaptive gameplay algorithms, and other innovative solutions in the field of video game creation. Analysis and modeling of processes using artificial intelligence makes it possible to predict various scenarios for implementing these technologies and their impact on the overall effectiveness of project management.

However, in the conditions of rapid development of the video game industry, the emergence of new technologies and development methodologies, the application of appropriate models and methods is impossible without a deep understanding of knowledge that characterizes the subject area of research, constitutes its nomological foundation, and defines the information model of artificial intelligence integration into the management processes of video game development projects.

Analysis of recent studies and publications

The modern development of the video game industry and information technologies is accompanied by growing scholarly interest in the integration of artificial intelligence into project management processes. Analysis of recent research reveals multidirectional approaches to AI application and its impact on the effectiveness of project management in video game development.

The fundamental research by Vasylchenko V.M. and Vakaluk T.A. [1] offers a comprehensive analysis of the transformational impact of AI on project management, identifying new opportunities for optimizing traditional practices and implementing innovative approaches. The authors emphasize that AI-based tools provide significant improvements in decision-making efficiency and risk prediction in the dynamic environment of video game development.

In the context of strategic AI implementation, the research by Tertechniy V. [2] is important, as it examines the features of artificial intelligence technology integration into business processes, focusing on organizational aspects and corporate environment optimization. These developments have direct application in forming project management strategies in the gaming industry, where resource and process optimization is critically important.

A significant contribution to understanding the risks and prospects of AI integration is made in the collection of professional development materials [3], which analyzes the possibilities of applying artificial intelligence in educational projects. These studies are especially valuable for developing educational video games that combine educational goals and game mechanics. This direction is complemented by Belinska Ya.V.'s research [4], which reveals the specifics of AI use in the educational environment.

Special attention should be paid to the research by Antipov K.O. [5], dedicated to the challenges of recognizing AI-generated texts. These developments have direct application in creating scripts, dialogues, and narrative elements for video games, where the quality and authenticity of text content directly affect the user experience.

An interesting aspect is the investigation by Antipova Zh.I. [6], which reveals the relationship between AI use and physical activity, which can be effectively applied in developing video games aimed at promoting healthy lifestyles and physical activity among users.

Theoretical aspects of AI use, including ethical and security issues of human interaction with intelligent systems, are thoroughly covered in publication [7]. These studies form an important foundation for understanding the ethical boundaries of AI application in video game development, especially in the context of interaction with users of different age categories.

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The analysis of publications demonstrates active research in the field of AI application in various areas, including video game development project management. However, there is a need for further study of issues related to the comprehensive application of AI throughout the entire life cycle of a video game development project, which emphasizes the relevance of our research and the necessity to develop a conceptual model that would integrate best practices of AI application in all aspects of project management in the gaming industry.

Objectives of the article

The aim of the research is to develop a conceptual model for the application of artificial intelligence in video game development project management, which allows not only to structure and optimize the production processes of creating a game product, but also to account for complex interrelationships between different stages of development, from idea generation to user feedback analysis.

The main material of the research

Artificial intelligence, with its ability to analyze large volumes of data, predict risks, automate routine tasks, and adapt to changes, opens new opportunities for optimizing game project management. The peculiarity of video games as a product lies in their high requirements for user experience quality, dynamic and often non-linear development process, as well as a complex structure involving various specialists – from designers and programmers to analysts and marketers. In such complex production cycles and the need to adapt to rapidly changing market conditions, AI provides tools for creating a flexible, integrated project management model focused on end results and efficient resource utilization.

The application of artificial intelligence in such a model is based on the principles of a systems approach, where each component of the development process is connected with others and ensures constant data exchange. From forecasting resource needs and optimizing planning to interactive testing and adaptive user interaction, AI helps automate and improve key development stages. Additionally, the conceptual model involves using AI as a feedback tool, which allows not only responding to changes in user requirements but also actively involving the audience in the process of improving game content. This approach contributes to risk reduction, cost optimization, and ensuring high quality of the final product that meets player expectations and increases competitiveness in the video game market.

The concept of applying artificial intelligence in video game development project management should be based on several fundamental principles covering technological, organizational, and integration aspects.

Principle 1: The implementation of artificial intelligence in video game development should be aimed at automating and optimizing routine and repetitive processes. This includes automated testing, data analysis, and task execution monitoring. AI can effectively ensure high-quality testing and real-time analysis, which is especially useful for game projects with a large volume of test scenarios and gameplay variations. Automation allows the development team to focus on creative and strategic aspects of the project without spending time on routine checks, which significantly accelerates the development process and reduces the likelihood of human errors.

Principle 2: Integration of AI as a tool for strategic planning and resource management. Artificial intelligence allows not only analyzing past projects but also predicting needs for the current project based on the data obtained, optimizing resource allocation, and adapting the work schedule depending on variable factors. In the context of video game development, this means that AI helps make decisions regarding the necessary number and specialization of personnel at each stage, proper distribution of tasks, and time management. As the project progresses, artificial intelligence can help the team adapt strategies, identify potential delays, and provide suggestions for problem-solving based on historical data and predictions. This principle is especially important for video game projects with complex and long-term production cycles, where accuracy and flexibility in planning are critical.

Principle 3: Concerns improving user interaction and strengthening feedback at all development stages. AI can collect and analyze large volumes of feedback from players based on their behavior in the game environment, reviews, and other actions. This allows the development team to better understand the needs of their audience, respond to their needs in a timely manner, and increase user engagement. Such feedback enables not only improving game mechanics and gameplay but also increasing audience satisfaction by adapting the game to user requests and preferences in real-time. For video game developers, this ensures a continuous improvement process that meets modern market requirements and allows creating games that remain competitive and relevant.

The application of AI in video game development project management is one of the key factors that allows for significant optimization of each stage of the development process and ensures a high level of adaptability and flexibility in resource and process management. The diagram (Figure 1) shows how the integration of AI into various management blocks improves the quality, accuracy, and speed of development, from initial idea planning to post-release feedback analysis. Each process block is connected with AI to achieve specific goals and objectives aimed at automation, efficiency, and flexibility in project management.

Let's proceed to a detailed examination of the first stage of development. At this initial stage – *Video Game Development*, the main goal is to create a video game that would meet user demands and market requirements. This goal is the foundation for all other stages, which are united by the integration of artificial intelligence tools with various aspects of project management, such as planning, development, testing, release, and feedback analysis. AI in this context is used to ensure the automation of repetitive and routine tasks, which allows focusing on creative and strategic processes.

Idea & Planning (Idea Generation and Initial Planning). At this stage of video game development,

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artificial intelligence plays a key role in forming a successful project concept. AI becomes an indispensable tool for the development team, helping not only to generate new and innovative ideas but also to evaluate their viability and relevance to market needs. Using powerful analytical capabilities of AI, such as machine learning and natural language processing, teams can analyze large volumes of data from various sources: social networks, forums, statistical reports, and market research. AI tools, for example, ChatGPT [8] or Google Trends [9], allow developers to gain a deeper understanding of current industry trends, identify popular genres, mechanics, and themes that resonate with the audience. AI supports the creative brainstorming process, generating various game development scenarios, suggesting innovative game mechanics and storylines. It can quickly assess the potential of each idea, analyzing possible game development options and considering specific characteristics that users will best perceive. Thanks to this, the team can focus on the most promising concepts, saving time and resources. In addition, AI helps predict potential risks and challenges associated with implementing certain ideas. It can model the target audience's reaction, forecast market demand, and determine optimal strategies for promoting the future game. This allows the team to make more informed decisions at early stages of the project.

Concept Development (Розробка концепції). На цьому етапі розробники переходять до Concept Development. At this stage, developers move to the detailed development of the game concept, which includes gameplay, plot, characters, objects, and other important aspects. Artificial intelligence plays a key role, helping to create concepts and prototypes using generative models such as DALL-E [10] and Midjourney [11]. These tools allow automatic generation of concept art, characters, objects, and environments for the game, which significantly accelerates the visual development process. Automation of routine processes related to visual elements allows the team to quickly test different concepts and make informed decisions about their further development. For example, using DeepMotion [12] to automate animation creation facilitates prototype preparation and allows the team to focus on improving gameplay and other creative aspects of the game. Additionally, AI contributes to the creation of scripts and core gameplay mechanics, tailoring them to the target audience and game style. It allows the automation of many processes related to conceptual development, such as creating characters and landscapes, which significantly reduces time and expenses for routine tasks. This enables the team to focus on more unique and innovative elements, enhancing the overall quality and competitiveness of the future product. Thus, at the concept development stage, artificial intelligence becomes an indispensable tool that not only optimizes processes but also opens new opportunities for creativity and innovation in video game development.

Market Research. At this stage, artificial intelligence performs an extremely important function, providing deep and comprehensive analysis of the market and target audience behavior. Using AI tools such as SimilarWeb [13], IBM Watson [14], and Google Analytics [15], developers can conduct multifactor analysis of large data volumes. These tools allow studying market trends, popularity of genres and game mechanics among different audiences, as well as analyzing user behavior on competitive platforms. Thanks to artificial intelligence capabilities, teams can identify which types of games and mechanics are most popular among certain demographic groups, which genres are in highest demand, and which elements are critically important for attracting and retaining users. AI helps understand the needs, preferences, and values of potential players,

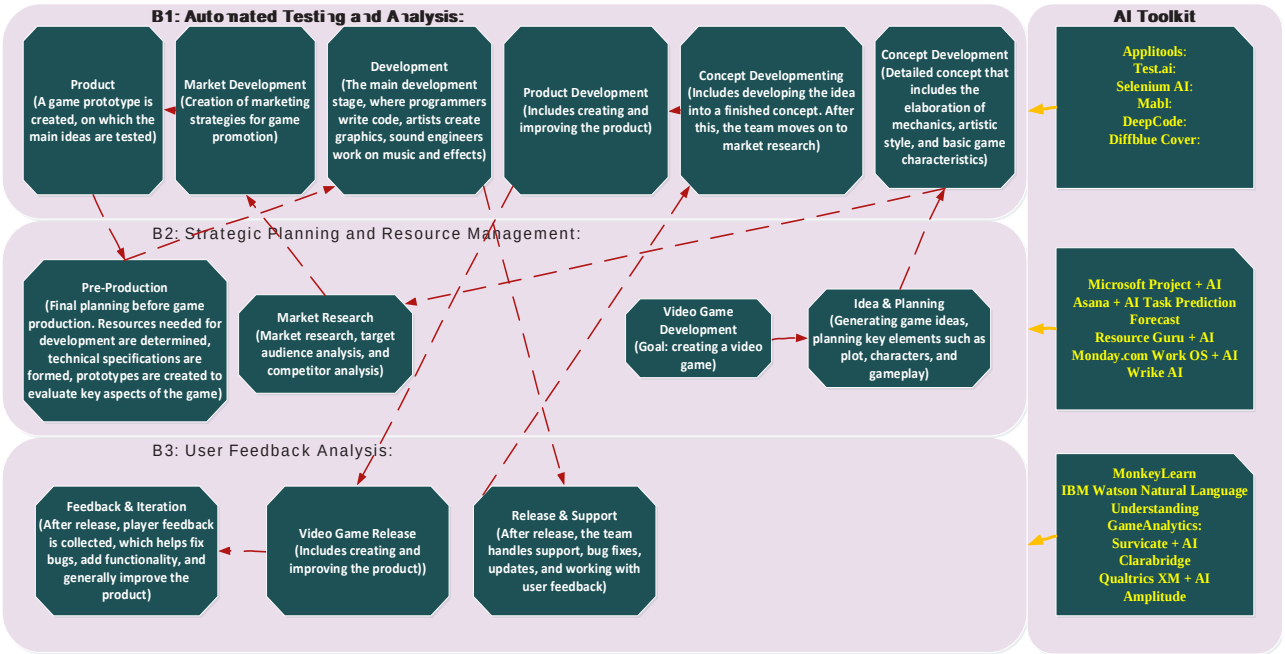

Fig. 1 – Conceptual scheme of artificial intelligence application in video game development project management

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allowing developers to more precisely tailor the game to the expectations of the target audience. Additionally, artificial intelligence can predict future market trends by analyzing historical data and current patterns of user behavior. This gives the team the ability to proactively respond to market changes, adapting game development and marketing strategies. AI also assists in audience segmentation, helping identify the most promising market niches and optimize advertising campaigns.

Market Development. At this stage, artificial intelligence plays a key role in game promotion and optimization of marketing efforts. AI helps the development team more effectively determine channels for product promotion and positioning, allowing more precise identification and reach of the target audience. AI tools such as Facebook Ads AI [16] enable automatic configuration of advertising taking into account user interests and behavior, which increases the effectiveness of marketing activities and audience engagement. HubSpot AI [17] analyzes the effectiveness of different promotion channels, optimizing marketing budget allocation for maximum user reach. AI can automatically analyze data on the effectiveness of various marketing strategies, segment the audience, and configure personalized messages for different groups. This increases the effectiveness of marketing efforts, allowing better results with fewer expenditures, increasing product visibility in the market and audience engagement. Thanks to artificial intelligence capabilities, teams can apply strategically important methods of promotion adapted to specific groups, which enhances the game's competitiveness.

Pre-Production. At this stage, which involves preparation for active game development, artificial intelligence is used to optimize resource allocation, organize tasks, and create detailed schedules. Project management tools with AI integration, such as Microsoft Project with AI [18] or Asana with AI Task Prediction [19], provide automatic schedule creation and resource usage forecasting. They allow automatic predictions for each task and assessment of its impact on the overall project schedule. AI helps the team avoid overloads and downtimes, automatically adapting the project plan depending on available resources and requirements. This automation optimizes task execution and resource usage, increasing the efficiency of the preparatory stage. Thanks to this, the team can minimize risks associated with planning and ensure timely completion of all necessary tasks before active development begins.

Development. At this stage, or development, artificial intelligence plays a significant role in automating many aspects of code creation and gameplay optimization, which significantly increases the efficiency and quality of the final product. AI tools such as Unity ML Agents [20] support the creation of procedural levels and game elements, allowing developers to quickly generate large game worlds with minimal time and resource expenditure. This is especially useful for creating diverse maps, characters, and other elements that can be procedurally generated, providing a unique experience for players. Additionally, technologies such as Nvidia DLSS (Deep Learning Super Sampling) [21] are used to increase game performance by optimizing graphics without overloading the system, which provides smoother and visually appealing gameplay even on less powerful devices. AI also facilitates automatic code generation, allowing developers to focus on more creative and strategic aspects of development, reducing the time needed for writing and debugging routine code. Additionally, artificial intelligence can be used for code analysis, error detection, and game performance optimization. This ensures high quality of the final product, reducing the number of bugs and increasing game stability. Thanks to AI capabilities, development teams can create complex and multilayered game mechanics more quickly and efficiently, corresponding to modern industry standards. Integration of artificial intelligence at the development stage not only automates many routine processes but also opens new possibilities for creativity and innovation, ensuring a high level of productivity and game quality.

Product. At this stage, the Product block is responsible for creating and testing game prototypes, ensuring high quality of the final product before its release. Artificial intelligence plays a key role in automating testing processes, which significantly reduces the time and resources necessary for error detection and code optimization. AI-based tools such as Applitools [22] and Test.ai [23] allow automated testing of visual game elements, detecting anomalies and errors in the user interface in real-time. This is especially useful for multiplayer games and games with large open worlds, where the complexity and scale of the project require thorough quality control. Additionally, tools such as DeepCode [24] and Diffblue Cover [25] analyze game code, suggesting fixes and automatically generating unit tests, which increases code quality and reduces the risk of bugs. DeepCode uses machine learning to identify potential problems in the code and offers recommendations for their correction, allowing developers to quickly respond to detected deficiencies. Diffblue Cover, in turn, automatically creates test scenarios, ensuring code test coverage without the need for manually writing each test, which significantly saves team time. AI also helps create realistic simulations of user behavior, allowing testing of different scenarios and verifying how the game will function in real conditions. This includes modeling player interaction with the game, analyzing their actions and reactions, which allows identifying potential problems in gameplay and game balance at early stages of development.

Release & Support. The final stages of video game development include Release & Support – game release and its subsequent support, as well as Feedback & Iteration – collection and processing of player feedback. Artificial intelligence plays a key role in these processes, providing effective user support and continuous product improvement. For user support, integrated chatbots and automated systems are used, such as Zendesk Chat [26] and Intercom [27], which can promptly process requests, providing instant responses and solving common problems without human intervention. This significantly improves user experience, providing them with quick access to help at any time. Additionally, AI-based tools, such as IBM Watson Natural Language Understanding, analyze player feedback in real-time, collecting data from various platforms, social networks, and forums. These systems automatically classify user reviews by sentiment and emotions, allowing developers

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to quickly respond to negative comments, identify potential problems, and implement necessary changes to increase player satisfaction. Thanks to this, the team can promptly correct game deficiencies, implement improvements, and adapt the product to user expectations, which contributes to game loyalty formation and its successful market positioning. AI integration at the Release & Support stage also optimizes support service work, automating routine tasks and allowing the team to focus on more complex and creative aspects of user service. This ensures high-quality support, reduces response time to requests, and increases the overall effectiveness of marketing and support activities. Thus, using artificial intelligence at the stage of game release and support not only improves user interaction but also contributes to continuous product improvement.

Feedback Analysis. User feedback analysis is a critical stage in video game development, ensuring a continuous process of product improvement based on player behavior and needs. Artificial intelligence plays a key role in this process, helping to collect and analyze large volumes of data about user actions in the game in real-time. Tools such as MonkeyLearn [28], Clarabridge [29], and GameAnalytics [30] allow developers to deeply understand player behavioral patterns, analyze their actions, and identify problematic moments in gameplay. Thanks to this, AI can detect which game elements evoke interest and which cause disappointment, which allows adapting mechanics and gameplay according to user needs. For example, tools such as GameAnalytics [30] or Amplitude [31] can identify player churn points – moments where players most often leave the game. This gives the team the opportunity to make timely changes to improve player retention and increase their engagement. Additionally, sentiment and emotional reaction analysis using tools such as IBM Watson Natural Language Understanding [32] allows classifying user reviews as positive, negative, or neutral, which helps quickly respond to negative comments and improve the game according to player expectations. AI also contributes to creating realistic simulations of user behavior, allowing testing of different scenarios and verifying how the game will function in real conditions. Thus, artificial intelligence integration at the feedback analysis stage provides a deep understanding of player needs and behavior, allowing developers to promptly improve the game, enhance its quality, and ensure high user satisfaction. This contributes to product loyalty formation and its successful positioning in the video game market.

All stages of the production cycle – from idea and planning to release and support – demonstrate how artificial intelligence integration provides automation of routine processes, more efficient resource allocation, and dynamic change management. Through the use of analytical tools for feedback, such as MonkeyLearn, Clarabridge, and GameAnalytics, developers gain a deeper understanding of user needs and their behavior, which allows promptly adapting the product and improving its quality. AI contributes to coordinated team work at every step of the process, helping avoid human errors, accelerating routine task processing, and providing additional tools for deep analysis and game improvement. This leads to risk reduction, cost optimization, and maintaining market competitiveness. Artificial intelligence integration into each block of video game development contributes to creating a quality and competitive product that meets current market demands and ensures maximum user satisfaction. Such comprehensive and all-encompassing application of AI covers both technological and managerial aspects, requiring constant improvement of artificial intelligence models and adaptation to the specific requirements of each new project.

Conclusions

The application of artificial intelligence in video game development project management is a complex and multifaceted process that has a significant impact on development efficiency and final product quality. The importance of researching this area is confirmed by the rapid development of the video game industry and high competition, which requires developers to use innovative approaches to organizing production processes.

In the modern dynamic environment of the gaming industry, the integration of artificial intelligence becomes a factor of economic efficiency and competitive advantage. At the same time, the specifics of the subject area is extremely important, which considers a set of actions and tools that reflect the peculiarities of video game development as both a creative and technical process.

This article proposes a conceptual model for applying AI in video game development project management, reflecting key aspects of artificial intelligence technology integration at various stages of the production cycle. The research confirmed the complexity and multidimensionality of video game development management processes and the need for a systematic approach to AI implementation.

As a result of the research, a conceptual scheme was developed that demonstrates the relationships between different blocks of the development process and corresponding AI tools. This model serves as an informational foundation for further improvement of project management systems in the video game industry and can serve as a basis for developing practical recommendations regarding the implementation of artificial intelligence technologies.

Creating a conceptual model allows for identifying key directions for further research and appropriate analysis methodologies for optimizing video game development processes using artificial intelligence, which opens new opportunities for improving project management efficiency in this dynamic industry.

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DIVERSIFICATION OF TRANSPORT AND LOGISTICS SUPPLY CHAINS OF OILSEEDS AND OIL AND FAT PRODUCTS UNDER SEAPORTS BLOCKADE CONDITIONS

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diversification, logistics chains, oilseeds, oil and fat products, transport logistics, export, multimodal transportation.

The article examines the problems and prospects of diversification of transport and logistics supply chains of oilseeds and oil and fat products in Ukraine under conditions of seaports blockade due to military aggression. The current state of production and export of oilseeds, the dynamics of changes in logistics routes and the economic consequences of cargo flow reorientation are analyzed. It is established that before the full-scale invasion, about 90% of exports of oil and fat products were carried out through seaports, which makes the industry vulnerable in the conditions of blocking traditional logistics routes. A detailed analysis of the effectiveness of four alternative logistics routes was conducted: western railway, south-western railway, Danube river and automobile. Comparative analysis showed that the most economically efficient is a combined route, which includes transportation by rail to the Danube ports of Ukraine and further by river transport to the port of Constanta with subsequent transshipment to sea vessels. However, all alternative routes are characterized by significantly higher costs (40-150% higher) compared to traditional sea exports through the Black Sea ports. Based on the analysis, key problems of diversification of logistics chains were identified, in particular: infrastructure constraints, insufficient capacity of border crossings, lack of specialized transport, high cost of transportation and low speed of delivery. To overcome these obstacles, a set of practical recommendations has been formed, including the development of multimodal transportation, investments in logistics infrastructure, creation of specialized logistics hubs, cooperation with European partners and digitalization of logistics processes. A model for calculating total logistics costs has been developed, which allows assessing the economic efficiency of different routes for different types of oil and fat products. The calculations showed that the implementation of the proposed measures will reduce the logistics costs for the export of sunflower oil by 15-20%, and delivery time - by 10-15%, which will increase the competitiveness of Ukrainian products in world markets. It is substantiated that effective diversification of transport and logistics chains should take into account not only economic but also strategic aspects related to Ukraine's integration into European transport networks and ensuring sustainable development of the oil and fat industry in conditions of geopolitical instability.

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ДИВЕРСИФІКАЦІЯ ТРАНСПОРТНО-ЛОГІСТИЧНИХ ЛАНЦЮГІВ ПОСТАЧАННЯ ОЛІЙНИХ КУЛЬТУР ТА МАСЛОЖИРОВОЇ ПРОДУКЦІЇ В УМОВАХ БЛОКУВАННЯ МОРСЬКИХ ПОРТІВ

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Ключові слова:
диверсифікація, логістичні ланцюги, олійні культури, масложирова продукція, транспортна логістика, експорт, мультимодальні перевезення.

У статті досліджено проблеми та перспективи диверсифікації транспортно-логістичних ланцюгів постачання олійних культур та масложирової продукції України в умовах блокування морських портів внаслідок військової агресії. Проаналізовано сучасний стан виробництва та експорту олійних культур, динаміку зміни логістичних маршрутів та економічні наслідки переорієнтації вантажопотоків. Встановлено, що до початку повномасштабного вторгнення близько 90% експорту масложирової продукції здійснювалося через морські порти, що робить галузь вразливою в умовах блокування традиційних логістичних шляхів. Проведено детальний аналіз ефективності чотирьох альтернативних логістичних маршрутів: західного залізничного, південно-західного залізничного, дунайського річкового та автомобільного. Порівняльний аналіз показав, що найбільш економічно ефективним є комбінований маршрут, який включає перевезення залізницею до дунайських портів України та далі річковим транспортом до порту Констанца з подальшим перевантаженням на морські судна. Проте всі альтернативні маршрути характеризуються значно вищими витратами (на 40-150% вище) порівняно з традиційним морським експортом через порти Чорного моря. На основі аналізу ідентифіковано ключові проблеми диверсифікації логістичних ланцюгів, зокрема: інфраструктурні обмеження, недостатню пропускну здатність прикордонних переходів, брак спеціалізованого транспорту, високу вартість перевезень та низьку швидкість доставки. Для подолання цих перешкод сформовано комплекс практичних рекомендацій, що включає розвиток мультимодальних перевезень, інвестиції в логістичну інфраструктуру, створення спеціалізованих логістичних хабів, співпрацю з європейськими партнерами та цифровізацію логістичних процесів. Розроблено модель розрахунку сукупних логістичних витрат, яка дозволяє оцінити економічну ефективність різних маршрутів для різних видів масложирової продукції. Проведені розрахунки показали, що реалізація запропонованих заходів дозволить знизити логістичні витрати на експорт соняшникової олії на 15-20%, а час доставки - на 10-15%, що підвищить конкурентоспроможність української продукції на світових ринках. Обґрунтовано, що ефективна диверсифікація транспортно-логістичних ланцюгів має враховувати не лише економічні, а й стратегічні аспекти, пов'язані з інтеграцією України до європейських транспортних мереж та забезпеченням сталого розвитку масложирової галузі в умовах геополітичної нестабільності.

Statement of the problem

The oil and fat industry is one of the key sectors in the structure of Ukraine's agricultural exports, providing significant foreign exchange earnings to the state budget. Ukraine has traditionally been among the top three exporters of sunflower oil in the world, controlling almost 50% of the global sunflower oil market [3]. In addition, the country is an important exporter of rapeseed, soybeans, and their processed products. According to the Ministry of Agrarian Policy and Food of Ukraine [10], in 2021, the export of oil and fat products brought the country more than $7 billion, which accounted for about 26% of the total agricultural exports.

Russia's military aggression against Ukraine, which began in February 2022, led to the blockade of Black Sea ports, through which up to 90% of oil and fat products were traditionally exported [2]. This situation forced producers and exporters to seek alternative logistics routes, accompanied by a significant increase in costs and time for delivering products to the end consumer. According to experts from the Ukrainian Club of Agrarian Business [9], the cost of logistics for the export of sunflower oil increased by 40-60% compared to the pre-war period, which significantly reduces the profitability of the industry and the competitiveness of Ukrainian products in world markets.

In addition to logistics problems, producers of oilseeds and oil and fat products face a number of additional challenges, including: reduction of sown areas due to the occupation of some territories, lack of qualified labor, disruptions in electricity supply to processing enterprises, difficulties with access to credit resources and risk insurance [11]. All these factors together create new

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realities for the functioning of the industry and require a systematic revision of development strategies both at the level of individual enterprises and the industry as a whole.

The search for optimal logistics solutions for the export of oilseeds and oil and fat products has not only economic but also social significance. The oil and fat industry provides jobs for more than 100,000 people in Ukraine and is also an important source of income for agricultural producers, especially small and medium-sized farms [7]. In addition, maintaining the export potential of the industry is critically important for global food security, as Ukrainian sunflower oil is supplied to more than 120 countries worldwide, including countries with a high risk of food crisis [6].

The transformation of logistics chains for the supply of oilseeds and oil and fat products should be considered in the context of Ukraine's integration into the European Union [5]. The development of multimodal transportation, modernization of transport infrastructure, implementation of European standards in the field of logistics will not only help overcome the current problems of the industry but also create a foundation for its competitive development in the long term. According to Melnyk T. and Puhachova K. [7], the integration of the Ukrainian transport system into European transport networks can become a catalyst for the modernization of the entire logistics infrastructure of the country.

Analysis of recent studies and publications

Problems of logistics of agricultural products, in particular oilseeds, have been studied by many domestic and foreign scientists. Thus, Nekrasenko L. and Tkachuk O. [1] investigated the current problems of grain logistics in Ukraine, noting that the volumes of transportation are related to the level of production within the country. The authors emphasize that "grain production is volatile and difficult to predict, so grain logistics chains must be reliable and elastic," which fully applies to oilseeds as well. Shults S. and Lutskiv O. [2] analyzed the problems of functioning of transport infrastructure and logistics of Ukraine during wartime, focusing on the need to diversify transport routes and cargo flows. They note that "due to the full-scale Russian aggression, six seaports suspended their activities in the field of transport logistics," which led to a radical change in logistics chains.

The issues of efficiency of export of oilseeds and their processed products were considered in detail by Kushnir T. and Berehovyi V. [3]. The authors note that "Ukraine's share in the global sunflower oil market before the full-scale invasion was about 50%," which demonstrates the strategic importance of this industry for the country's economy. The study indicates that about 90% of oil exports were carried out by sea transport, which makes the industry extremely vulnerable in the conditions of port blockade.

Logistics aspects of export of oil and fat products were studied by Lebedynska O. [4], who conducted a detailed analysis of the transport component in the formation of the export price of oilseeds and their processed products. The researcher notes that "in the structure of costs for the export of sunflower oil, the transport component accounts for 12% to 25%," which makes the optimization of logistics chains a key factor in improving the competitiveness of products. The author pays special attention to multimodal transportation, which, in her opinion, has the greatest potential for optimizing export flows in conditions of limited access to traditional sea routes.

Makarenko S. and Antoshchenkova V. [5] in their studies highlight the main problems of logistics support for the export of agricultural products of Ukraine during the war. The authors emphasize that "the reorientation of export flows from sea to rail and road transport led to an increase in logistics costs by 120-180%," which significantly reduces the profitability of exports and the competitiveness of Ukrainian products in world markets. The paper also analyzes the possibilities of using river transport, in particular, the potential of Ukrainian Danube ports for the export of oil and fat products.

Among foreign researchers, the works of Gentilini M. [6] should be noted, who analyzes the global market of vegetable oils and the impact of the Russian-Ukrainian war on it. The author notes that "the blockade of Ukrainian ports caused an increase in world prices for sunflower oil by 30-45% during the first months of the war," which confirms the importance of Ukraine as a global player in the oil and fat products market. Also worth noting are the studies by Melnyk T. and Puhachova K. [7], who studied the transformation of logistics chains of agri-food products of Ukraine in conditions of war and post-war recovery. The authors propose a model for optimizing logistics routes taking into account the risks and uncertainties characteristic of wartime.

At the same time, the specifics of logistics of oilseeds and oil and fat products in the conditions of seaport blockade remains insufficiently studied, which determines the relevance of this work. In particular, there are no comprehensive studies on the effectiveness of alternative logistics routes and their economic feasibility for different types of oil and fat products.

Objectives of the article

The aim of this study is to analyze the possibilities and economic efficiency of diversification of transport and logistics supply chains of oilseeds and oil and fat products in the conditions of seaport blockade, as well as to develop recommendations for optimizing logistics routes.

The main material of the research

Ukraine is one of the leading producers of oilseeds in the world. The main oilseeds grown in Ukraine are sunflower, rapeseed, and soybean [3]. According to the State Statistics Service of Ukraine [8] and analytical materials of the Ukrainian Club of Agrarian Business [9], before the full-scale invasion, Ukraine controlled about 50% of the global sunflower oil market, which confirms the strategic importance of the industry for the country's economy. Table 1 presents data on the production and export of main oilseeds in Ukraine for 2019-2023.

As can be seen from Table 1, military actions have significantly affected the production and export of oilseeds and their processed products. Thus, in 2022, there was a significant reduction in the production of sunflower (by

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Table 1 – Dynamics of production and export of main oilseeds in Ukraine, 2019-2023, million tons

Crop	Показник	2019	2020	2021	2022	2023	Change 2023/2019, %
Sunflower	Production	15,3	13,1	16,9	10,5	12,4	-19
	Export	0,1	0,2	0,3	0,4	0,5	400
Sunflower oil	Production	6,8	5,9	7,3	4,2	5,1	-25
	Export	6,4	5,3	6,7	3,5	4,2	-34,4
Rapeseed	Production	3,1	2,6	2,9	3,2	4	29
	Export	2,9	2,4	2,7	2,5	3,4	17,2
Soybean	Production	4,5	3,1	3,5	3,7	4,8	6,7
	Export	2,1	1,8	2	1,9	2,5	19

Source: calculated by the author based on data [8, 9]

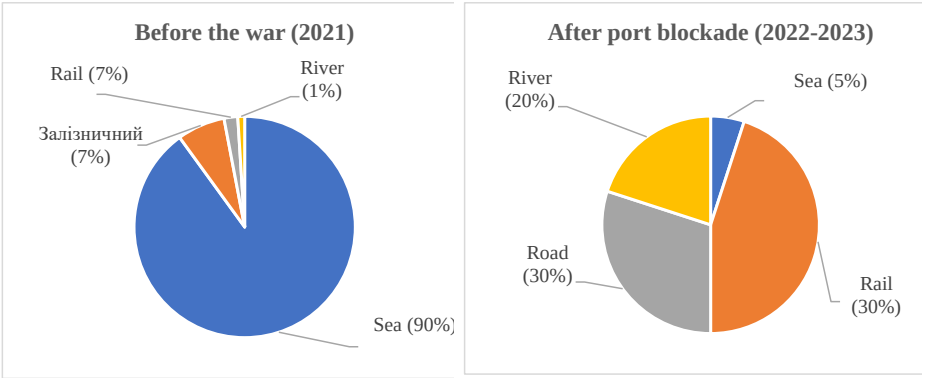

Fig. 1 – Structure of export of oilseeds and oil and fat products of Ukraine by types of transport, %

37.9% compared to 2021) and sunflower oil (by 42.5%). In 2023, the situation somewhat stabilized, but indicators still have not reached the pre-war level. These results correlate with the studies of Gentilini M. [6], who notes that the global sunflower oil market has undergone significant transformations due to the reduction of exports from Ukraine.

Before the full-scale invasion of Russia into Ukraine, the export of oil and fat products was carried out mainly through the Black Sea ports. Figure 1 shows the structure of export of oilseeds and oil and fat products of Ukraine by types of transport before the war (2021) and after the blockade of ports (2022-2023).

As we can see from the figure, before the war, sea transport dominated in the export structure of oilseeds and oil and fat products (about 90%). After the blockade of ports, there was a significant reorientation of export flows to rail (45%), road (30%), and river (20%) transport, which led to an increase in logistics costs and delivery time.

In connection with the blockade of seaports, exporters of oil and fat products were forced to develop and implement alternative logistics routes. Based on the analysis of industry practices, the following main routes can be identified:

– *western railway route:* Ukraine – Poland – Baltic Sea ports (Gdańsk, Gdynia);

– *south-western railway route:* Ukraine – Romania/ Moldova – port of Constanta;

– *danube river route:* Ukrainian ports on the Danube (Reni, Izmail, Kiliya) – ports of Romania and Bulgaria;

– *road route*: Ukraine – EU countries (Poland, Slovakia, Hungary, Romania).

To assess the economic efficiency of alternative logistics routes, a comparative analysis of the costs of transporting 1 ton of sunflower oil from a producer in Central Ukraine to the final buyer in Europe, the Middle East, and North Africa was conducted (Table 2). This analysis methodology corresponds to the approaches proposed in the works of Lebedynska O. [4] and Makarenko S. [5].

As can be seen from Table 2, all alternative routes are characterized by significantly higher costs compared to traditional sea exports through the Black Sea ports. The most economically efficient among the alternatives is the Danube river route, but it is characterized by the longest delivery time.

For a more detailed analysis of the economic efficiency of different logistics routes, a model for calculating the total logistics costs for the export of oilseeds and oil and fat products has been developed:

$$LC = TC + SC + HC + IC + OC,$$

where: LC – total logistics costs for the export of 1 ton of products, USD/t;
TC – transport costs, USD/t;
SC – storage costs, USD/t;
HC – loading and unloading costs, USD/t;
IC – cargo insurance costs, USD/t;
OC – other costs (documentation, customs clearance, etc.), USD/t.

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Based on this model, the calculation of total logistics costs for different types of oil and fat products by alternative routes was performed (Fig. 2).

The analysis shows that the most economically efficient for the export of sunflower oil is a combined route, which includes transportation by rail to the Danube ports of Ukraine, and further by river transport to the port of Constanta with subsequent transshipment to sea vessels. This conclusion is consistent with the data from studies by Lebedynska O. [4] and Shults S. and Lutskiv O. [2], who also note the prospects of multimodal transportation for optimizing export flows.

Currently, there are a number of obstacles that complicate the effective diversification of logistics chains for the supply of oilseeds and oil and fat products:

– *infrastructure constraints* – the railway infrastructure of western regions of Ukraine and EU countries is not sufficiently developed to handle increased export volumes. A particular problem is the different rail gauge in Ukraine and the EU, which requires transshipment of products at the border;

– *insufficient capacity of border crossings* – waiting time at the border can be up to 10-15 days, which significantly increases the total delivery time and creates risks for product quality;

– *lack of specialized transport* – there is a shortage of railway tanks for oil transportation, as well as specialized vehicles (tank trucks);

– *high cost of transportation* – alternative routes are characterized by significantly higher costs compared to traditional sea exports, which reduces the competitiveness of Ukrainian products in the world market;

– *low speed of delivery* – alternative routes often involve longer delivery time, which creates additional risks for exporters.

To overcome these obstacles and improve the efficiency of logistics chains for the supply of oil and fat products, the following measures are proposed, which are partially based on the recommendations of Melnyk T. and Puhachova K. [7]:

– *development of multimodal transportation* – combining different types of transport allows optimizing costs and delivery time. Particularly promising is the combination of rail and river transport;

– *investments in logistics infrastructure* – construction of new and modernization of existing elevators, terminals, warehouses, and transshipment complexes, especially in the western regions of Ukraine and at the border with the EU;

– *creation of logistics hubs* – formation of specialized logistics centers for storage, transshipment, and processing of oilseeds and oil and fat products;

– *cooperation with European partners* – expansion of cooperation with European logistics companies and port operators to increase the efficiency of export operations;

– *digitalization of logistics processes* – implementation of digital technologies for optimization of logistics routes, monitoring of cargo movement, and simplification of document flow.

Table 2 – Comparative analysis of costs for exporting 1 ton of sunflower oil by alternative logistics routes, USD/t

Route	To EU	To Middle Eas	To North Africa	Average delivery time, days
Traditional sea (before the war)	40	55	60	15-20
Western railway	85	130	140	25-30
South-western railway	75	110	120	20-25
Danube river	65	100	110	25-35
Road transport	95	150	160	15-20

Source: calculated by the author based on data from logistics companies and expert assessments

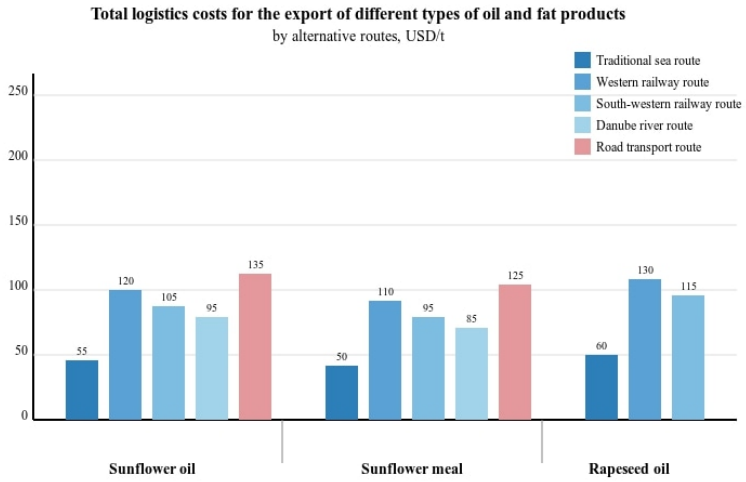

Fig. 2 – Total logistics costs for the export of different types of oil and fat products by alternative routes, USD/t

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Table 3 – Projected indicators of the efficiency of logistics chains for the supply of oil and fat products

Indicator	Current state	After implementing measures	Change, %
Average logistics costs for the export of sunflower oil, USD/t	110	90	-18,2
Average delivery time to the end consumer, days	25	22	-12
Capacity of border crossings, thousand t/month	450	600	33,3
Share of multimodal transportation in the total export volume, %	30	50	66,7
Volume of export of oil and fat products, million t/year	5	6,5	30

Source: calculated by the author based on expert assessments and forecast calculations

The calculations show that the implementation of the proposed measures will reduce the logistics costs for the export of sunflower oil by 15-20%, and delivery time – by 10-15%. Table 3 presents the projected indicators of the efficiency of logistics chains for the supply of oil and fat products with the implementation of the proposed measures.

It is important to note that the diversification of transport and logistics chains for the supply of oilseeds and oil and fat products creates not only economic advantages but also ensures strategic sustainability of the industry in conditions of geopolitical instability. The formation of alternative export routes reduces the industry's dependence on individual transport directions and reduces risks associated with possible restrictions or blockade of individual transport corridors. This is especially important in the conditions of ongoing military aggression, which creates a high level of uncertainty regarding the use of traditional export routes through the Black Sea ports [2].

It should also be taken into account that military actions have caused significant migration of the population, including qualified specialists in the logistics industry. According to the Ministry of Infrastructure of Ukraine [13], the deficit of truck drivers and railway transport operators is about 25-30%. This creates additional challenges for the effective functioning of new logistics routes and requires the development of training and retraining programs for the transport and logistics sphere. The implementation of digital technologies and automation of logistics processes can partially compensate for the deficit of personnel, but require significant investments [7].

Deepening the integration of Ukraine into the European transport system opens new opportunities for modernizing the logistics infrastructure and implementing modern technologies for transportation and storage of oil and fat products. According to experts from the Ukrainian Club of Agrarian Business [9], about 65% of exporters of oilseeds and oil and fat products have already reoriented their logistics chains to European directions, with 42% of them planning to continue using these routes even after the full restoration of Black Sea ports. This indicates the formation of stable business relationships with European partners and the integration of Ukrainian producers into European logistics networks, which will have a long-term positive impact on the competitiveness of the domestic oil and fat industry in

Conclusions

The blockade of Ukrainian seaports due to Russia's military aggression has led to the need for diversification of transport and logistics supply chains of oilseeds and oil and fat products. The main alternative routes have become the western and south-western railway routes, the Danube river route, and road transportation.

The analysis of the economic efficiency of alternative logistics routes showed that the most optimal is a combined route, which includes transportation by rail to the Danube ports of Ukraine with further transportation by river and sea transport. However, all alternative routes are characterized by significantly higher costs compared to traditional sea exports through the Black Sea ports, which reduces the competitiveness of Ukrainian products in the world market.

To improve the efficiency of logistics chains for the supply of oil and fat products, a set of measures has been proposed, including the development of multimodal transportation, investments in logistics infrastructure, creation of logistics hubs, cooperation with European partners, and digitalization of logistics processes. The implementation of these measures will reduce the logistics costs for the export of sunflower oil by 15-20%, and delivery time – by 10-15%.

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NATIONAL ECONOMY'S MARKET MECHANISMS OF ACCOUNTING, ANALYSIS AND AUDIT

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FIXED ASSETS IN AN ENTERPRISE: ACCOUNTING AND THEORETICAL ASPECT

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Key words:
fixed assets, accounting, depreciation, asset classification, inventory, harmonization, innovation, digital technologies.

The study focuses on the accounting and theoretical aspects of fixed assets in enterprises, which are an important part of the assets, production potential and financial stability of economic entities. The relevance of this work is due to the growing requirements for transparency of financial reporting, the integration of international standards, the need to automate accounting processes in the context of globalization and digitalization of the economy. In the context of dynamic economic changes, the issue of effective accounting of fixed assets becomes critically important for ensuring long-term sustainability and competitiveness of enterprises. The main hypothesis of the study states that improving the classification, assessment and accounting of fixed assets will contribute to increasing the efficiency of their use, reducing costs, improving management decisions and adapting to changing business conditions.

The research methodology includes the analysis of scientific sources, regulatory legal acts, accounting practices, as well as the application of systematization, comparison and generalization methods. The research revealed the need to update the classification of fixed assets, improve depreciation methods, adapt approaches to the valuation and revaluation of assets, as well as introduce unified standards for the use of digital technologies. This will contribute to the automation of accounting processes, ensure accuracy, transparency and compliance with modern requirements.

The practical significance of the work lies in formulating recommendations for optimizing the accounting policy of enterprises, taking into account industry specifics, legislative requirements, and innovative approaches. Progressive depreciation methods, digitalization of inventory procedures, and harmonization of reporting with international standards are proposed, which allows increasing the competitiveness of enterprises in global markets.

The scientific novelty of the study lies in the substantiation of new theoretical approaches to accounting for fixed assets, which take into account modern economic conditions and changes in regulatory and legal support in the context of digital transformation and harmonization of accounting processes. The results of the study can be used to improve accounting efficiency, transparency of reporting and adaptation of enterprises to modern challenges. Prospects for further research include improving accounting methods, analyzing the impact of fixed assets on the efficiency of the enterprise, assessing depreciation methods, studying the impact of external factors, environmental aspects of fixed assets management and introducing innovations in the use of fixed assets.

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ОСНОВНІ ЗАСОБИ НА ПІДПРИЄМСТВІ: ОБЛІКОВО-ТЕОРЕТИЧНИЙ АСПЕКТ

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Ключові слова:
основні засоби, бухгалтерський облік, амортизація, класифікація активів, інвентаризація, гармонізація, інновації, цифрові технології.

Дослідження зосереджене на обліково-теоретичних аспектах основних засобів у підприємствах, які є важливою частиною активів, виробничого потенціалу та фінансової стабільності господарських суб'єктів. Актуальність цієї роботи обумовлена зростаючими вимогами до прозорості фінансової звітності, інтеграцією міжнародних стандартів, необхідністю автоматизації облікових процесів в умовах глобалізації та цифровізації економіки. В умовах динамічних економічних змін питання ефективного обліку основних засобів стає критично важливим для забезпечення довгострокової стійкості та конкурентоспроможності підприємств. Основна гіпотеза дослідження стверджує, що покращення класифікації, оцінки та обліку основних засобів сприятиме підвищенню ефективності їх використання, зменшенню витрат, поліпшенню управлінських рішень і адаптації до змінюваних умов господарювання.

Методологія дослідження включає аналіз наукових джерел, нормативно-правових актів, практик обліку, а також застосування методів систематизації, порівняння та узагальнення. У процесі дослідження виявлено необхідність оновлення класифікації основних засобів, вдосконалення методів амортизації, адаптації підходів до оцінки та переоцінки активів, а також запровадження уніфікованих стандартів для використання цифрових технологій. Це сприятиме автоматизації облікових процесів, забезпечить точність, прозорість і відповідність сучасним вимогам.

Практична значущість роботи полягає у формулюванні рекомендацій для оптимізації облікової політики підприємств з урахуванням галузевих особливостей, законодавчих вимог та інноваційних підходів. Пропонуються прогресивні методи амортизації, цифровізація інвентаризаційних процедур і гармонізація звітності з міжнародними стандартами, що дозволяє підвищити конкурентоспроможність підприємств на глобальних ринках.

Наукова новизна дослідження полягає у обгрунтуванні нових теоретичних підходів до обліку основних засобів, що враховують сучасні економічні умови та зміни нормативно-правового забезпечення в умовах цифрової трансформації та гармонізації облікових процесів . Результати дослідження можуть бути використані для підвищення ефективності обліку, прозорості звітності та адаптації підприємств до сучасних викликів. Перспективи подальших досліджень включають вдосконалення облікових методів, аналіз впливу основних засобів на ефективність підприємства, оцінку амортизаційних методів, дослідження впливу зовнішніх факторів, екологічні аспекти управління основними засобами та впровадження інновацій у використанні основних засобів.

Statement of the problem

Topicality research main means conditioned theirs key role in ensuring effective functioning enterprises. Main means constitute significant part assets enterprises, affecting the financial stability, production potential and competitiveness. In the conditions globalization, technical progress and strengthening transparency requirements financial reporting, correct accounting main means becomes critically important. Changes in the economic environment and growth difficulties resource management requires a review of approaches to the organization accounting process. Effective using main means can be achieved only if clear understanding theirs economic essence, classification and influence on the formation the financial result of the enterprise.

Analysis of latest research and publications

Research on fixed asset accounting has received significant attention in the works of both Ukrainian and foreign scientists. In particular: F. F. Butynets, T. V. Baranovska, V. A. Kulyk, M. S. Pushkar. Despite the significant contribution of scientists to the study of theoretical and practical aspects of fixed asset accounting, a number of important issues remain unresolved. In particular, the classification of fixed assets requires further improvement to adapt to new economic conditions and industry characteristics. It is also relevant to study approaches to the formation of asset useful lives that take into account technological changes and the specifics of the use of fixed assets in various fields of activity. In addition, the introduction of modern digital technologies

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into accounting processes requires a revision of traditional methods of valuation, revaluation and inventory of fixed assets. The development of universal recommendations for the implementation of innovative approaches to accounting for these assets, taking into account international financial reporting standards, is of particular importance.

Formulating goals

It is believed that improving the classification, valuation methods, and accounting for fixed assets, taking into account current economic conditions and technological changes, will help increase their efficiency, reduce costs, and ensure compliance with international financial reporting standards.

The purpose of the study is to analyze the theoretical foundations of accounting for fixed assets at an enterprise. This includes generalizing theoretical approaches to the definition, classification, and valuation of fixed assets, identifying key principles underlying their accounting, and developing recommendations for improving the theoretical framework.

The article consists of several sections. The first section provides an analysis of the concept and classification of fixed assets. The second section considers modern approaches to depreciation, valuation and revaluation of fixed assets. The third section offers recommendations for improving the theoretical basis of accounting for fixed assets at the enterprise. The conclusions summarize the results of the study, confirm the hypothesis and identify prospects for further developments in this area.

Presentation of the main research material

Fixed assets occupy an important place in the accounting policy of any enterprise, as they significantly affect the structure of assets and the level of capital investments. Their accounting and disclosure in financial statements are regulated by NP(S) BO 7 “Fixed Assets”. According to this standard, fixed assets are tangible assets that are used for production purposes, the supply of goods, the provision of services, leasing, as well as for administrative or socio-cultural functions. The duration of their useful life exceeds one year or the operating cycle (depending on which is longer).

Fixed assets include: investment property, land, capital expenditures for land improvements, buildings, structures, machinery, equipment, vehicles, tools, appliances, inventory, animals, perennial plantings, and other tangible objects in this category (Table 1).

In addition, NP(S)BO 7 introduces the concept of “Other non-current tangible assets”. These are assets with a useful life of more than one year or operating cycle (if longer), which are not included in fixed assets. These include, in particular, library collections, low-value non-current tangible assets, temporary structures, natural resources and inventory containers.

The standard identifies key aspects relating to the recognition, measurement and accounting for fixed assets [14] .

Thus, from the table it is clear that fixed assets in most definitions of the authors are considered as tangible assets or means of labor that are used by enterprises for a long time (more than one year) and transfer their value to products gradually through depreciation. They retain their physical form and bring economic benefits in several operating cycles.

Fixed assets constitute an important part of the assets of most business entities. Their value is usually significant, but it can only be included in expenses affecting taxation in the form of accrued depreciation. Thus, the company's expenses gradually include the depreciated value of the fixed asset.

Tax Code of Ukraine regulates this process by establishing minimum amortization periods depending on the group of fixed assets. There are 16 such groups, and the amortization periods vary from 2 to 20 years [11] .

We suggest considering these groups and their minimum acceptable useful lives (Table 2).

Table 1 – Generalization of the results of the study of the economic essence of the concept of "fixed assets"

Author	Characteristic features							
	Tangible asset	Tools	Used in the process of production, rental, administrative or socio-cultural functions	Assets participate in multiple operating cycles	Gradual transfer of value through depreciation.	Assets are used in production, administrative or social functions	Economic benefit expected	Operate in the production process for a long period
Butynets F. F.	+		+					
Mikhailov A. M.	+			+	+		+	
Verkhoglyadova N.I., Shylo V.P., Ilyina S.B., Kysla V.I.		+			+			
Aggres O.G.		+	+		+	+		
Kovalenko O.V. Gromova I.V.	+				+			+
Babyak N.D.	+			+	+			

Source: compiled by the authors based on source 5.

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According to Article 1 of the Law of Ukraine "On Accounting and Financial Reporting in Ukraine" dated July 16, 1999 No. 996-XIV, accounting policy is a set of principles, methods and procedures that an enterprise chooses to prepare and present financial statements [8]. International Accounting Standard (IAS) 8 "Accounting Policies, Changes in Accounting Estimates and Errors" provides a somewhat broader definition, considering accounting policy as a set of principles, bases, agreements, rules and practices used by a business entity in preparing and presenting financial statements [8].

Also, Table 3 grouped how different researchers interpret the concept of "Accounting Policy" (Table 3).

The enterprise independently establishes its accounting policy and chooses the form of accounting, adhering to the principles defined by law.

The accounting policy of the enterprise for fixed assets is based on the established rules for their valuation, measurement and accounting, which directly affect the financial results of the activity. According to subparagraph 14.1.138 of the Tax Code of Ukraine, fixed assets are defined as tangible assets, including reserves of minerals provided for use on subsoil areas. Fixed assets do not include land plots, unfinished capital investments, public roads, library and archival funds, tangible assets worth up to 20,000 hryvnias, non-production fixed assets and intangible assets. Such assets are used in the economic activities of the enterprise, have a value of more than 20,000 hryvnias and gradually lose their value due to physical or moral wear and tear. Their expected useful life exceeds one year or the operating cycle, if it is longer. These provisions define key aspects of accounting policies that contribute to the accurate reflection of financial results and ensure compliance with the requirements of tax and accounting legislation [11].

Table 2 – Groups of fixed assets and their minimum useful lives

Group	Name	Useful life under the PKU
1	land plots	the minimum allowable useful life has not been established
2	capital expenditures for land improvements not related to construction	15 years
3	buildings, structures and transmission devices	20, 15 and 10 years respectively
4	machinery and equipment	5 years
5	vehicles	5 years
6	tools, appliances, inventory (furniture)	4 years
7	animals	6 years
8	perennial plantings	10 years
9	other fixed assets	12 years
10	library funds	the minimum allowable useful life has not been established
11	low-value non-current tangible assets	the minimum allowable useful life has not been established
12	temporary (non-title) structures	5 years
13	natural resources	the minimum allowable useful life has not been established
14	inventory container	6 years
15	rental items	5 years
16	long-term biological assets	7 years

Source: Grouped by authors by source 11.

Table 3 – The concept of accounting policy

Researcher	Treatment
F.F. Butynets	"an enterprise's accounting policy is not just a set of accounting methods selected in accordance with business conditions, but also the choice of accounting methodology, which provides the opportunity to use different options for reflecting the facts of economic life in accounting (depending on the goals set)"
T. V. Baranovskaya	The accounting policy of the enterprise should be aimed at revealing the creative abilities of entrepreneurs in increasing the efficiency of management, introducing new technologies to meet their own needs and fulfill obligations to the state.
V.A. Kulyk	The accounting policy of an enterprise is an important tool that allows for a reasonable combination of state regulation and the enterprise's own initiative in matters of organization and accounting.
M.S. Pushkar	"Accounting policy is the constitution of an enterprise, which provides for the rights and obligations of the accounting system regarding the formation of information resources for managers"
L.G. Lovinska, I.B. Stefanyuk	"an entity's accounting policy is a set of principles, methods and procedures used by an entity for current accounting, preparation and submission of financial statements within the limits specified by the Law of Ukraine "On Accounting and financial reporting in Ukraine", accounting regulations (standards), other regulatory documents approved by the Ministry of Finance and other executive authorities after consultation with the Ministry of Finance"
V.A. Derii	Accounting policy should be understood as the right of choice officially approved by the enterprise and granted by the state, taking into account the specifics of the enterprise's activities and current legal acts, relevant methods and forms, and accounting techniques.

Source: Grouped by authors by sources 1 , 2 , 3 , 6 , 7 , 15.

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The Order of the Ministry of Finance of Ukraine "On Approval of Methodological Recommendations on the Accounting Policy of an Enterprise and Amendments to Certain Orders of the Ministry of Finance of Ukraine" dated June 27, 2013 No. 635 established a regulatory document regulating the accounting policy of an enterprise in terms of fixed assets.

1) Depreciation methods for these assets, including fixed assets, other non-current tangible assets, intangible assets, long-term biological assets and investment property, if they are recorded at historical cost.

In the order on accounting policy, the enterprise should indicate the method of calculating depreciation of fixed assets (Table 4). According to paragraph 145.1.5 of the Tax Code of Ukraine [11], the enterprise may use the following methods:

In modern accounting practice, progressive depreciation methods (Table 6) play an important role, allowing an enterprise to effectively manage fixed asset costs and which can be useful for analyzing and selecting the optimal approach in managing an enterprise's assets.

For other non-current tangible assets, depreciation can be calculated using the straight-line or production methods. In the case of low-value non-current tangible assets and library funds, depreciation can be calculated in one of two ways: in the first month of use of the object - 50% of its depreciable value, and the remaining 50% - in the month of its removal from assets (write-off from the balance sheet), or in the first month of use - 100% of the value of the object [11].

Thus, if an enterprise needs to minimize costs, it is advisable to choose the 50/50 method, and if a business entity seeks to reduce its financial result before taxation, then in this case it can take into account the method that allows for 100% depreciation, which is accordingly enshrined in the accounting policy.

The cost characteristics of objects included in the category of low-value non-current tangible assets can be determined by the enterprise at its own discretion in accordance with the NP(S)BO [14]. Any change in these cost characteristics is considered a change in accounting estimates. As a result of the change in cost characteristics,

Table 4 – Methods of depreciation of fixed assets

Method	Characteristic
Rectilinear	Depreciation is calculated evenly over the entire useful life of the asset. The annual depreciation amount remains unchanged.
Reduction of residual value	Depreciation is charged on the residual value of the fixed asset, which decreases each year, so depreciation deductions also gradually decrease.
Accelerated depreciation	An increased depreciation rate is used, which allows for faster depreciation of the asset at the beginning of its useful life.
Cumulative	Depreciation is calculated proportionally over the remaining useful life of the asset. The depreciation amount is higher at the beginning and decreases towards the end of the useful life.
Industrial	Depreciation is calculated based on the volume of production or other indicator of asset usage.

Source: Grouped by authors by source 8.

Table 5 – Advantages and disadvantages of traditional methods of depreciation of fixed assets

Depreciation method	Advantages	Disadvantages
Straight-line method	Simplicity of calculations, stability of costs.	Does not take into account the difference in depreciation of assets in different years of use.
Cost reduction method	Takes into account depreciation, more expenses in the first years.	The complexity of calculations requires constant monitoring of monetary value.
Accelerated depreciation method	It reflects the depreciation cost of an asset more quickly, useful for rapidly aging assets.	May result in significant costs in the early years, which will affect the financial results of the enterprise.
Cumulative method	Ability to adapt to changes in asset usage throughout their service life.	Complexity in calculations and the need for detailed accounting of asset use.
Production method	Corresponds to the actual use of the asset, which allows for a more accurate reflection of costs.	Not suitable for all types of assets, especially those that do not have clear production metrics.

Source: Grouped by authors by source 12 .

Table 6 – Progressive methods of depreciation of fixed assets

Progressive method	Description
Accelerated depreciation method	Using algorithms for automated calculation of depreciation costs, adapted to a rapidly changing environment.
Method based on production indicators	Implementing IoT to monitor equipment condition and automatically calculate depreciation costs based on actual usage.
Adaptation to international standards	Using IFRS to harmonize approaches to depreciation and increase transparency of financial reporting.
Digitalization of accounting processes	ERP system integration to automate fixed asset accounting processes and simplify depreciation calculation.
Flexible models	Development of flexible depreciation models that take into account changes in market conditions and technological progress.

Source: Grouped by authors by source 12 .

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no adjustments are made in accounting for fixed assets that were included in the balance sheet in previous periods. This allows enterprises to maintain stability in accounting policies and avoid the need to re-record accounting records related to already recorded assets. Changing cost characteristics can also be applied in the context of updating or optimizing accounting processes, which can increase the efficiency of asset management as a whole.

To ensure control over the availability and condition of fixed assets, it is advisable to provide for an inventory procedure in the order on the accounting policy of the enterprise. Such an inventory is carried out in accordance with the requirements of the "Regulations on the Inventory of Assets and Liabilities", approved on September 2, 2014 by order No. 879.

The organization of the inventory is entrusted to the head of the enterprise, who must create appropriate conditions for its conduct in the shortest possible time, determine the objects of the inventory, their number and terms of conduct, except for cases when the inventory is mandatory.

In accordance with paragraph 18 of the "Regulations on the Inventory of Assets and Liabilities" dated 02.09.2014 No. 879, during the inventory carried out in connection with the change of the materially responsible person, the procedure provides for the provision of receipts: the person receiving the assets confirms their receipt, and the person transferring the assets confirms their transfer. In addition, acts of acceptance and transfer of material values are drawn up, and an agreement on full material liability is concluded with the new employee. Two persons participate in the process: the materially responsible person who is dismissed and the person who assumes these responsibilities.

According to the Law of Ukraine "On Accounting and Financial Reporting in Ukraine" dated July 16, 1999 No. 996-XIV, the periodicity of the inventory is specified in the accounting policy and fixed by the order of the enterprise, and is established by the owner or manager of the enterprise, if its conduct is not mandatory by law [13].

The author, T. M. Vlasyuk, has developed regulatory documents and formed the periodicity of inventory, which can be followed by business entities [5].

Digitalization of fixed asset inventory procedures is a step towards optimizing management processes. Each of them has its own advantages and disadvantages, which can influence the choice of the optimal solution for a particular enterprise or industry, depending on needs and resources (Table 8).

The valuation of fixed assets consists in the monetary expression of their value, which is necessary for the accurate determination of the total volume of fixed assets, their

Table 7 – Periodicity of inventory of fixed assets

Types of property and financial obligations	Date of event	Periodicity
Buildings, structures and other immovable objects	Not earlier than October 1	At least once every three years
Library funds	Not earlier than October 1	Once every five years
Museum treasures	Not earlier than October 1	Within the established deadlines Ministry of Culture
Other fixed assets, low-value and perishable items		
– in ministries, other central executive bodies, local state administrations, their departments (departments), executive bodies of local councils	Not earlier than October 1	At least once every two years
– in other institutions	Not earlier than October 1	At least once a year
Precious metals, precious stones and articles thereof, as well as precious metals and precious stones contained in waste and scrap	As of January 1 and July 1	2 times a year
Capital works of an inventory nature and major repairs	Not earlier than December 1	At least once a year

Source : compiled by the authors based on source 5.

Table 8 – Digitalization of fixed asset inventory procedures

Procedure for digitizing fixed asset inventory	Description
Use of RFID technologies	Implementation of radio frequency identification for automated calculation of fixed assets. This procedure involves the installation of RFID tags on fixed assets, which allows automatic reading of information about them using readers. This greatly simplifies the inventory process and ensures accuracy of accounting.
Mobile add-ons for fixed asset accounting	Using mobile devices to collect real-time asset data. Mobile devices can be used to collect asset data in the warehouse or production area. Workers can scan barcodes or manually enter data on the spot.
Process automation through ERP systems	Integration with resource management systems for monitoring and managing fixed assets. ERP system integration allows an enterprise to centrally manage all aspects of fixed asset accounting, including monitoring their value.
Digital inventory lists	Using spreadsheets or specialized software to maintain a list of fixed assets, spreadsheets or specialized software to maintain lists of fixed assets simplifies the process of updating information on deeds.
Analyze them using BI systems	Using business intelligence to analyze inventory data and forecast fixed asset needs. Business intelligence allows businesses to analyze fixed asset data and make forecasts of their needs based on historical data.

Source: Grouped by authors by source 2.

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dynamics and structure, as well as for the calculation of the economic indicators of the enterprise's activity for a certain period. The initial cost of a fixed asset object is determined depending on the method of its receipt by the enterprise.

The enterprise has the right to revalue fixed assets if their residual value differs significantly from the fair value at the balance sheet date. If one of the fixed assets is revalued, all other objects belonging to the same group are also subject to revaluation at the same date.

According to IFRS 13 "Fair Value Measurement", certain approaches and methods are used to estimate the fair value of assets, including property, plant and equipment. Fair value is defined as the price that could be received to sell an asset or paid to transfer a liability in an orderly transaction between market participants at the measurement date. The frequency of revaluation of property, plant and equipment should be such that the residual value at the balance sheet date does not differ materially from its fair value. This is an important aspect for ensuring the reliability of financial reporting and increasing its transparency for external users, such as investors and creditors.

It is worth noting that low-value non-current tangible assets and library funds are not subject to revaluation if their depreciation is carried out in accordance with the methods. This allows the enterprise to focus resources on managing fixed assets that have a significant impact on financial results and strategic development.

Thus, the methodological and organizational framework for the revaluation of fixed assets, taking into account the approaches defined by IFRS 13, provides the enterprise with flexibility in asset management, increases their economic efficiency, and contributes to the correct reflection of assets in financial statements.

The process of harmonizing fixed asset accounting reporting according to international standards involves adapting national standards to international ones such as International Financial Reporting Standards (IFRS), which allows enterprises to align their accounting practices with international requirements (Table 9), increase the clarity and transparency of financial reporting, simplify the comparison of financial information between enterprises and countries, and attract foreign investment.

The main areas of harmonization include the unification of accounting methods, the adaptation of legislation, and the automation of accounting processes.

Recommendations for improving the theoretical basis of accounting for fixed assets at the enterprise:

– develop a unified terminology for accounting for fixed assets that meets international standards in order to avoid ambiguities and simplify the process of learning and implementing new methods;

– study and adapt international accounting standards for fixed assets (IFRS) to national legislation, which will improve the quality of financial reporting and facilitate international cooperation;

– develop detailed methodological recommendations for accounting for fixed assets, including the specifics of depreciation, combining different depreciation methods for different categories of fixed assets, revaluation of assets and costs of accounting for their maintenance;

Table 9 – International standards for accounting for fixed assets to harmonize reporting

Стандарт	Опис	Основні положення	Область застосування
МСФЗ 16 "Основні засоби"	Визначає принципи визнання, оцінки, амортизації та знецінення основних засобів.	– Первісна оцінка за собівартістю.	Облік основних засобів у фінансовій звітності підприємств.
		– Нарахування амортизації протягом строку корисного використання.	
		– Оцінка на знецінення.	
МСФЗ 36 "Знецінення активів"	Регулює процедуру оцінки знецінення активів, включаючи основні засоби.	– Проведення тесту на знецінення, якщо є ознаки зменшення вартості.	Оцінка та коригування балансової вартості основних засобів.
		– Відновлення вартості активу, якщо причини знецінення усунути.	
МСФЗ 23 "Витрати на позиковий капітал"	Регулює облік витрат на позиковий капітал, який може бути включений до собівартості основних засобів.	– Витрати на позиковий капітал капіталізуються, якщо вони також пов'язані з придбанням або будівельним активом.	Облік витрат на позиковий капітал, пов'язаних із створенням або придбанням основних засобів.
МСБО 16 "Основні засоби"	Попередня версія МСФЗ 16, яка регулює облік основних засобів.	– Первісна оцінка за собівартістю.	Використовується в країнах, які ще не вийшли повністю на МСФЗ 16.
		– Подальша оцінка за переоціненою вартістю або собівартістю.	
		– Амортизація та знецінення.	
Інтерпретації IFRIC (Міжнародні інтерпретації)	Надаються додаткові вказівки щодо застосування стандартів у конкретних ситуаціях, пов'язаних із видом основних засобів.	– Тлумачать складні або неоднозначні аспекти стандартів.	Специфічна ситуація в обліку основних засобів (наприклад, оренда чи реконструкція).
		– Забезпечують єдине трактування облікових положень.	

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– implement information systems to automate accounting processes, which will reduce the laboriousness of accounting and increase data accuracy. This includes the use of software to manage basic needs;

– establish internal control procedures over the form of fixed assets, including regular inspections and audits, to ensure the reliability of data and the efficiency of asset use;

– organize training programs for accountants and managers to improve their skills in the field of fixed asset accounting, focusing on the latest methods and technologies;

– conduct research into new approaches to fixed asset accounting, including analysis of the impact of technological innovations on asset management, such as the Internet of Things (IoT) and blockchain ;

– develop methods for assessing the efficiency of fixed assets use, allowing enterprises to more accurately determine the profitability of investments in assets.

These recommendations will contribute to improving the theoretical basis of accounting for fixed assets, which in turn improves management decisions and financial results of enterprises.

Conclusions from the research conducted

The study confirmed that improving the classification, valuation and accounting of fixed assets contributes to increasing their effective use, reducing costs, improving management decisions and adapting enterprises to changing economic conditions. The authors emphasize the need to implement progressive depreciation methods, regular revaluation of assets, as well as the integration of digital technologies to automate accounting processes and increase the transparency of financial reporting.

The following stages of scientific research are aimed at forming a comprehensive paradigm for improving fixed asset accounting, which combines methodological, analytical and innovative components:

– improvement of accounting methods, which is associated with determining the optimal ratio between assets and enterprise performance by integrating the analysis of nonlinear models - using polynomial dependencies to assess the impact of the structure of fixed assets on financial indicators, implementing specialized software packages with the functionality of automated depreciation calculation, asset status monitoring, and real-time data synchronization;

– systematic analysis of factors influencing fixed assets on the efficiency of the enterprise – analysis of the direct impact between asset liquidity and the financial stability of the enterprise, indirect effects caused by the imbalance between production capacities and operational efficiency, segmented time periods with significant structural shifts in the entity's business model;

– multifactorial research of exogenous determinants, the scientific tools of which include a mechanism for adapting accounting procedures to the dynamics of macroeconomic conditions (inflationary correctors, technological obsolescence standards), scenario modeling of the impact of regulatory changes on asset value parameters;

– research into the eco-oriented transformation of fixed asset accounting, which involves the integration of ISO environmental standards into the accounting assessment system (in particular, carbon footprint and energy efficiency analysis), asset life cycle methodology (LCA) with an assessment of environmental costs at the operation and disposal stages.

– research into implementing digital innovations for predictive maintenance and real-time analysis of equipment performance, providing analytical reports to predict the optimal time for asset replacement based on depreciation trends and market conditions.

Thus, a scientific approach to improving the accounting system requires a synthesis of econometric modeling, adaptive mechanisms for responding to external factors, and interdisciplinary integration of ecological and economic assessment criteria.

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APPLICATION OF ARTIFICIAL INTELLIGENCE IN MANAGEMENT ACCOUNTING: KEY ASPECTS, PROSPECTS AND RISKS

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Key words:
management accounting, artificial intelligence, artificial intelligence technologies, machine learning, neural network.

The article explores current issues regarding the application of artificial intelligence technologies in management accounting. Modern domestic business is characterized by changes associated with the processes of digital transformation. Management accounting, as a key tool for supporting management decision-making, acquires new opportunities through the introduction of digital innovative technologies. One of such technologies is artificial intelligence, which offers new opportunities for automation, analysis and forecasting. The use of artificial intelligence is one of the key tools that ensures the transformation of accounting processes, thereby increasing their efficiency, reliability and adaptability to changes in the market. The prerequisites and current directions for the application of artificial intelligence in management accounting were clarified, the possibilities of artificial intelligence technologies that can be used to increase the productivity of management accounting at the enterprise were identified, in particular: expert systems (planning, assessment, control, resource reporting and preparation of external reports); data analytics (identification of new models of relationships in large volumes of data); machine learning (analysis and identification of patterns in data and use of information obtained from this data to improve decision-making processes); neural networks (detection of fraud and unfair practices based on the analysis of a significant number of transactions). The impact of artificial intelligence technologies on the management accounting system was analyzed and its main advantages and prospects were systematized, which includes automation of accounting, increasing the efficiency of activities, conducting analysis, processing large amounts of information and making management decisions, at the same time, key risks that an enterprise may encounter are highlighted, in particular: significant financial costs; regulatory barriers and technical limitations; risks of loss of information confidentiality; the need for advanced training; personnel adaptation and ethical aspects of implementing innovative technologies; compliance risks. The prospects for the development of artificial intelligence technologies for the transformation of management accounting and the formation of competitive advantages and strategic business development are substantiated.

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ЗАСТОСУВАННЯ ШТУЧНОГО ІНТЕЛЕКТУ В УПРАВЛІНСЬКОМУ ОБЛІКУ: КЛЮЧОВІ АСПЕКТИ, ПЕРСПЕКТИВИ ТА РИЗИКИ

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Ключові слова:
управлінський облік, штучний інтелект, технології штучного інтелекту, машинне навчання, нейронна мережа.

У статті досліджено актуальні питання щодо застосування технологій штучного інтелекту в управлінському обліку. Сучасному вітчизняному бізнесу притаманні зміни, що пов'язані з процесами цифрової трансформації. Управлінський облік, як ключовий інструмент підтримки прийняття управлінських рішень, набуває нових можливостей завдяки впровадженню цифрових інноваційних технологій. Однією з таких технологій є штучний інтелект, який пропонує нові можливості для автоматизації, аналізу та прогнозування. Застосування штучного інтелекту є одним із ключових інструментів, що забезпечує трансформацію облікових процесів, тим самим підвищуючи їх ефективність, достовірність та адаптивність до змін на ринку. З'ясовано передумови та актуальні напрями застосування штучного інтелекту в управлінському обліку, визначено можливості технологій штучного інтелекту, які можуть застосовуватися для підвищення продуктивності управлінського обліку на підприємстві, зокрема: експертні системи (планування, оцінка, контроль, звітність за ресурсами та підготовка зовнішніх звітів); аналітика даних (виявлення нових моделей взаємозв'язків у великих обсягах даних); машинне навчання (аналіз і виявлення закономірностей у даних та використання інформації, отриманої з цих даних, для покращення процесів прийняття рішень); нейронні мережі (виявлення фактів шахрайства та недобросовісної діяльності на основі аналізу значної кількості операцій). Проаналізовано вплив технологій штучного інтелекту на систему управлінського обліку та систематизовано його основні переваги і перспективи, що включає автоматизацію бухгалтерського обліку, підвищення ефективності діяльності, проведення аналізу, обробки великих масивів інформації та прийнятті управлінських рішень, разом з тим виділено ключові ризики з яким може стикнутися підприємство, зокрема: значні фінансові витрати; нормативно-правові бар'єри та технічні обмеження; ризики втрати конфіденційності інформації; потреба у підвищенні кваліфікації; адаптація персоналу та етичні аспекти впровадження інноваційних технологій; комплаєнс-ризики Обґрунтовано перспективи розвитку технологій штучного інтелекту для трансформації управлінського обліку та формування конкурентних переваг і стратегічного розвитку бізнесу.

Statement of the problem

In the conditions of the modern business environment, which is characterized by dynamic changes, global competition and increased complexity of production and logistics processes, there is a need to use innovative technologies in accounting. The application of artificial intelligence technologies in management accounting at domestic enterprises is not yet widespread. Given that management reporting is confidential information, the development of tools based on artificial intelligence and their practical implementation are carried out in a protected space so as not to lose competitive advantages. However, artificial intelligence in management accounting is a necessary tool for improving the efficiency of management decision-making. It analyzes large volumes of financial and operational data, identifies patterns and trends, can forecast financial indicators, assess risks and develop optimization strategies. The application of artificial intelligence technologies in management accounting allows you to make informed decisions regarding budgeting, investment, as well as determining growth and development strategies for the enterprise. In general, the use of AI in management accounting expands the capabilities of management personnel, contributes to the optimization of resource use and the achievement of greater competitiveness of the enterprise in the market. In the future, technological innovations, in particular artificial intelligence, will significantly affect management accounting. These changes require new knowledge and skills from specialists who want to maintain their competitive advantage and work confidently with artificial intelligence.

Analysis of recent studies and publications

The integration of innovative technologies into accounting processes is an objective necessity of today, therefore their implementation in accounting is increasingly being discussed in scientific circles. One of such innovations is artificial intelligence, which is at the stage of its active development. However, the issue of

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using artificial intelligence in management accounting has not yet received significant attention in the works of domestic scientists.

Thus, Lyakhovich G.I., Vakun O.V. investigate the potential possibilities of using artificial intelligence to increase the efficiency of the management accounting system [4]. Modern aspects of the application of AI in management accounting are considered by Pravdyuk M.V. and Filipov R.V. [6]. Artificial intelligence technologies in management accounting and the possibilities of their use are revealed by Hocha N.V., Tenyukh Z.I., Pelekh U.V. [9]. The study by Shigun M.M., Furda V.O. is devoted to determining the key prospects for the application of artificial intelligence methods in the field of management accounting to optimize the further implementation of specific practical tasks [10]. At the same time, the issue of digitalization as a tool for optimizing management accounting at domestic enterprises is revealed by Pushkar I.V., Gladchuk G.G., Khrapach K.G. [7]. Sklyaruk I.P., Vovk N.O. investigate the transformation of management accounting in the context of digitalization and analyze how digital innovations can contribute to the efficiency and adaptability of management accounting [8].

The issue of the use of artificial intelligence in management accounting was indirectly, through the prism of the use of AI in accounting, studied in the works of such scientists as: Gnatyeva T. M., Yakovenko A. O., Zlatova M. G. [2]; Bilous O. S., Kundeus O. M. [1]; Kryvoshey O. V. [3]. The prospects for the use of artificial intelligence and its practical significance are revealed by the provisions of the National Strategy for the Development of Artificial Intelligence in Ukraine for the Period 2021-2030 [5]. It should be noted that the topic of the use of artificial intelligence in management accounting is not sufficiently covered in the works of domestic scientists and requires further research and development.

Objectives of the article

The purpose of the article is to study the main technologies of artificial intelligence and their capabilities for improving the management accounting system at the enterprise, taking into account the existing risks and prospects for accelerating the development of management accounting based on artificial intelligence.

The main material of the research

Artificial intelligence technology, in one form or another, is becoming widespread in all areas of the economy, including accounting. The development of artificial intelligence is changing the way accounting tasks are performed, with the potential to transform the entire profession.

Artificial Intelligence is a branch of computer science that studies methods and algorithms for creating automated systems capable of performing cognitive functions inherent in the human mind. To achieve its goals, the field of artificial intelligence uses a combination of approaches from mathematics, statistics, information theory, machine learning, neuroscience, and software engineering, creating a basis for automating complex processes in various fields [3]. Based on the analysis of scientific approaches to defining the concept of artificial intelligence [1, 2, 6], this category will be understood as a branch of computer science that studies the creation of software systems and algorithms that are endowed with the ability to perform tasks that usually require the application of human intelligence, in particular: the ability to think; understand; generalize and learn from experience.

The goal of AI technology development is to reduce the use of human resources to solve complex intellectual tasks that are difficult to manually algorithmize due to their multifactorial nature and complexity [11]. Management accounting in the modern economic environment increasingly relies on digital tools and technologies, such as ERP systems, Cloud technologies and computing, Big data, Block chain and Artificial intelligence, which contribute to new opportunities for collecting, processing and analyzing accounting and analytical data [8]. The formation and strengthening of the competitive environment forces management structures to respond in a timely manner to changes in the market situation. In this context, the requirements for management accounting as a basis for ensuring the adoption of sound management decisions are increasing. That is why artificial intelligence is developing every year and gradually occupying important links in business. The use of artificial intelligence technologies allows you to perform various tasks faster, more accurately, increase the efficiency of accounting processes, data analysis and decision-making, and also reduce the involvement of human resources. So, the current directions of application of artificial intelligence technology in management accounting are shown in Fig. 1.

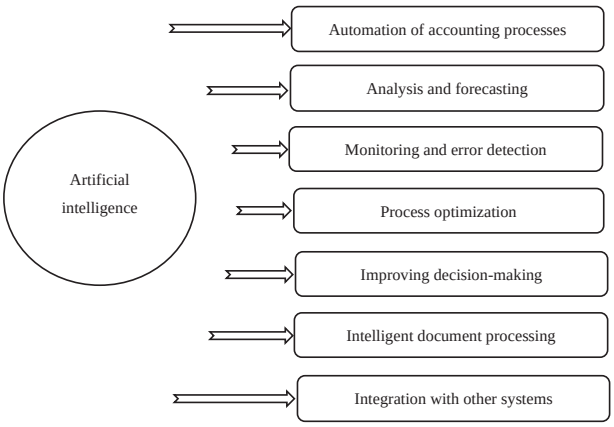

Fig. 1 – Directions of application of artificial intelligence in management accounting

Let's take a closer look at each of these areas.

First of all, automation of accounting processes is that artificial intelligence can significantly facilitate and accelerate many aspects of management accounting by automating routine and labor-intensive tasks. For example, data entry, processing and classification of transactions, which allows you to reduce errors and the cost of employee time, as well as reduce the cost of administrative tasks.

Artificial intelligence is able to analyze data and predict indicators. Automation of these processes helps to quickly identify trends and patterns. Thanks to this, machine

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learning algorithms can predict future financial results, demand for products, costs and other key indicators, which helps to make informed decisions. Monitoring and error detection. With the help of artificial intelligence, you can detect atypical transactions or anomalies in accounting systems that may indicate financial violations, fraud or errors in data processing, which in turn allows you to quickly respond to potential problems and reduce risks when conducting management accounting.

Thanks to the use of artificial intelligence, it is possible to optimize a number of processes, for example, automatic generation of reports. This process can occur automatically based on real-time input data, which allows managers to receive up-to-date information without having to spend time on manual reporting. Also, thanks to artificial intelligence, it is possible to optimize the process of analyzing financial efficiency, because artificial intelligence allows you to analyze not only quantitative criteria, but also the relationships between various financial indicators. For example, between advertising costs and sales growth, which allows you to take into account the efficiency of various business processes and make decisions on them in the context of management accounting.

In general, due to the constant improvement of the functions performed by artificial intelligence, it is possible to conduct analysis of various processes through AI, and based on the conclusion to it, make informed decisions, providing detailed descriptions of the data obtained thanks to a computer program, analysis of financial data, forecasts and other factors. This allows you to thoroughly plan the company's development strategy, reduce business risks and increase the efficiency of management decisions. In the process of intelligent document processing, the use of artificial intelligence has become an integral part of management accounting. In particular, natural language processing (NLP) technologies can automatically process and classify documents (invoices, contracts, etc.), which allows you to reduce labor costs and reduce the likelihood of errors when entering data manually.

Also, artificial intelligence, through its large base of various software and forms of use, allows for the integration of other systems into management accounting. For example, customer relationship management through Customer Relationship Management (CRM) or enterprise resource planning Enterprise Resource Planning (ERP), which improves the connection between financial and operational data, provides a more complete picture of the company's activities [9]. As noted earlier, artificial intelligence has a wide base of different technologies, each of which specializes in certain capabilities (Fig. 2).

It should be noted that artificial intelligence includes specific areas of technology that can be used to improve the productivity of management accounting in an enterprise, in particular:

− Expert systems (planning, evaluation, control, reporting on resources and preparation of external reports);

− Data analytics (identifying new patterns of relationships in large volumes of data);

− Machine learning (analyzing and identifying patterns in data and using information obtained from this data to improve decision-making processes);

− Neural networks (detecting fraud and unfair practices based on the analysis of a significant number of transactions).

Expert systems are computer programs or subsystems that integrate expert experience into a knowledge base system.

For management accounting, expert systems are used in inventory control, variance analysis, cost analysis, and diagnostics of management control systems. They can also be used in management accounting to automate the analysis of financial data, identify unusual situations, and provide recommendations on financial and economic activities [9]. In the context of management accounting, expert systems can increase the efficiency of planning, evaluation, control, and preparation of external reports, as well as checking the accuracy and reliability of financial and accounting information. That is, expert systems can help reduce risks by providing more reliable management accounting information.

Data Analytics has a significant impact on the work of a management accountant, as it allows you to discover new patterns of relationships in large volumes of data, and also provides improved data analysis and support

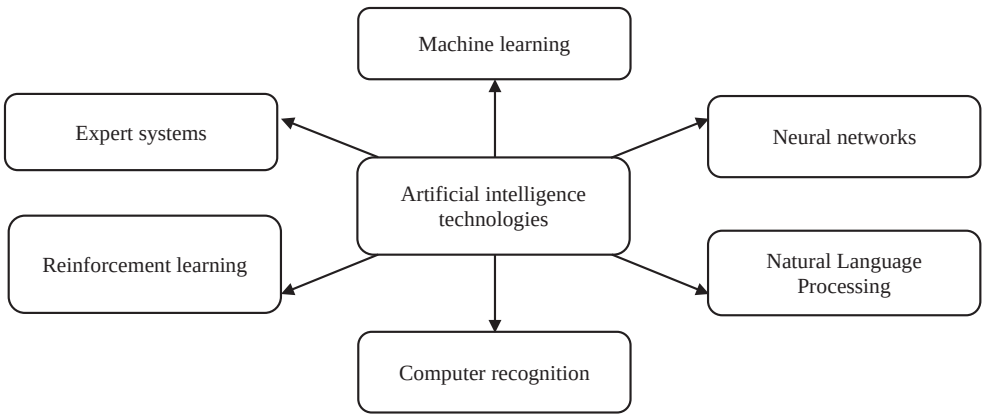

Fig. 2 – Basic artificial intelligence technologies

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for decision-making based on management accounting information [4]. It is important to ensure the connection between data analytics, business intelligence and the productivity of management accountants. Without data analysis tools, an accountant will not be able to effectively perform his tasks in today's digital environment.

Machine Learning is a subfield of artificial intelligence in computer science that uses statistical techniques to give computers the ability to learn from data without explicit programming [10]. Machine learning in management accounting can be used to automate and optimize many financial and production processes. Machine learning algorithms can help analyze large amounts of financial data, predict performance, identify threats, and recommend optimal strategies. This will contribute to the accuracy of forecasts, reduce risks, and optimize financial management, and as a result, increase business efficiency.

In the matter of detecting risky or potentially fraudulent activities in the enterprise, management accountants (as well as internal auditors) will find a neural network useful. Neural Networks are another area of artificial intelligence that aims to simulate the analytical mechanisms implemented by the human brain [10]. They are more advanced machine learning algorithms, computing systems that are capable of finding more complex patterns. In management accounting, a neural network is an effective tool for detecting fraud by analyzing the data that is available for building a network and the need to detect unusual transactions. Neural networks can also be used to analyze customers and suppliers. When analyzing cooperation with buyers and suppliers in an enterprise, difficulties may arise, especially if there are a large number of counterparties. A management accountant using neural networks can analyze and identify the most profitable counterparties, identify debtors, and, if necessary, divide them into groups, classify them according to certain indicators, if this is necessary for analytical work [4].

So, we can systematize the positive impact of the use of artificial intelligence technologies on the management accounting system (Fig. 3).

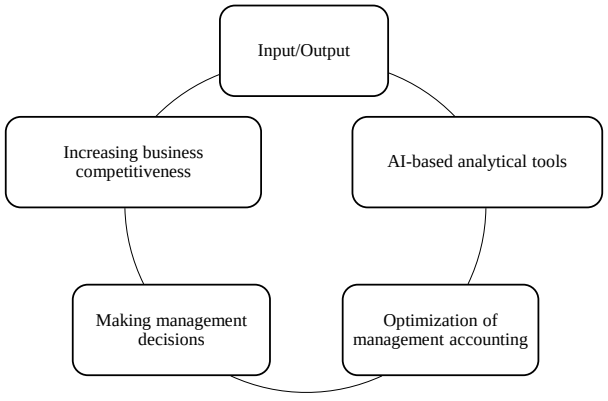

Fig. 3 – The impact of artificial intelligence on management accounting

The use of artificial intelligence technologies in management accounting has significant advantages and opens up certain prospects. However, AI also has a number of disadvantages and problematic aspects, namely: training artificial intelligence models and experiments with them requires large data sets, training time and powerful equipment with a graphics processor and a large amount of RAM. Also, the use of AI in management accounting may encounter certain problems, in particular: insufficient quality data for training models, the need for a large amount of technical expertise, and others (Table 1).

Table 1 – Advantages and prospects, disadvantages and risks of using AI in management accounting

Advantages and prospects	Disadvantages and risks
–	–
–	–
–	–

Source: grouped based on [9, 7, 10]

Therefore, for the effective implementation of artificial intelligence technologies in the management accounting system, companies must first assess the presence of prerequisites, namely: the growth in the volume and complexity of data that need to be processed and analyzed; the increase in the complexity of business operations due to the expansion of markets and the development of new technologies; the relevance of the introduction of innovations; the spread of technological solutions in business. It is also important to assess their own needs and capabilities, thereby reducing possible financial and operational risks. It can be considered that artificial intelligence is a catalyst for the transformation of approaches to doing business and organizing management accounting.

The relevance and importance of the practical application of artificial intelligence elements in all spheres of the national economy is evidenced by the approval by the Cabinet of Ministers of Ukraine of the National Strategy for the Development of Artificial Intelligence for the period 2021-2030 [5]. The main purpose of which is to create a balanced legal framework for the development and integration of artificial intelligence, which will promote investments and innovations, minimizing potential risks and solving a set of problems that require solutions at the state level. All this indicates the importance, targeted orientation and potential of the development of artificial intelligence in Ukraine.

Conclusions

The concept of artificial intelligence is based on the ability of information systems to detect patterns in structured and unstructured data, predict outcomes based on the results of analyzing large amounts of information, and optimize decision-making processes in complex multifactorial decision-making environments. The application of artificial intelligence in management accounting aims to increase the productivity of accountants who perform management accounting and form an information base for making management decisions.

Relevant areas of application of artificial intelligence technology in management accounting have been

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identified: automation of accounting processes; analysis and forecasting; monitoring and detection of errors; process optimization; increasing the validity and efficiency of decision-making; intelligent document processing and integration with other systems.

Having analyzed the role and impact of artificial intelligence technologies on the management accounting system, it was found that the use of AI has significant advantages and prospects: automation and acceleration of management accounting and analysis processes, control and rapid sorting of information into certain categories, detection of errors and fraud, etc. However, it is worth noting that artificial intelligence has disadvantages and risks: significant financial costs; regulatory barriers and technical limitations; risks of loss of information confidentiality; the complexity of integrating artificial intelligence technologies with software products already existing at the enterprise; the lack of qualified specialists and a low level of digital literacy imply significant costs for personnel training; the need for constant monitoring and updating, as technologies are constantly changing, this can lead to additional costs and be a resource-intensive process for the company. However, despite the negative aspects, the opportunities provided by artificial intelligence in management accounting and its advantages are much more significant and promising. Of course, innovation cannot be ignored, because the application of artificial intelligence technologies will help bring the management accounting system to a new, higher quality level. This, in turn, will provide the enterprise with competitive advantages, operational efficiency and strategic business development.

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THE ROLE OF BIG DATA IN FORECASTING THE FINANCIAL RESULTS OF AN ENTERPRISE

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Key words:
big data (Big Data). innovative technologies, information systems, financial forecasting, integration.

In today's dynamic economic environment, enterprises face increasing challenges in terms of effective financial management, risk assessment and strategic decision-making. In the face of constant market changes, price fluctuations, global competition and unstable external factors, the ability of a business to quickly and accurately forecast its financial results plays a key role. Traditional financial analysis tools, which are based on historical reports and linear models, are increasingly proving insufficient to fully take into account all the variables that affect the financial stability of the enterprise. In this context, innovative approaches, in particular the use of Big Data processing technologies, come to the fore.

Big Data is not only huge amounts of digital information, but also a new way of thinking in financial management. Thanks to modern information systems, enterprises can collect, process and analyze data from dozens of sources: transactional systems, CRM platforms, social networks, Internet resources, sensors, etc. All this allows you to detect hidden patterns, model future financial flows, quickly identify risks and predict the effectiveness of management decisions. It is analytics based on Big Data that provides a new quality of decision-making, more accurate, more adaptive and one that takes into account the multifactorial reality of modern business.

The value of Big Data in financial forecasting also lies in the ability to provide up-to-date, relevant and personalized data for different divisions of the enterprise. This allows you to integrate financial analytics with production, marketing and logistics processes, forming a single information and analytical platform for management. The use of big data not only improves the accuracy of forecasts, but also optimizes budget planning, increases investment efficiency, allows you to minimize costs and avoid financial losses in the future.

РОЛЬ ВЕЛИКИХ ДАНИХ В ПРОГНОЗУВАННІ ФІНАНСОВИХ РЕЗУЛЬТАТІВ ПІДПРИЄМСТВА

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Ключові слова:
великі дані (Big Data). інноваційні технології, інформаційні системи, фінансове прогнозування, інтеграція.

Big Data – це не лише величезні масиви цифрової інформації, а й новий спосіб мислення у фінансовому менеджменті. Завдяки сучасним інформаційним системам, підприємства можуть збирати, обробляти й аналізувати дані з десятків джерел: транзакційних систем, CRM-платформ, соціальних мереж, інтернет-ресурсів, сенсорів тощо. Усе це дозволяє виявляти приховані закономірності, моделювати майбутні фінансові потоки, оперативно виявляти ризики та прогнозувати ефективність управлінських рішень. Саме аналітика на основі Big Data забезпечує нову якість прийняття рішень, точнішу, адаптивнішу й таку, що враховує багатофакторну реальність сучасного бізнесу. Значення Big Data у фінансовому прогнозуванні полягає також у здатності надавати актуальні, релевантні й персоналізовані дані для різних підрозділів підприємства. Це дозволяє інтегрувати фінансову аналітику з виробничими, маркетинговими та логістичними процесами, формуючи єдину інформаційно-аналітичну платформу для управління. Застосування великих даних не лише покращує точність прогнозів, а й оптимізує бюджетне планування, підвищує ефективність інвестицій, дозволяє мінімізувати витрати та уникнути фінансових втрат у майбутньому.

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Statement of the problem

Traditional methods of financial analysis and forecasting, based on historical data and static approaches, no longer meet the needs of business in a rapidly changing market. There is a need to implement innovative approaches to forecasting that are able to process both structured and unstructured information in large volumes.

The problem is that a significant part of enterprises does not use the potential of Big Data in financial forecasting due to the lack of appropriate IT infrastructure, qualified personnel, or due to insufficient awareness of the capabilities of such technologies. This limits the accuracy of forecasts, complicates the adoption of informed financial decisions and reduces the competitiveness of the company.

Analysis of latest research and publications

In scientific literature and practice, more and more attention is paid to the topic of Big Data and its application in the economy. Research by scientists, in particular, such as Balabanov O.S., Dzyamudych M.I., Kanygin S.M., Nikitenko K.S., Pichkurova Z.V., Samoilenko L.B. and others, demonstrate the significant potential of Big Data in transforming accounting, auditing and financial forecasting systems.

The works of these authors describe big data analytics tools (for example, machine learning, predictive modeling, natural language processing), but the issue of adapting Big Data to the practice of small and medium-sized businesses in Ukraine, as well as the integration of these technologies into accounting and analytical systems of enterprises, remains insufficiently studied.

Formulating goals

The purpose of the research is:

– study the role of big data technologies in forecasting the financial results of the enterprise;

– analysis of modern information systems that provide Big Data processing;

– identification of the advantages and risks of implementing Big Data in financial activities;

– formulation of recommendations for the implementation of Big Data technologies in accounting practice.

Presentation of the main research material

In the modern digital environment, the term Big Data has gained exceptional popularity in various sectors of the economy, including accounting, auditing, finance, marketing, logistics, and others. This concept has become synonymous with deep analysis, high-speed information processing, and the ability to forecast based on complex models. Despite the frequent use of the term, it is important to understand its essence, characteristics, and significance for the activities of enterprises in the 21st century.

Big Data are extremely large amounts of information that cannot be processed by traditional methods and analysis tools [3, pp. 97-100]. It is not only about large volumes of data, but also about their diversity, speed of receipt, complexity of the structure, and the need for constant updating. The term "big data" first began to be used in the IT environment in the late 90s, but it became truly widespread with the development of the Internet of Things, social networks, mobile devices, cloud technologies, and artificial intelligence.

The classic definition of Big Data is often based on the concept of "5V", which includes five main characteristics of big data (Fig. 1): Volume, Velocity, Variety, Veracity, Value [1, pp. 47-51].

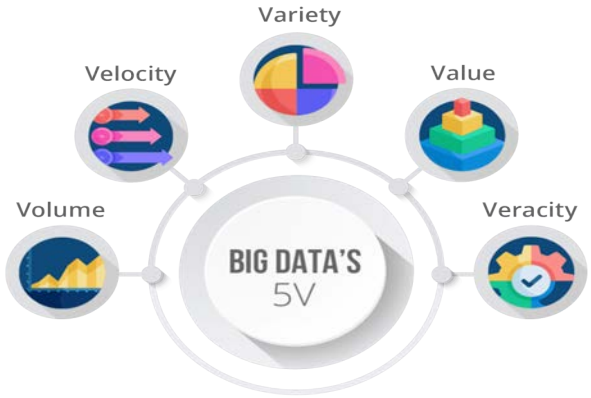

Fig. 1 – The 5Vs of Big Data

Volume is the first and most obvious characteristic of Big Data. Every day, the world creates petabytes of

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information: transaction data, customer orders, sensor data, videos, social media posts, etc. For example, large retail chains collect millions of records of purchases, and banks collect records of customer funds. This data can accumulate for years and has significant analytical potential.

Velocity is the rate at which data is generated, processed, and analyzed. In real time, companies need to be able to respond quickly to changes in the environment, demand, consumer behavior, or financial performance. That is why streaming analytics tools are especially important, providing instant analytics and automated decision-making.

Variety refers to the multiple sources and formats of data. While traditional accounting works with structured numerical tables, Big Data includes text documents, videos, images, recordings from IoT devices, GPS data, customer feedback, audio recordings of conversations, etc. This necessitates the need for new storage and processing tools, including NoSQL databases, cloud storage, and distributed computing.

Veracity refers to the degree of accuracy and reliability of data. In the world of Big Data, much of the information comes from external or unverified sources (for example, social networks or open APIs), so before using it to make management decisions, it is necessary to verify, filter and validate the data. A large amount of noise, repetitions or incomplete records can significantly reduce the effectiveness of the analysis.

Value is the most significant characteristic that determines the economic feasibility of working with Big Data. The presence of large volumes of information in itself does not create advantages, what is important is the ability to turn this data into knowledge, and knowledge into specific actions. For example, analyzing customer behavior based on purchase history, preferences and communications allows you to form personalized offers, increase loyalty and, accordingly, profits.

All this changes the traditional approach to accounting and auditing. Instead of statically collecting information once a month or quarter, organizations are moving to constant monitoring and operational analytics. For example, instead of retrospective analysis of costs, an enterprise can obtain a forecast of future financial results based on current transactions and market behavior in real time [6].

The essence of Big Data also lies in the interaction of three components: data, processing tools and analytical models. Data becomes raw material, tools become means of transformation, and models become a way to obtain value. The most common technologies for processing big data are Hadoop, Spark, Flink, Cassandra, as well as cloud platforms such as AWS, Azure, Google Cloud. They allow processing terabytes of data in a matter of minutes, ensuring scalability, security and flexibility [9].

Big data is radically changing the approach to accounting. For example, an accountant-analyst with Big Data skills can not only prepare financial statements, but also make analytical conclusions about future trends, financial risks, and justify investment decisions. This leads to the emergence of new specialties, such as Big Data accountant-analyst, digital auditor, data economist, etc.

Therefore, the essence of Big Data is a new approach to information processing, which is based on scalability, flexibility, speed and deep analytics. Its characteristics are volume, speed, diversity, reliability and value reflect the key challenges and opportunities facing modern enterprises. The use of big data in the field of accounting and finance opens up new horizons for business development, ensuring accuracy, transparency and proactivity of financial management [2, p. 16-17].

In the modern business environment, the ability to predict future financial results is a key competitive advantage. With the development of digital technologies, traditional approaches to financial forecasting, based on the analysis of past indicators and statistical trends, no longer meet the requirements of a rapidly changing market. In this context, big data technologies (Big Data) are becoming a revolutionary tool for a qualitative breakthrough in the field of financial analytics and forecasting.

Big Data in financial forecasting opens access to a huge array of diverse information, which allows not only to analyze past performance indicators, but also to take into account a wide range of external and internal factors that affect financial results. These can be economic indicators, changes in market prices, consumer behavior, macroeconomic and political risks, customer feedback, seasonal fluctuations, news and even events that are actively discussed in social networks.

One of the key areas of application of Big Data is forecasting the income of an enterprise. Traditionally, this is done on the basis of statistical analysis of sales for previous periods [4, pp. 63-66]. However, Big Data allows you to expand this model by including external environmental factors, weather conditions, dynamics of raw material prices, competitor activity, consumer behavior in real time. Thanks to this, forecasting becomes more accurate, adaptive and personalized. For example, retail chains can predict changes in demand for goods depending on the weather, advertising activity or mass events.

In the area of costs, Big Data allows you to model future costs taking into account the dynamics of purchases, rising resource costs, logistics costs and changes in the structure of suppliers. This makes it possible to identify hidden trends, optimize budgeting and operational planning. Moreover, financial analytics systems based on big data can automatically detect anomalies that signal inefficient use of resources or the risk of fraud.

Big Data plays a special role in the field of risk management. Using machine learning algorithms and neural networks, companies can analyze large data sets on transactions, customer behavior patterns, payment histories, credit ratings and identify potential financial threats. This is extremely important for banks, insurance companies, investment funds and other financial institutions that work with risky assets.

Another example is cash flow forecasting. Accurate planning of revenues and expenses based on historical data, market data, customer and supplier behavior allows companies to avoid cash gaps, plan investments and optimize financing. At the same time, processing such data is possible only thanks to Big Data technologies, which

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combine automatic information retrieval, cloud computing, analytical panels and integration with financial systems.

Financial forecasting using big data also involves building complex mathematical and econometric models. Thanks to this, enterprises can test various scenarios of events, from the most optimistic to critical [7, pp. 71-72]. This is important not only for strategic planning, but also for preparing for crisis situations or unexpected market fluctuations.

A key role in this process is played by such tools and platforms as Apache Hadoop, Apache Spark, Tableau, Microsoft Power BI, Google BigQuery, SAS, IBM Watson Analytics. They provide storage, processing, analysis and visualization of data on a large scale. These tools integrate with corporate ERP systems (e.g., SAP, Oracle), which allows financial analysts to work with information in real time and generate forecast reports with high accuracy [10].

The use of Big Data in financial forecasting also allows to increase the transparency of reporting, to avoid the human factor in the analysis, to reduce the time of preparation of analytical information. In the future, with the development of artificial intelligence and automated analytical systems, companies will be able to almost completely automate the process of making financial decisions based on forecasting models.

However, the introduction of Big Data into the financial sphere is not without challenges. These are high costs for digital infrastructure, the need for highly qualified data analytics specialists, risks associated with confidentiality and cybersecurity, as well as the complexity of adapting big data to national accounting and tax legislation. At the same time, despite these obstacles, the trend of development of Big Data in finance is irreversible. Companies that are the first to adapt these technologies have much higher chances of stable growth and survival in the conditions of global competition.

In the modern world, information technologies play a key role in the process of processing and analyzing big data (Big Data). The rapid growth of digital information generated by enterprises, consumers, social networks, sensors, financial systems and other sources has necessitated the creation of powerful information systems capable of working effectively with Big Data. These systems must provide rapid collection, storage, processing, analysis, interpretation and visualization of data in real time, often in conditions of high complexity, heterogeneity and dynamism of the information environment [5].

Information systems that work with Big Data have a fundamentally different architecture compared to traditional IS. They are based on the principles of distributed data storage and processing, which allows for scalability, flexibility and high performance when working with petabytes of information. The central place in such systems is occupied by cloud technologies, neural network models, machine learning, as well as specialized tools for processing structured, semi-structured and unstructured data.

One of the most popular information platforms for Big Data is Hadoop, an open-source framework designed for distributed storage and processing of large amounts of data. Its core is the Hadoop Distributed File System (HDFS) file storage system and the MapReduce processing engine. Thanks to this architecture, Hadoop is able to run on ordinary servers, combined into clusters, which significantly reduces the cost of processing large amounts of information [8].

Another powerful tool is Apache Spark, which supports in-memory data processing, which makes it much faster than Hadoop in many cases. Spark has modules for SQL queries, stream processing (Streaming), machine learning (MLlib) and graph analytics (GraphX). Due to this, it is widely used in financial systems, analytical services, retail and scientific research.

NoSQL databases are another important component of information systems for Big Data. They allow you to store and efficiently process unstructured and semi-structured data that is not suitable for classic relational databases (SQL). The most common NoSQL solutions include MongoDB, Cassandra, Couchbase, Redis. For example, MongoDB allows you to work with JSON-like documents, which is especially convenient for real-time analytics.

Information systems working with Big Data also actively use visualization and BI (Business Intelligence) tools. These are systems that provide the user with convenient interfaces for viewing, analyzing and displaying data in the form of graphs, charts, dashboards. The most famous of them are Tableau, Microsoft Power BI, QlikView, Looker. They allow you to combine data from different sources, create interactive reports and build predictive models without deep knowledge of programming.

A special place in Big Data systems is occupied by cloud platforms that provide infrastructure as a service (IaaS), platform as a service (PaaS) or analytics as a service (AaaS). The most popular of them are Amazon Web Services (AWS), Google Cloud Platform (GCP) and Microsoft Azure. These platforms provide a secure, scalable environment for data storage and processing, automated machine learning, flexible APIs for integration and convenient analytics.

Modern information systems for Big Data are also closely integrated with artificial intelligence tools [9]. For example, based on the collected data, predictive models can be automatically formed, risks assessed, and recommendations for management decisions formed. This allows significantly improving the quality of financial planning, fraud detection, customer segmentation, and service personalization.

In the financial sector, accounting, and auditing, information systems that work with Big Data are used for detailed transaction analysis, detection of deviations, automation of financial processes, and assessment of counterparties' solvency. They help analysts see the full picture of business processes and make informed decisions based on objective, comprehensive, and up-to-date data.

The versatility of such systems allows them to be integrated with internal corporate ERP, CRM, SCM systems, as well as with open data sources, namely market indices, macroeconomic statistics, news feeds, geodata, etc. This provides multidimensional analysis and support for strategic thinking in enterprise management.

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Table 1 – Information systems and technologies that work with Big Data

System/technology name	Type / category	Main purpose	Advantages	Usage examples
Hadoop	Framework for Big Data	Distributed data storage and processing	Scalability, reliability, processing large amounts of data	Banking transaction analysis, log audit, client action accounting
Apache Spark	Analytical framework	In-memory data processing, fast analytics	High speed, modules for ML, SQL, graphs	Revenue forecasting, risk assessment, credit analytics
MongoDB	NoSQL database	Storing unstructured data	Flexible document structure, scalability	CRM systems, customer feedback analysis, financial operations
Cassandra	NoSQL database	Processing large amounts of data with high availability	High fault tolerance, horizontal scalability	Online analytics, transaction history, financial data flow
Microsoft Power BI	BI platform	Data visualization, reporting, interactive dashboards	User-friendly interface, integration with Excel, cloud availability	Construction of financial reports, cost dynamics, KPI assessment
Tableau	BI platform	Analysis and visualization of data from various sources	Intuitiveness, deep analytics, interactive panels	Sales analytics, management reports, profitability forecasts
AWS / Azure / GCP	Cloud platforms	Storage, processing, machine learning, scalable computing	Security, flexibility, scalability, turnkey services	Platforms for predictive analysis, cyber defense, and financial automation
Kafka	Streaming data processing	Real-time data transmission	Speed, reliability, real-time event processing	Stock market transactions, bank transactions, payment monitoring
Looker (Google Cloud)	BI and analytics	Creating analytical models and reports	Deep integration with Google BigQuery, fast access to data	Financial planning, customer analytics, budgeting
IBM Watson Analytics	AI analytics and data processing	Automated analysis, machine learning	Powerful AI engine, intuitive interface	Identifying financial trends, optimizing costs, assessing profitability

Source: created by the authors based on [9; 10]

The use of Big Data in financial analytics and enterprise management opens up new horizons of efficiency, forecast accuracy and understanding of market dynamics. One of the key advantages is the ability to deeply analyze large amounts of information from various sources – financial transactions, customer bases, social networks, sensor devices. This allows you to build accurate forecast models, quickly respond to changes in the economic environment and make decisions based on data, and not only on intuition or past experience. Companies get the opportunity to see a more complete picture of their business, identify risks at an early stage, detect hidden trends that can affect profitability.

Thanks to Big Data, it becomes possible to personalize customer service. For example, in the financial sector, this allows you to accurately assess creditworthiness, form individual offers, prevent financial losses by quickly identifying fraudulent transactions. An important advantage is the ability to process data in real time, which is extremely valuable for banking, stock trading, logistics management and internal company resources. In addition, Big Data integrates with machine learning and artificial intelligence algorithms, which helps automate operations, reduce costs and accelerate business processes [2, pp. 16-18].

An equally important advantage is the discovery of new business models and sources of profit. Companies can monetize their own data, develop digital services based on them, create new products focused on the needs of specific consumer segments.

However, the implementation of Big Data is accompanied by a number of serious challenges. First of all, it is significant implementation costs: powerful computing resources, licensed software, cloud platforms, as well as personnel training are required. At the same time, the issue of personnel shortage arises – the market urgently needs qualified data analysts, engineers, data science specialists.

Another significant obstacle is the difficulty of integrating Big Data into existing enterprise management systems, especially if they are outdated or unable to handle large amounts of information. No less critical are the issues of data protection and confidentiality: the information collected often includes personal or sensitive data, which requires compliance with strict legal norms, in particular the Ukrainian law on personal data protection or the international regulation GDPR.

The quality of the collected data is also a concern: it can be noisy, duplicated, and irrelevant, which complicates its analytical processing. We should also not forget about the difficulties of scaling Big Data architectures, which require constant updating and adaptation to growing volumes of information.

Finally, even with all the necessary tools, companies may face problems interpreting the results of the analysis. Without a proper understanding of the conclusions obtained, there is a risk of making wrong decisions that can lead to financial losses.

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Conclusions and prospects for further research

As a result of the study, it was found that big data processing technologies are becoming an increasingly important tool in the field of financial forecasting of enterprises. Big Data allows enterprises to more deeply analyze huge volumes of heterogeneous information obtained from internal and external sources, including in real time. This opens up opportunities for more accurate forecasting of income, expenses, cash flows, identification of financial risks and formation of flexible budget policy. The use of Big Data significantly expands the horizons of the analytical capabilities of the enterprise, contributing to the construction of an adaptive and proactive financial management model.

It is important to emphasize that big data not only increases the accuracy of financial forecasts, but also allows you to respond more quickly to changes in the external environment, identify new market trends, change investment priorities and reasonably develop growth strategies. Integration of Big Data with artificial intelligence, machine learning, cloud computing and blockchain technologies allows you to automate complex analytical processes, increase the transparency of financial information, reduce the level of errors and fraud, and also reduce the time for preparing management decisions.

However, the implementation of Big Data in the financial practice of enterprises is accompanied by a number of challenges, among which we can single out the need for highly qualified personnel, significant costs for building an appropriate IT infrastructure, issues of cybersecurity, protection of personal and commercially sensitive data, as well as the need for legal regulation of the circulation of big data. No less important is the issue of adapting management to work in conditions of constantly changing and updated data, because traditional financial approaches require transformation at all levels of decision-making.

In this context, the prospects for further research lie in the in-depth study of specific algorithms and models of financial forecasting based on Big Data, in particular, the construction of neural network models, the application of cluster analysis, regression methods and scenario modeling. The development of information and analytical platforms for small and medium-sized businesses that would ensure the availability of Big Data tools without the need for excessive investments is also a relevant direction. It is worth exploring the possibilities of integrating Big Data with accounting, auditing and management information systems, which will make management reporting more operational, analytically rich and strategically oriented.

Thus, Big Data plays an increasingly important role in financial forecasting processes, providing enterprises with new competitive advantages and strategic opportunities. Further study of this topic will allow not only to better understand the potential of big data in the financial sector, but also to contribute to the formation of new approaches to enterprise management in the era of digital transformation.

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REGULATORY AND ACCOUNTING ASPECTS OF THE ENTERPRISE TERMINATION PROCESS UNDER MODERN CONDITIONS

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Key words:
business termination, liquidation, reorganization, bankruptcy, digitalization.

In the current conditions of dynamic economic development, accompanied by frequent crises, changes in the legislative framework, and an unstable geopolitical situation, the issue of business termination is gaining particular importance. The growing number of companies forced to cease operations for financial, economic, political, or strategic reasons highlights the need for a clear, lawful, and transparent accounting process to support these procedures.

The termination of a business is not only a legal fact but also a complex, multi-stage process that encompasses a wide range of accounting procedures: from asset inventory to the final closure of accounts and preparation of financial statements. Proper organization of accounting at this stage ensures not only compliance with legal requirements but also the protection of the rights of all interested parties: founders, creditors, employees, and tax authorities.

This topic is especially relevant in the context of the transformation of the national accounting system in accordance with international standards, as well as the active implementation of digital technologies in accounting practices. Under these conditions, there arises a need to rethink traditional approaches to accounting at the final stage of a company's operations, particularly considering automation and electronic document management.

Thus, the study of accounting support in the process of business termination is not only of scientific importance but also has significant practical implications, contributing to enhanced transparency, efficiency, and accountability in the management of economic entities within a volatile market environment.

НОРМАТИВНО–ПРАВОВІ ТА ОБЛІКОВІ АСПЕКТИ ПРОЦЕСУ ПРИПИНЕННЯ ДІЯЛЬНОСТІ ПІДПРИЄМСТВА В СУЧАСНИХ УМОВАХ

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Ключові слова:
припинення діяльності, ліквідація, реорганізація, банкрутство, цифровізація.

У сучасних умовах динамічного розвитку економічного середовища, що супроводжується частими кризовими явищами, змінами законодавчої бази та нестабільною геополітичною ситуацією, питання припинення діяльності підприємств набуває особливої важливості. Зростаюча кількість компаній, що змушені зупиняти свою діяльність, як з фінансово-економічних, так і з політичних або стратегічних міркувань, зумовлює потребу в чіткому, правомірному та прозорому обліковому супроводі цих процесів.

Припинення діяльності підприємства – це не лише юридичний факт, але й складний багатоступеневий процес, що охоплює широкий спектр бухгалтерських процедур: від інвентаризації активів до остаточного закриття рахунків і формування фінансової звітності. Належна організація бухгалтерського обліку на цьому етапі забезпечує не лише виконання вимог законодавства, а й захист прав усіх зацікавлених сторін: засновників, кредиторів, працівників, податкових органів.

Особливої актуальності ця тема набуває в контексті трансформації національної системи обліку відповідно до міжнародних стандартів, а також активного впровадження цифрових технологій в облікову практику.

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У цих умовах виникає необхідність переосмислення традиційних підходів до ведення обліку на завершальному етапі функціонування підприємства, зокрема з урахуванням автоматизації та електронного документообігу.
Таким чином, дослідження облікового забезпечення процесу припинення діяльності підприємства є не лише науково значущим, а й має важливе практичне значення, сприяючи підвищенню прозорості, ефективності та відповідальності в управлінні економічними суб'єктами в умовах змінного ринкового середовища.

Problem statement

The termination of a company's operations is a complex and multifaceted process that requires strict compliance with regulatory requirements and accurate accounting. In the current environment, considering recent changes in legislation and the economic situation, this procedure has become particularly relevant and challenging. Ukrainian legislation is undergoing constant updates; notably, in 2025, substantial amendments were introduced that affect the termination process of enterprises – such as the repeal of certain legal codes and the implementation of new requirements for the registration and liquidation of legal entities. The termination process involves the mandatory preparation of numerous documents, adherence to legally defined timelines and procedures, and the correct maintenance of accounting records at all stages. Improper documentation or procedural violations may result in refusal of liquidation or create tax-related complications. Termination of operations requires the preparation of a final balance sheet, settlements with creditors and debtors, payment of taxes and fees, and the submission of corresponding reports. Neglecting these aspects can lead to financial and legal risks for both the enterprise and its owners. New regulatory acts adopted in 2025 have reshaped the framework for administration, registration, and reporting, demanding continuous monitoring and adaptation by businesses to meet new legal standards. Due to the complexity of the legal and accounting environment, enterprises require professional legal and accounting support to ensure the successful completion of the termination process.

Thus, the authors have identified the main issues that must be addressed to successfully terminate a company's operations without legal or financial complications.

Analysis of the latest research and publications

Modern scientific research focuses on the comprehensive study of legal, accounting, and organizational aspects of business termination, aiming to improve the quality of accounting and the transparency of financial reporting in this area.

The key scholars who explore modern aspects of accounting in the process of enterprise termination are: N.I. Dorosh and K.O. Hergel [11] – authors of the work "Accounting for the Enterprise Liquidation Process". They study the specifics of maintaining accounting records during liquidation, taking into account legal requirements, state registration procedures, and accounting operations related to termination of activity. V.O. Khomenko [12] – author of a scientific paper that examines the legal and accounting aspects of the termination of business entities, with special attention to the analysis of termination forms and their accounting representation. P. Yurkevych, Andrusiv, Verba-Sydor and other scholars [13] –authors of a textbook that covers the legal foundations of establishment, operation, and termination of legal entities, including the liquidation procedure. Their research is important for understanding the regulatory framework that influences accounting during enterprise termination. Nazarova [14] – investigates issues of accounting and information disclosure in the context of transformational processes, which also include accounting for enterprise termination.

Formulation of goals

The aim of the study is to:

– analyze the current legislative framework and the procedure for state registration of enterprise termination;

– analyze the existing legal forms of termination, specifically liquidation, reorganization, and bankruptcy, and their representation in accounting;

– examine the peculiarities of accounting for operations related to liquidation (asset write-off, settlements with creditors, preparation of the liquidation balance sheet), including under martial law conditions;

– identify the specific features of tax accounting related to the termination of enterprise activity;

– investigate the impact of digitalization and automation on the accounting process during enterprise termination.

Presentation of the main research material

In the context of the modern economy, the termination of enterprise activity is a natural element of economic life. In Ukraine, this process can be carried out in various forms, which are conventionally divided into voluntary and compulsory. Voluntary forms include liquidation and reorganization, while bankruptcy represents a compulsory form. Each of these processes has its own characteristics, determined by current legislation.

The legal regulation of the termination of enterprises in Ukraine is governed by a number of legislative acts. The Civil Code of Ukraine occupies a central place among them, as it defines the general provisions regarding the termination of legal entities. The Commercial Code of Ukraine elaborates on these norms in relation to business entities. [1, pp. 5–10; 2, pp. 11–14]

Voluntary liquidation of an enterprise entails the complete termination of its activities without the transfer of rights and obligations. This process is initiated by a decision of the founders or participants and consists of several stages. First, a liquidation commission is established, followed by the publication of a liquidation notice. Then, interim and final liquidation balance sheets are prepared, settlements with creditors are made, and at the

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final stage, the enterprise is removed from the state register. Each of these stages is accompanied by the appropriate documentation, including minutes of decisions, orders, publications, and balance sheets (see Table 1).

Reorganization as a form of termination of an enterprise's activity is characterized by the transfer of rights and obligations to other legal entities. It may be carried out in various forms: merger, accession, division, separation, or transformation. Each of these forms has its specific features, but the general procedure includes the adoption of a resolution by the participants, notification of creditors, preparation of a transfer deed or a distribution balance sheet, and the final state registration of changes. The documentation of the reorganization process is quite complex and requires a meticulous approach to the preparation of all necessary documents (see Table 2).

Bankruptcy as a compulsory form of enterprise termination is regulated by a separate Code of Ukraine on Bankruptcy Procedures. This procedure is applied in cases of the enterprise's financial insolvency, when it is unable to meet its monetary obligations over an extended period. The bankruptcy process includes several stages: initiation of proceedings, potential rehabilitation (financial recovery), liquidation procedure, and final removal from the state register. Each stage is accompanied by specific documentation, among which court decisions, reports of the insolvency practitioner, and the liquidation balance sheet are of particular importance. [3, pp. 20–25]

An important aspect of enterprise termination is the protection of creditors' rights. The legislation provides mechanisms that ensure creditors have the opportunity to receive due satisfaction of their claims. In the case of voluntary liquidation, this is achieved through the publication of notices and compliance with the prescribed settlement procedures. In bankruptcy cases, the interests of creditors are protected through specific procedures that involve the recognition and satisfaction of claims in a legally established order of priority.

Ukraine's modern legal system is continuously being improved in the area of regulating enterprise termination. In recent years, a number of reforms have been adopted to simplify procedures, increase process transparency, and protect the rights of all interested parties. However, practice shows that many issues still require further improvement, particularly in the area of preventing abuses during the termination of enterprise activity.

Thus, the termination of enterprise activity in Ukraine is a complex procedure governed by numerous legislative acts. The choice of a specific form depends on the circumstances under which the termination occurs and on the objectives pursued by the founders or other interested parties. Regardless of the method chosen, it is crucial to follow the procedure established by law and to properly prepare all necessary documentation, as this ensures the legality of the process and protects the rights of all participants involved.

Among the key aspects of this process, it is important to emphasize accounting in the context of enterprise termination. Its role in ensuring the transparency and legality of financial operations is fundamental. The process of terminating enterprise activity is accompanied by a number of complex accounting procedures aimed at ensuring the completeness of financial settlements. Proper organization of accounting at this stage is critically important for safeguarding the interests of all stakeholders: owners, creditors, government authorities, and employees.

The inventory of assets and liabilities is the first stage of accounting procedures in the process of enterprise liquidation or bankruptcy. It allows for determining the actual availability and condition of assets, as well as clarifying obligations to counterparties, the state budget, and employees. Based on the inventory results, adjustments to accounting data are made.

The next stage involves the valuation and write-off of property that cannot be sold or used. The enterprise's assets that can be realized must be assessed at fair value. The remaining assets are subject to write-off in accordance with the established procedure. All operations are recorded in the relevant accounting registers (see Tables 4, 5, 6).

Table 1 – Main Deadlines for the Implementation of Key Stages of Enterprise Liquidation in Ukraine

Stage of liquidation	Execution period
Adoption of the decision on liquidation and registration	The application must be submitted to the state registrar within 3 working days after the decision is made. The registration is carried out within 24 hours after the documents are received.
inventory of assets	It is carried out after the decision on liquidation has been made; no statutory deadline is established.
Publication of the liquidation announcement	It is published to notify creditors and other stakeholders.
Term for creditors to submit their claims	Not less than 2 months from the date of publication of the liquidation decision.
Settlements with creditors and debtors	They commence after the expiration of the term for creditors to submit their claims and continue until all obligations are fully discharged.
Preparation of the liquidation balance sheet	Prepared after all settlements with creditors and debtors have been completed.
Inspection by regulatory authorities and obtaining certificates	Verification by the Tax Authority and the Pension Fund for outstanding debts. Obtaining certificates
Closure of bank accounts	After all settlements have been completed.
Removal of the company from the Unified State Register	After receiving all certificates and completing all procedures.

Source: developed by the authors

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An important role is played by the accounting of expenses related to the liquidation of an enterprise. These include costs for the services of a liquidator, court fees, utilities, property security, document storage, and other related expenses. At the same time, accounting is maintained for settlements with creditors and debtors, including debt repayment, debt collection, and settlements with employees and the state budget.

At the final stage of the termination of an enterprise's activities, accounting accounts are closed and liquidation financial statements are prepared. All account balances must be zero, and the statements must accurately reflect the financial position of the enterprise as of the date of its liquidation. The core element of this stage is the liquidation balance sheet – a document that officially certifies the completion of the enterprise's financial and economic operations [10].

Particular attention should be paid to the preparation of a zero liquidation balance sheet, which includes: closure of all accounts: after the write-off of assets and

Table 2 – Forms of Enterprise Reorganization: Characteristics and Specific Features

Form of reorganization	Essence	Result	Key documents	Features
Merger	Consolidation of two or more enterprises into a new one	Termination of all enterprises, formation of a new legal entity	Participants' resolution, transfer deed	All rights and obligations are transferred to the newly established enterprise.
Acquisition	Merger of one enterprise into another	Cessation of one enterprise, the other continues operations	Participants' resolution, transfer deed	Transfer of assets, accounting records, and obligations to the successor enterprise.
Division	Division of one enterprise into two or more	Termination of the initial enterprise, creation of several new ones	Participants' resolution and distribution balance sheet	The property, rights, and obligations are apportioned among the newly created enterprises.
Spin-off	Spin-off of one or more new enterprises from an existing one	The initial enterprise is retained, a new one is created	Participants' resolution and distribution balance sheet	Part of the assets and liabilities is transferred to the newly established enterprises.
Transformation	Change of legal form of the enterprise	The same legal entity, but in a different form	Participants' resolution, transformation plan, updated charter	The legal entity is not terminated; only its legal form is changed (for example, from an LLC to a Private Enterprise).

Source: developed by the authors

Table 3 – Forms of Enterprise Termination in Ukraine

Criterion	Voluntary liquidation	Reorganization	Bankruptcy
The nature of the procedure	Voluntary	Voluntary	forced
Grounds	Resolution of the founders/ participants	Resolution of the founders/ participants	Financial insolvency
Regulation	Civil Code of Ukraine, Commercial Code of Ukraine	Civil Code of Ukraine, Commercial Code of Ukraine	Bankruptcy Procedures Code of Ukraine
Main stages	1. Establishment of the liquidation commission 2. Publication of the notice 3. Preparation of balance sheets 4. Settlements with creditors 5. Removal from the register	1. Decision-making 2. Notification of creditors 3. Drawing up a transfer deed/ balance sheet 4. Registration of changes	1. Commencement of proceedings 2. Rehabilitation (if possible) 3. Liquidation procedure 4. Removal from the register
Documents	Minutes of decisions, orders, publications, interim and liquidation balance sheets	Participants' resolution, transfer deed, distribution balance sheet	Court decision, reports of the insolvency practitioner, liquidation balance sheet
Transfer of rights	Not provided	The transfer to other legal entities is envisaged	Not provided
Protection of creditors	Publication of notices, compliance with the settlement procedure	Notification of creditors, guarantees of obligations fulfillment	Special procedures for recognition and satisfaction of claims in the established sequence
Complexity	Medium (regulated procedure)	High (requires coordination with other legal entities)	Very high (significant oversight by the court and the insolvency practitioner)
Time	From 2 to 6 months	From 2 to 12 months (depending on the form)	From 6 months to several years

Source: developed by the authors

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Table 4 – Accounting Entries for the Write-Off of Fixed Assets

Transaction	Debit	Credit	Supporting document
Write-off of the residual value of fixed assets	976	10 (sub-account by type of fixed asset, e.g., 103 «Buildings and structures»)	Write-off Act, inventory
Accumulated depreciation written off	13	10	Write-off Act
Recognition of revenue from sales	36	719	Contract, transfer Act
Accrual of VAT	719	641	Tax Invoice

Source: developed by the authors

Table 5 – Accounting Entries for the Write-Off of Goods

Transaction	Debit	Credit	Supporting document
Cost of Goods Sold	902	281	Consignment Note, act of Sale
Income recognition	36	702	Consignment Note
Accrual of VAT	702	641	Tax Invoice

Source: developed by the authors

Table 6 – Accounting Entries for the Write-Off of Other Assets (Materials, Raw Materials)

Transaction	Debit	Credit	Supporting document
Write-off of material costs	976	201 (202)	Write-off Act
Income recognition	36	719	Act of Transfer
Accrual of VAT	719	641	Tax Invoice

Source: developed by the authors

the completion of settlements with creditors and debtors, no balances should remain.

Example of a transaction for closing a settlement account: Dr 311 «Current accounts in national currency» – Cr 36 «Settlements with customers and clients» – for the amount of the remaining funds.

Recognition of liquidation costs (e.g., dismantling, transportation, security): Dr 976 «Write-off of non-current assets» – Cr 685 «Settlements with other creditors».

Closing the financial result:

− If the enterprise has a profit: Dr 79 «Financial results» – Cr 441 «Retained earnings»

− If the enterprise incurs a loss: Dr 442 «Uncovered losses» – Cr 79 «Financial results».

Among the key accounting accounts actively used at this stage are:

976 – «Write-off of non-current assets expenses related» – to reflect the costs associated with the liquidation and write-off of non-current assets;

902 «Cost of goods sold» – to reflect the cost of selling inventory before liquidation;

719 «Other income from operating activities» – to reflect income from the sale of current assets;

702 «Income from the sale of goods»;

641.15 «VAT settlements».

Before the final write-off of assets, the company is required to carry out an inventory and prepare the relevant acts. Only after that is it allowed to compile the final financial statements and the liquidation balance sheet. It is essential to ensure that all assets and liabilities have been written off, sold, or transferred, because only in this case can the liquidation balance be considered zero and reliable (see Table 7).

Table 7 – Zero liquidation balance

Assets	Amount	Liabilities	Amount
Balance	0	Balance	0

Source: developed by the authors

Thus, accounting during the termination of a company's activity is a complex process that requires high accuracy, knowledge of legislation, and compliance with established standards. Its proper organization ensures a transparent and controlled completion of the business entity's existence.

No less important a component in the process of terminating a company's activity is tax accounting. In this context, it plays a key role, as it must ensure the correct accrual and payment of all tax obligations, the submission of final reporting, and compliance with all requirements of the supervisory authorities. Any violation or non-compliance with these obligations may lead to legal consequences and additional expenses, complicating the liquidation process.

Prior to the final termination of its activity, the enterprise must make full settlements for all types of taxes: corporate income tax, value-added tax (VAT), personal income tax (PIT), unified social contribution (USC), etc. It is important to take into account all accrued but unpaid obligations, as well as possible adjustments based on the results of inventory or audit. [4, pp. 12–15]

According to tax legislation, an enterprise that ceases its operations is required to submit final tax reporting in full. The reporting period is the date of termination of activity. Mandatory reporting forms include the corporate income tax return, VAT return, unified social contribution (USC) and personal income tax (PIT) reports, as well as financial

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statements submitted to the supervisory authorities. After the submission of reports, the supervisory authorities conduct an audit to verify the accuracy of the data. In case of any violations, the enterprise is obliged to correct them before the completion of the liquidation procedure. The supervisory authorities (State Tax Service, Pension Fund, and other social insurance funds) must issue certificates confirming the absence of outstanding debts. These certificates are mandatory for completing the liquidation procedure. Often, before such certificates are issued, an unscheduled documentary audit is conducted, covering the enterprise's most recent reporting periods.

To expedite interaction with tax authorities, the enterprise should agree in advance on the procedure and timeline for the audit, prepare all required documents, and ensure access to electronic archives if electronic reporting forms were used.

Thus, tax accounting during the liquidation of an enterprise must be organized clearly and in accordance with legal requirements, taking into account all potential risks. The settlement of tax obligations is a mandatory stage that precedes the final closure of the enterprise [9, c. 123].

In the current conditions, it is also necessary to take into account the specifics of accounting during the period of martial law. The introduction of martial law in Ukraine has significantly influenced the conduct of accounting, reporting, and tax administration. In response to extraordinary circumstances, the state has introduced a number of simplifications, benefits, and deferrals aimed at reducing the administrative burden on businesses. However, these measures do not eliminate the necessity to comply with the general principles of accounting, but only adjust the forms and deadlines for their implementation.

Enterprises were granted the opportunity to:

– refrain from submitting tax reports in the absence of technical capability;

– apply the simplified taxation system without income limitations;

– refrain from accruing and paying certain taxes during the period when the enterprise does not operate due to hostilities;

– receive a deferral of tax audits. [5]

These measures are regulated by Resolutions of the Cabinet of Ministers of Ukraine, laws of Ukraine, and other acts adopted after February 2022. [6]

Accounting for property losses, destroyed documents, and inability to maintain records. During the hostilities, many enterprises suffered losses of fixed assets, inventories, documentation, and access to information systems. Under such circumstances, accounting becomes complicated or may be temporarily suspended. The legislation allows for the submission of reports on property destruction, applications for compensation, as well as the preparation of explanatory notes to accompany financial statements. Whenever possible, documentary evidence of losses should be supported by photo and video documentation, and by official reports from local authorities, the police, the State Emergency Service, and other relevant bodies.

The State Tax Service has allowed enterprises to:

– submit reports after the termination of force majeure circumstances;

– conduct correspondence in electronic form through the Taxpayer's Electronic Cabinet;

– use digital signatures even in the absence of the authorized individual at the company's office.

These measures contribute to the preservation of accounting procedures, even under conditions where physical access to the office or accounting records is impossible.

In real conditions, accounting becomes challenging not only technically but also psychologically. The most common difficulties include:

– loss of personnel or relocation of accountants abroad;

– lack of access to banks, counterparties, and electronic systems;

– constant changes in the regulatory framework requiring prompt response;

– difficulties with inventory and control over remaining assets.

Thus, accounting under martial law requires a flexible approach, adaptation to changes, and a heightened level of professional responsibility. At the same time, government support and digital technologies create the necessary prerequisites for maintaining basic accounting functions in emergency situations (see Table 8) [7, 8].

Nevertheless, even with the availability of such instruments, the full-scale war in Ukraine has become a true test for national businesses, causing a wave of forced termination of enterprises' operations (Figure 1). The realities of warfare, loss of production capacities, physical destruction of assets, loss of personnel, and blocked logistics routes have all compelled companies to make difficult – and in some cases, unavoidable – decisions regarding liquidation or bankruptcy (see Table 9).

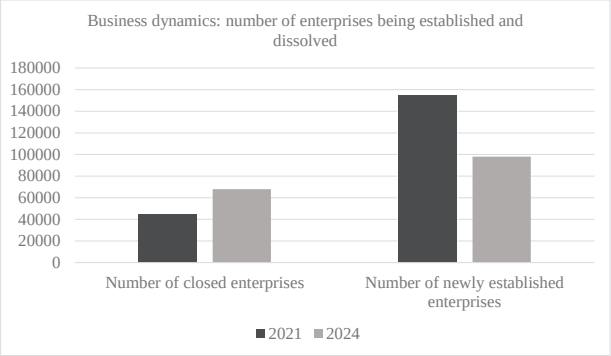

Fig. 1 – Business balance: how many enterprises open and how many close.

Source: developed by the author

In practice, enterprises affected by the war are facing unprecedented difficulties. In several regions, particularly in frontline areas, numerous cases have been recorded where businesses have completely lost access to accounting data, financial records, and tangible assets. In many cases, it is impossible to carry out inventory, assess losses using conventional methods, or ensure reporting in compliance with applicable standards.

At the same time, even under these critical conditions, enterprises are striving to find solutions. Some are switching to cloud-based accounting systems, others are using remote tax support services, and engaging experts to document losses and to legalize the inability to maintain accounting records. This gives rise to a number of challenges: how to document the loss of assets, how to write off assets without

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Table 8 – Changes in accounting under the impact of martial law

Indicator	Before the war (standard accounting)	During martial law	Comment / source of changes
Submission of reports	Strictly according to schedule (tax, statistical, financial)	Deferral possible in case of force majeure	Law No. 2115-IX, clarifications by the State Tax Service of Ukraine
Taxation	General/simplified system with income limits	Simplified system without income limits; exemption from certain taxes	Law No. 2120-IX
Tax audits	Scheduled/unscheduled according to the plan	Most inspections suspended	Cabinet of Ministers Resolution No. 89, Law No. 2115-IX
Loss of assets / accounting for damages	Full inventory and documentary confirmation	Loss reports, photo/video documentation, reports by the State Emergency Service of Ukraine, or reports issued by local authorities.	Letters from the State Tax Service of Ukraine, Methodological Guidelines by the Ministry of Finance of Ukraine
Bookkeeping / access to systems	Physical or online access to software and archives	Often limited; use of backup channels and cloud solutions possible	Practical recommendations, clarifications by IT accounting platforms
Digital interaction with the State Tax Service	Mainly in person or via email	Full correspondence via the Taxpayer's Electronic Office	Website of the State Tax Service of Ukraine, orders concerning electronic document management
Human resources	Full staff at the head office	Often dispersed: relocation, mobilization, part-time employment	Accountant's comments, real business cases
Updating the regulatory framework	Periodic changes	Constant updates, need for daily monitoring	Official websites of the Verkhovna Rada of Ukraine, the Cabinet of Ministers, and the State Tax Service

Source: developed by the authors

Table 9 – Comparative analysis of enterprise closures and openings in Ukraine

Criterion	Year 2021 (pre-war)	Year 2024 (during the war)	Differences (+/–)
Total number of closed businesses	~45,000	~68,000	+51%
Main reasons for closure	– Economic inefficiency – Competition – Tax burden	– Hostilities (37% of cases) – Loss of assets (28%) – Logistical constraints (19%)	Change in the structure of causes
Regions with the highest number of closures	Eastern regions (25%)	Frontline zones (42%) Occupied territories (not calculated)	Shift in the geographical distribution of problems
Number of newly established businesses	~155,000	~98,000	–37%
Top industries among new businesses	1. Retail trade (32%) 2. Services (25%) 3. Construction (18%)	1. IT sector (27%) 2. Logistics (23%) 3. Military–civilian production (19%)	Shift in priorities
Average operational period of an enterprise before closure	5.2 years	3.8 years	–27%
Share of forced liquidations	12%	34%	+22 percentage points
Forms of reorganization instead of closure	18% of cases	9% of cases	–9 percentage points
Use of digital solutions during liquidation	23% of enterprises	61% of enterprises	+38 percentage points
Average costs of the closure procedure	~25 thousand UAH	~42 thousand UAH	+68%

Source: developed by the authors

a physical inspection, and how to account for destroyed warehouse inventory if it cannot be restored.

In addition, the war has compelled enterprises to reassess their approaches to terminating operations. Whereas in peacetime, liquidation followed a clearly defined legal and procedural framework, under wartime conditions it is complicated by the absence of a number of key elements of the process – in particular, the ability to properly settle accounts with all counterparties or to compile a complete liquidation balance sheet. These circumstances complicate the legal standing of enterprises and create grounds for further disputes with regulatory authorities

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However, despite all the difficulties, many economic entities continue to demonstrate resilience and adaptability. In a number of cases, they have managed to retain part of their documentation, carry out partial inventories, and submit liquidation reports in electronic form. This underscores the importance of developing flexible, digital accounting and legal mechanisms that are better suited to meeting the challenges of the present time.

Conclusions. The termination of an enterprise's activity is a complex process that spans legal, financial, and accounting dimensions. In the context of current economic instability, intensified by the full-scale war, this issue becomes particularly pressing. Legislative changes, the risk of asset loss, and limited access to resources and personnel compel enterprises to look for flexible exit mechanisms that, at the same time, ensure compliance with legal regulations and the protection of the interests of all stakeholders.

Termination of operations may take the form of liquidation, reorganization, or bankruptcy. Each of these forms has its own procedural specifics that require clear legal documentation and thorough accounting support. Accounting plays a key role in this process, as it ensures the accuracy of information on the company's assets and liabilities, records liquidation costs, reflects settlements with creditors, and generates liquidation reports.

Proper implementation of tax obligations is of particular importance: the final accrual and payment of taxes, submission of tax reports, as well as obtaining certificates from the controlling authorities. The legality of the termination of a company's operations and the avoidance of further legal complications depend on the timeliness and accuracy of these actions.

Under martial law, traditional accounting procedures have become significantly more complicated. In many cases, enterprises lose property, documentation, or access to accounting systems. The government's response has been the introduction of temporary simplifications: postponement of reporting deadlines, suspension of inspections, and electronic communication with tax authorities. Although these measures partially compensate for the losses, enterprises still face a number of practical challenges, such as the inability to conduct inventory, the absence of supporting documents, and difficulties in preparing financial and tax reports.

Despite this, many business entities demonstrate an ability to adapt by using digital technologies, cloud-based solutions, alternative forms of accounting, and consulting with auditors. Wartime experience clearly outlines the need to update accounting standards taking into account emergency conditions, and to develop universal approaches to documenting business transactions under limited access to resources.

Thus, the termination of an enterprise is not merely a procedure of ceasing operations, but a complex and responsible process that requires a comprehensive approach. In times of war, this process becomes even more complicated, emphasizing the urgent need to adapt the regulatory framework and accounting mechanisms to the new realities. Further scientific research should focus on developing standardized methodologies for accounting in the context of enterprise termination, harmonizing national legislation with international standards, and implementing modern digital tools capable of ensuring transparency and efficiency even under the most critical conditions.

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THE ROLE OF DIGITAL TECHNOLOGIES IN IMPROVING THE EFFICIENCY OF CURRENT ASSETS MANAGEMENT OF THE POST-WAR ECONOMY

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Key words:
digital technologies, working capital, financial management, accounting automation, ERP systems, predictive analytics, Big Data, artificial intelligence, blockchain.

The article examines the role of digital technologies in enhancing the efficiency of working capital management in industrial enterprises in the post-war economy. After the conflict ends and considering economic instability, there is a need to develop new management strategies that ensure the rapid recovery and sustainable development of enterprises. One such solution is the digitalization of financial management, particularly the automation of accounting processes and the use of modern technologies to optimize working capital management. Contemporary approaches to digitalizing financial management are analyzed, focusing on innovative technologies such as ERP systems, Big Data analytics, artificial intelligence (AI), blockchain, and automated inventory management platforms. The advantages of these technologies are discussed in detail, including the ability to reduce costs, increase the transparency of financial transactions, improve forecasting accuracy, and minimize financial risks. One key aspect is the role of automation in financial and accounting processes. ERP systems, which integrate all enterprise data into a single platform, enable the automation of inventory management, accounts receivable and payable, and contribute to efficient cash flow management. Additionally, the use of Big Data and predictive analytics allows for accurate demand forecasting, optimal inventory levels, and ensures financial stability. The implementation of blockchain technologies promotes transparency in financial transactions and minimizes the risks of fraud and unauthorized interference. Digital payment systems and smart contracts automate transactions with suppliers and significantly reduce the time spent on verifying financial operations. The article highlights the challenges and issues enterprises face when implementing digital solutions, particularly the need for significant financial investments, cybersecurity concerns, and the demand for qualified personnel. Practical recommendations are proposed for the implementation of digital solutions, including the integration of ERP systems, the use of Big Data analytics, the application of artificial intelligence, and machine learning for financial analysis, which reduce costs, improve working capital forecasts, and enhance the efficiency of management processes in industrial enterprises.

РОЛЬ ЦИФРОВИХ ТЕХНОЛОГІЙ У ПІДВИЩЕННІ ЕФЕКТИВНОСТІ УПРАВЛІННЯ ОБОРОТНИМИ ЗАСОБАМИ ПОВОЄННОЇ ЕКОНОМІКИ

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Ключові слова:
цифрові технології, оборотні засоби, фінансовий менеджмент, автоматизація обліку, ERP-системи, прогнозна аналітика, Big Data, штучний інтелект, блокчейн.

У статті досліджено роль цифрових технологій у підвищенні ефективності управління оборотними засобами промислових підприємств у повоєнній економіці. Після завершення конфлікту та з урахуванням економічної нестабільності постає необхідність розробки нових стратегій управління, які дозволяють забезпечити швидке відновлення та стійкий розвиток підприємств. Одним із таких рішень є цифровізація фінансового менеджменту, зокрема автоматизація облікових процесів та використання сучасних технологій для оптимізації управління оборотним капіталом.

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Проаналізовано сучасні підходи до цифровізації фінансового менеджменту, розглядаючи інноваційні технології, такі як ERP-системи, аналітика великих даних (Big Data), штучний інтелект (AI), блокчейн та автоматизовані платформи для управління запасами. Детально розглянуто переваги цих технологій, зокрема можливість зниження витрат, підвищення прозорості фінансових операцій, точності прогнозування та мінімізації фінансових ризиків. Одним з ключових аспектів є роль автоматизації у фінансово-облікових процесах. ERP-системи, які інтегрують всі дані підприємства в єдину платформу, дають змогу автоматизувати облік запасів, дебіторської та кредиторської заборгованості, а також сприяють ефективному управлінню грошовими потоками. Крім того, застосування Big Data та прогнозної аналітики дозволяє точно оцінювати попит на продукцію, оптимізувати рівень запасів і забезпечити фінансову стійкість підприємств. Застосування блокчейн-технологій сприяє прозорості фінансових транзакцій, а також мінімізації ризиків шахрайства та несанкціонованого втручання. Цифрові платіжні системи та смарт-контракти дозволяють автоматизувати угоди з постачальниками та значно зменшити час на перевірку фінансових операцій. Висвітлено проблеми та виклики, з якими стикаються підприємства при впровадженні цифрових рішень, зокрема необхідність значних фінансових інвестицій, питання кібербезпеки та потребу в кваліфікованих кадрах. Запропоновано практичні рекомендації щодо впровадження цифрових рішень, зокрема інтеграцію ERP-систем, використання аналітики великих даних, застосування штучного інтелекту та машинного навчання для фінансового аналізу, що дозволяють знижувати витрати, покращувати прогнози щодо оборотного капіталу та підвищувати ефективність управлінських процесів у промислових підприємствах.

Statement of the problem

Modern industrial enterprises operate in difficult conditions of war, which is accompanied by significant difficulties: the destruction of production facilities, disruption of logistics chains, shortage of financial resources and increasing uncertainty. War creates an unstable economic environment in which enterprises have great difficulties in ensuring the continuity of their activities. After the end of hostilities, enterprises will have to face the need to restore the economy in the post-war period, which will be an important stage in ensuring stability and restoring normal activity.

The post-war period will bring numerous challenges, in particular the need to restore production facilities, adapt to new market conditions and ensure effective management of working capital. Effective management of such funds will be one of the key factors in maintaining the liquidity, competitiveness and sustainability of enterprises in the recovery process.

Digital technologies play an important role in this process. They make it possible to automate the control and analysis of financial flows, forecast the needs for working capital, effectively manage inventories and receivables. The use of technologies such as artificial intelligence, blockchain, cloud computing and big data analytics allows to increase the accuracy of management decisions, which is especially important for enterprises recovering from the war and requiring rapid adaptation to changes.

The relevance of the topic is due to several factors

First, after the war, the economy is faced with the problem of disruption of production and supply chains, which complicates planning and requires new approaches to managing material flows.

Second, the shortage of financial resources poses the task of enterprises to carefully monitor the movement of cash and receivables. Third, it becomes more difficult to assess the financial stability of counterparties, which increases the risks of partners' insolvency. Finally, in conditions of uncertainty, it is necessary to ensure greater flexibility of management decisions, which is possible only with the introduction of digital technologies and process automation.

Thus, digital technologies are an important tool for modernizing the working capital management system in the conditions of economic recovery after the war. They contribute to the rational use of resources, reduce financial risks and increase the efficiency of enterprises' operational activities. Research into the impact of digitalization on the management of working capital is an important area of significant scientific and practical interest in the context of post-war economic recovery.

Analysis of recent studies and publications

In the current conditions of post-war economic recovery, the management of working capital of industrial enterprises is becoming particularly relevant. This issue is being studied by both Ukrainian and foreign scientists who pay attention to the digital transformation of financial management, automation of accounting processes and the use of advanced technologies to increase the efficiency of financial decisions.

Domestic research focuses on the adaptation of enterprises to changes in the post-war economy. In particular, Kovalenko V.V. analyzes the digital transformation of financial resource management and its impact on the optimization of working capital [1]. Lytvynenko O.P. investigates the possibilities of using big

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data analytics to forecast the movement of working capital and minimize financial risks [2]. Considerable attention is also paid to the automation of accounting: Savchenko I.V. in his work considers ERP systems as a tool for financial control and inventory management [3]. In turn, Romanenko S.M. investigates the mechanisms of financial adaptation of enterprises in post-war conditions, focusing on new approaches to managing current assets [4].

Foreign scientists are also actively exploring the possibilities of digitalization in the field of working capital management. For example, Anderson J. and Williams R. analyze how digital solutions affect the efficiency of financial processes and reduce the risks of a shortage of working capital [5]. Miller T. investigates the application of artificial intelligence in supply chain management and inventory optimization [6]. Chen H. and Zhang L. highlight the advantages of blockchain technologies in corporate financial management, in particular for the transparency of cash flows and receivables management [7]. Johnson P.'s research is aimed at developing financial strategies that help enterprises adapt to economic changes in post-crisis conditions [8].

Thus, the analysis of scientific works demonstrates that modern working capital management is impossible without digital technologies. Domestic researchers focus on adaptation mechanisms for Ukrainian enterprises, while foreign authors consider the possibilities of using artificial intelligence, blockchain, and big data analytics. In the future, further research should be aimed at developing integrated digital financial management strategies that will increase the efficiency of industrial enterprises in an unstable economic situation.

Objectives of the article

The aim of the article is to study the role of digital technologies in increasing the efficiency of working capital management of industrial enterprises in the post-war economy. Analysis of modern approaches to the digitalization of financial management, identification of the main challenges and opportunities for using innovative technologies to optimize working capital management, as well as substantiation of practical recommendations for the implementation of digital solutions to increase the sustainability and competitiveness of enterprises.

Statement of the main material

In the post-war economy, industrial enterprises will face numerous challenges related to the resumption of production, resource shortages, instability of the financial system and the need to quickly adapt to changes. In such conditions, effective management of working capital becomes critically important for ensuring business continuity, maintaining liquidity and achieving financial stability. Digital technologies play an important role in this process, which allow optimizing management processes, increasing forecasting accuracy and accelerating decision-making. One of the key aspects of digitalization of working capital management is the automation of financial and accounting processes.

The use of ERP (Enterprise Resource Planning) systems provides comprehensive control over the movement of assets, allows automating the accounting of inventories, receivables and payables, and also contributes to effective cash flow management. Such systems integrate all financial data of the enterprise into a single platform, which allows for a prompt assessment of the state of working capital and reducing the risks of financial instability [3].

The use of Big Data technologies and predictive analytics makes it possible to accurately assess product demand, optimize inventory levels, and effectively manage financial flows. Thanks to the analysis of large data sets, enterprises can identify key factors affecting working capital, as well as formulate strategies for managing them in an unstable economic environment [2].

Blockchain technologies help increase the transparency of financial transactions and minimize the risks of fraud. Smart contracts allow you to automate transactions with suppliers and simplify the payment control process, which is especially important during the period of economic recovery, when trust in financial partners plays a key role. In addition, digital payment systems provide speed and reliability of transactions, which allows enterprises to manage their financial resources more effectively.

The use of cloud technologies allows industrial enterprises to quickly adapt to changes, reducing infrastructure costs and providing access to data in real time. Digital platforms for supply chain management allow you to effectively coordinate interaction with suppliers, optimizing the level of current assets and minimizing the costs of their maintenance [4].

Thus, digital technologies play an important role in increasing the efficiency of current asset management of industrial enterprises in an unstable economic environment. They contribute to the automation of business processes, increasing forecasting accuracy, accelerating financial transactions and improving the overall resilience of enterprises to economic challenges. The use of modern digital tools allows not only to optimize working capital management, but also creates the basis for the stable development of the industrial sector in the conditions of recovery. One of the key modern approaches to the digitalization of financial management is the automation of working capital management processes. The use of specialized software solutions allows for real-time analysis of cash flows, receivables and payables, inventory status and financial risks. This provides flexibility in decision-making and allows enterprises to quickly respond to changes in the economic situation. At the same time, the widespread use of predictive analytics based on Big Data technologies makes it possible to accurately assess the need for financial resources, plan expenses and determine optimal financial strategies.

Despite the obvious advantages of digitalization, the process of its implementation is accompanied by certain challenges. One of the main problems is the need for significant financial investments in the implementation and support of modern information systems. For many companies, raising funds for such projects is a difficult task. An additional challenge is the need to ensure cybersecurity, as the digitalization of financial processes increases the risks of confidential data leakage and

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fraudulent transactions. In addition, the problem of human resources plays a significant role: there is still a shortage of qualified specialists who can work effectively with the latest digital financial instruments [1].

Despite these difficulties, the digitalization of financial management opens up wide opportunities for optimizing working capital management. In particular, the use of blockchain technologies allows making financial transactions more transparent and secure, eliminating the risks of fraud and unauthorized intervention. The integration of digital financial management platforms and the automation of financial transactions allows enterprises to reduce costs, reduce payment processing time and increase efficiency.

Modern approaches to the digitalization of financial management also involve the active use of cloud technologies that provide access to financial data from anywhere in the world. This allows enterprises to effectively manage financial flows even in difficult conditions, when access to traditional financial instruments may be limited.

For a deeper understanding of the main challenges and opportunities for digitalization of working capital management, it is advisable to compare traditional and digital management methods in Table 1.

Analyzing the data in Table 1, we can conclude that digital methods of working capital management significantly outperform traditional methods in terms of data processing speed, transparency of operations, forecasting accuracy, and security. The use of modern technologies, such as blockchain, ERP systems, Big Data analytics, and artificial intelligence, allows enterprises to reduce costs, automate financial processes, and increase the efficiency of capital management.

However, the transition to digitalization is not without certain challenges. The main ones are the need for significant financial investments in new technologies, as well as the need to train personnel to effectively use new tools. At the same time, the introduction of innovative technologies opens up new opportunities for optimizing working capital management, in particular through the integration of modern tools for automatic analysis, forecasting, and monitoring of financial flows [9].

Figure 1 shows the main challenges and opportunities associated with the use of innovative technologies to optimize working capital management.

Table 1 – Traditional and digital methods of working capital management

Parameter	Traditional methods	Digital methods
Transparency of operations	Limited, high level of paper document flow	High, thanks to blockchain technologies and ERP systems
Data processing speed	Slow, depends on the human factor	High, real-time processing
Forecasting accuracy	Limited, based on historical data	High, analytics based on Big Data and AI
Cybersecurity	Relatively low, paper document risks	High, use of cryptography and secure servers
Management costs	High due to the involvement of a large number of personnel	Reduced due to process automation

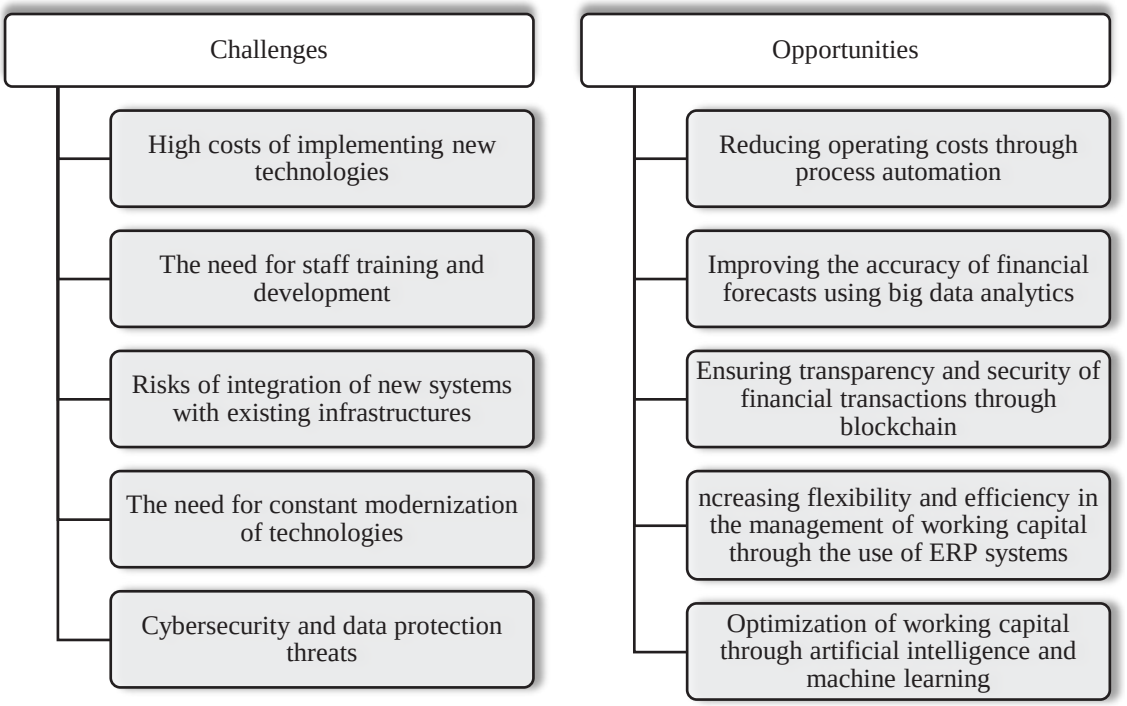

Fig. 1 – Main challenges and opportunities associated with the use of innovative technologies to optimize working capital management

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It should be noted that although the introduction of innovative technologies into financial management is accompanied by certain challenges, their potential for increasing the efficiency of working capital management is significant.

Thus, digital technologies open up new prospects for the effective management of working capital of industrial enterprises during an unstable economic situation. They ensure the accuracy of financial forecasting, reduce the costs of administrative processes, increase the level of security of financial transactions and contribute to rapid decision-making.

The use of modern digital solutions allows enterprises to adapt to new realities and form effective financial strategies, which is a key factor in their sustainable development [10].

For effective management of working capital in the post-war economy, industrial enterprises should implement modern digital technologies that will help increase financial stability, reduce costs and improve the flexibility of business processes. Below are key practical recommendations for the digitalization of working capital management.

The proposed recommendations for the implementation of digital solutions in the management of working capital of industrial enterprises provide an opportunity to significantly increase the efficiency of financial management and adapt to the conditions of the post-war economy. The integration of ERP systems, the use of big data analytics, the implementation of artificial intelligence and blockchain technologies allow to reduce operating costs, ensure transparency and security of financial transactions, as well as optimize the management of inventories and working capital.

Digital solutions will help enterprises to increase the efficiency of financial decision-making, reduce the time for document processing, and reduce the risks of errors and fraud. The implementation of these technologies will be a key factor in achieving the sustainability and competitiveness of enterprises in the conditions of rapid changes in the post-war economy, where flexibility and speed of response to external challenges are crucial for success. The proposed measures are aimed at maximizing the use of digital technologies to increase the efficiency of the management of working capital of enterprises. The implementation of ERP systems and automated inventory management allows enterprises to minimize losses, optimize logistics processes and increase financial discipline [3].

The use of Big Data and artificial intelligence significantly improves the accuracy of forecasting the needs of an enterprise in financial resources, which makes it possible to reduce the risks of cash gaps and working capital shortages. Blockchain technologies and electronic document management increase the level of security of financial transactions, ensure their transparency and minimize administrative costs [2].

Taken together, these measures allow enterprises not only to adapt to the challenges of the post-war economy, but also to create competitive advantages through the rapid adoption of sound financial decisions, minimizing costs and increasing operational efficiency.

Conclusions

Based on the research conducted, we note that modern current asset management is impossible without the use of innovative technologies, such as ERP systems, big data analytics, artificial intelligence, blockchain and cloud platforms. These technologies significantly improve the accuracy of financial forecasts, increase the transparency of operations, reduce management costs and ensure better adaptation of enterprises to changes in an unstable economic environment.

The analysis showed that the digitalization of financial processes not only allows you to optimize inventory accounting and financial flow management, but also

Table 2 – Practical recommendations for implementing digital solutions

№	Digitalization direction	Solution description	Expected results
1	Using ERP systems	Integration of digital platforms for enterprise resource management, automation of inventory control processes, receivables and payables.	Optimization of working capital, increasing transparency of financial transactions, reducing decision-making time.
2	Big Data Analytics	Using analytical platforms to process large amounts of financial and operational data to forecast financial and inventory needs.	Reducing the risk of financial losses, increasing the accuracy of current asset planning.
3	Implementation of artificial intelligence and machine learning	Automation of financial analysis and calculations, creation of algorithms for forecasting working capital based on historical data.	Reduction of errors in calculations, increase of accuracy of financial planning, reduction of the human factor.
4	Blockchain technology	Using blockchain to increase the security of financial transactions, ensure the reliability and transparency of data on working capital.	Reducing the risk of fraud, increasing trust in financial transactions, reducing the cost of verifying financial documents.
5	Automated inventory management	Implementation of digital systems for controlling the balance of material resources, use of IoT for monitoring warehouses.	Reduction of excess inventory, acceleration of capital turnover, minimization of storage costs.
6	Electronic Document Management (EDM)	Automation of accounting for financial documentation, implementation of electronic signature, digital contracts and acts.	Reduction of costs for document management, increase in speed of processing of financial transactions, reduction of bureaucratic procedures.

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minimizes the risks of fraud, increases cybersecurity and reduces the impact of the human factor. At the same time, the process of implementing new technologies is accompanied by certain challenges, in particular the need for significant investments and training qualified personnel.

In view of this, it is recommended to more actively implement digital solutions, in particular ERP systems, analytical platforms for processing big data and artificial intelligence technologies, which will not only optimize the management of working capital, but also create a foundation for the stable development of enterprises in the period of post-war recovery. Digitalization is a key factor for increasing the resilience, competitiveness and financial stability of industrial enterprises in the future.

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DIGITAL TECHNOLOGIES IN THE ANALYSIS, ACCOUNTING, AND MANAGEMENT OF LABOR RESOURCES IN INDUSTRIAL ENTERPRISES

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Key words:
human resource potential, personnel management, digital transformation, industrial enterprises, HRM systems, development strategy.

The article examines the theoretical and practical aspects of developing a strategy for managing the human resource potential of industrial enterprises in the context of digital transformation. The role of human resource potential is identified as one of the key factors in ensuring enterprise competitiveness in modern economic conditions. Contemporary approaches to personnel management are analyzed, including the use of information technologies, big data analytics, artificial intelligence, automated HRM systems, and other digital tools. The advantages of implementing digital technologies in human resource management processes are characterized, such as improving recruitment efficiency, automating personnel management processes, enhancing communication among employees, and optimizing training and professional development processes. The impact of digitalization on the efficiency of human resource management, personnel adaptation to changes, workforce optimization, and increasing enterprise competitiveness is studied. Special attention is given to the methodological aspects of developing human resource management strategies, including assessing the level of digital maturity of enterprises, selecting technological solutions, and implementing innovative personnel management models. The main challenges and risks associated with the digital transformation of human resource management are identified, such as the need for additional investments in digital infrastructure, resistance to change among employees, cybersecurity issues, and the necessity of continuous staff training. Methods for minimizing these risks are proposed through the gradual implementation of digital solutions, the creation of flexible personnel management models that combine traditional and innovative approaches. The research results indicate the need to integrate digital technologies into the personnel management system of industrial enterprises to enhance productivity, reduce costs, and improve personnel adaptability. Strategic directions for human resource development are proposed, contributing to the formation of a stable and efficient workforce management system in the context of dynamic market changes.

ЦИФРОВІ ТЕХНОЛОГІЇ В АНАЛІЗІ, ОБЛІКУ ТА УПРАВЛІННІ ТРУДОВИМИ РЕСУРСАМИ ПРОМИСЛОВИХ ПІДПРИЄМСТВ

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Ключові слова:
кадровий потенціал, управління персоналом, цифрова трансформація, промислові підприємства, HRM-системи, стратегія розвитку.

У статті розглядаються теоретичні та практичні аспекти розробки стратегії розвитку управління кадровим потенціалом промислових підприємств в умовах цифрової трансформації. Визначено роль кадрового потенціалу як одного з ключових факторів забезпечення конкурентоспроможності підприємств у сучасних економічних умовах. Проаналізовано сучасні підходи до управління персоналом, зокрема використання інформаційних технологій, аналітики великих даних (Big Data), штучного інтелекту, автоматизованих HRM-систем та інших цифрових інструментів.

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Охарактеризовано переваги впровадження цифрових технологій у процеси кадрового менеджменту, такі як підвищення ефективності рекрутингу, автоматизація процесів управління персоналом, покращення комунікації між співробітниками та оптимізація процесів навчання і підвищення кваліфікації. Досліджено вплив цифровізації на ефективність кадрового менеджменту, адаптацію персоналу до змін, оптимізацію трудових ресурсів та підвищення конкурентоспроможності підприємств. Особливу увагу приділено методологічним аспектам розробки стратегій управління кадровим потенціалом, включаючи оцінку рівня цифрової зрілості підприємств, вибір технологічних рішень та впровадження інноваційних моделей управління персоналом. Визначено основні виклики та ризики, пов'язані з цифровою трансформацією кадрового менеджменту, такі як необхідність додаткових інвестицій у цифрову інфраструктуру, опір змінам з боку персоналу, проблеми кібербезпеки та необхідність постійного навчання кадрів. Запропоновано шляхи мінімізації зазначених ризиків через поступову імплементацію цифрових рішень, створення гнучких моделей управління персоналом, що поєднують традиційні та інноваційні підходи. Результати дослідження свідчать про необхідність інтеграції цифрових технологій у систему управління персоналом промислових підприємств для підвищення продуктивності, зниження витрат та покращення адаптаційних можливостей персоналу. Запропоновано стратегічні напрямки розвитку кадрового потенціалу, які сприяють формуванню стійкої та ефективної системи управління трудовими ресурсами в умовах динамічних змін ринку.

Statement of the problem

In today's digital transformation of the economy, industrial enterprises are faced with the need to improve approaches to human resources management. Traditional methods of personnel analysis and planning are becoming less effective due to dynamic changes in the labor market, high competition for qualified personnel, and the growing need to automate management processes. In this regard, digital technologies play an important role, allowing for a comprehensive analysis of human resources potential, forecasting personnel needs, increasing the efficiency of labor resources use, and optimizing their management processes. The introduction of digital solutions in the field of human resources management contributes to increasing labor productivity, reducing costs for administrative procedures, increasing employee satisfaction, and ensuring the strategic development of enterprises. The use of HR analytics, artificial intelligence, human resource management systems (HRM systems), blockchain technologies for accounting for human resources, as well as Big Data and machine learning tools can significantly improve the process of making managerial decisions.

The relevance of studying digital technologies in the management of human resources of industrial enterprises is due to several key factors. Modern industrial enterprises are actively implementing Industry 4.0, which involves the automation and digitalization of all business processes, including personnel management. Industrial enterprises are faced with a shortage of qualified personnel, which requires effective forecasting of personnel needs and rapid adaptation of personnel strategies to changes in the external environment. Digital technologies allow to significantly increase the efficiency of the use of labor resources by analyzing labor productivity, optimizing personnel distribution and automating routine processes. The use of large data sets (Big Data), machine learning algorithms and predictive analysis contributes to informed decision-making regarding personnel development, motivation management and employee performance assessment. Thanks to digital technologies, it is possible to quickly respond to changes in production processes and adjust personnel policy in accordance with the strategic goals of the enterprise. Thus, the research and implementation of digital technologies in the processes of analysis and management of labor resources is an urgent need for modern industrial enterprises. This not only ensures the effective use of human resources, but also contributes to the competitiveness and sustainable development of enterprises in the long term.

Analysis of recent studies and publications

In the current conditions of digital transformation of the economy, the issue of introducing digital technologies into the management of human resources of industrial enterprises is becoming particularly relevant. Domestic researchers, such as A.S. Ustilovskaya, in their work emphasize the need to adapt personnel management systems to the requirements of the fourth industrial revolution [11]. She notes that the integration of digital technologies into HR processes helps to increase the efficiency of personnel management and ensures the competitiveness of enterprises in the market. Domestic researchers, such as M. D. Vedernikov, L. V. Volyanska-Savchuk, O. O. Chernushkina and N. P. Bazaliyska, in their work emphasize the need to adapt personnel management systems to the requirements of the fourth industrial revolution [5]. They note that the integration of digital technologies into HR processes helps to increase the efficiency of personnel management and ensures the competitiveness of enterprises in the market.

In modern research, foreign scholars pay considerable attention to the impact of digital technologies on the

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management of labor resources of industrial enterprises. In particular, Stefan Stromeyer explores the conceptual aspects of digital human resource management, emphasizing the importance of strategic integration of digital technologies into HR processes to improve the effectiveness of personnel management [2]. Mohammad Reza Azizi analyzes innovative HR management strategies during the COVID-19 pandemic, focusing on the use of digital technologies to support employee satisfaction, productivity, and adaptation to new working conditions [1]. Other researchers, such as L. Wang and G. Zheng, investigate the relationship between digital HR management practices and their effectiveness, emphasizing the role of the maturity of HRM capabilities in this context [3].

Thus, both domestic and foreign scientists are investigating various aspects of the implementation of digital technologies in human resources management, from conceptual foundations to practical strategies and their impact on the effectiveness of HR processes.

Thus, an analysis of recent research indicates that the implementation of digital technologies in human resources management is a key factor in increasing the efficiency and competitiveness of industrial enterprises both in Ukraine and abroad.

Objectives of the article

The purpose of the article is to study the role and impact of digital technologies on the processes of analysis and management of labor resources of industrial enterprises, identify key trends in their implementation, and assess the effectiveness of digital tools in increasing labor productivity, optimizing personnel processes, and ensuring the competitiveness of enterprises in modern conditions of digital transformation.

Statement of the main material

Digital technologies have undoubtedly become an important tool in the management of human resources of industrial enterprises, significantly changing both the management processes themselves and the role of labor potential in the activities of companies. The introduction of modern information technologies not only automates routine operations, but also makes it possible to more effectively analyze human resources, which allows you to increase productivity and reduce costs. Digital technologies in human resources management include various tools, such as human resource management systems (HRM systems), platforms for employee training and development, as well as programs for big data analytics (Big Data). They allow you to collect and process significant amounts of information about personnel, which is the basis for making more informed decisions at all stages of work with personnel: from personnel selection to employee development and performance evaluation [7].

One important aspect is the use of Big Data analytics, which helps not only to identify the needs for new employees, but also to predict potential problems in human resource management, for example, the level of staff turnover, trends in labor productivity or the effectiveness of training programs [7]. This allows enterprises to adapt their human resource management strategy in accordance with changes in the external environment and internal processes. For a more clear understanding of the impact of digital technologies on human resource management, we present Table 1, which reflects the main benefits of implementing digital tools in various aspects of human resource work.

This table demonstrates the variety of tools that can be used to optimize human resource management processes at industrial enterprises. The introduction of such technologies allows not only to increase the efficiency of internal processes, but also contributes to increasing the competitiveness of enterprises, which is important in the context of global competition and technological change. Thus, digital technologies allow enterprises in the industrial sector not only to optimize internal processes, but also to significantly improve the quality of human resource management. The introduction of such tools allows not only to increase the efficiency of employees, but also to adapt the enterprise to new challenges facing the industry in the context of rapid technological change. Analysis of the use of digital technologies in the processes of analysis and management of human resources of industrial enterprises is an important step for assessing the current state of innovation in this area, as well as for formulating a development strategy for the future. The use of digital tools allows to significantly improve management processes, reduce costs, increase the accuracy of decision-making and efficiency in performing tasks related to human resource management [4].

The first thing to note is that the introduction of digital technologies into HR practice allows enterprises to more effectively carry out personnel selection, automate the processes of labor productivity assessment, working time accounting and staff turnover. Tools for automating these processes significantly reduce the human factor, errors, and

Table 1 – The impact of digital technologies on human resource management processes

Human resource management process	Digital technologies	Benefits
Selection of personnel	HRM systems, online interview platforms	Quick access to candidates, optimization of the selection process
Employee Performance Assessment	Big data analytics, performance appraisal software	Objective data on performance, reduction of subjectivity in assessments
Training and Development	Online learning platforms, artificial intelligence	Individualized training programs, availability of training materials
Personnel turnover management	Predictive algorithms, big data analytics	Identification of problems at early stages, prevention of personnel outflow

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thereby contribute to improving the quality of personnel management.

Secondly, digital technologies, such as human resource management systems (HRM), data analytics tools and artificial intelligence, are able to provide deep analysis and forecasting, which allows you to optimize the use of labor resources. They allow you to accurately predict the need for labor in the future, help reduce staff turnover, and also predict the effectiveness of employees at different stages of their careers.

Thirdly, the need for such analysis is due to the rapid development of digital technologies, which are constantly being improved. Assessing the effectiveness of these technologies in industrial enterprises allows you to identify problem areas, for example, insufficient use of system capabilities or problems with integrating new technologies into existing business processes. Such analysis makes it possible to timely adjust innovation implementation strategies and adapt them to changing labor market conditions.

Determining directions for further development of digital solutions allows enterprises to remain competitive, increasing the efficiency of personnel management. This includes not only improving internal processes, but also involving innovative methods of training, employee development, as well as the use of the latest technologies to ensure the adaptability and flexibility of organizational structures.

The main stages where digital technologies can be applied to automate management processes are (Fig. 1):

Thus, the analysis of the use of digital technologies in the processes of analysis and management of labor resources is not only important for assessing the current state, but also for forming a development strategy in the future, which contributes to increasing productivity and efficiency of work at industrial enterprises.

The introduction of digital technologies in labor resources management at industrial enterprises directly contributes to the automation of various management processes. This aspect of digitalization is key, since automation not only reduces the amount of manual labor, but also significantly increases the accuracy and efficiency of task performance. For industrial enterprises, where the scale of production and the number of employees can be very large, automation becomes a necessary condition for achieving high results. Digital technologies in all these processes allow not only to increase efficiency and reduce costs, but also to reduce the human factor, which makes personnel management processes more transparent, objective and operational. Thanks to the integration of such systems, enterprises can focus on more strategic aspects of management, such as talent development and workflow optimization [6].

The introduction of digital technologies in the automation of human resources management processes in industrial enterprises contributes to a significant reduction in administrative costs, increased accuracy of management decisions, as well as improved overall staff efficiency. This allows enterprises to adapt to rapid changes in the technological environment and maintain competitiveness in the industry.

In line with the introduction of digital technologies for the automation of human resources management processes, the next important step is the development of big data analytics (Big Data) for in-depth analysis of human resources. Since traditional methods of information processing and employee evaluation are no longer able to cope with the large volumes of data generated at enterprises, new analytical tools make it possible not only to quickly process large volumes of information, but also to identify key patterns that affect human resources management.

Big data analytics is an important element in human resources management processes at modern industrial enterprises. It allows you to collect, process and analyze huge amounts of data about employees and their activities in real time, which makes it possible to make more accurate forecasts and effectively manage personnel. This becomes possible thanks to the use of various analytical platforms, machine learning and artificial intelligence algorithms [7].

One of the main areas of use of big data analytics is the forecasting of staff turnover, which is an important aspect of personnel management. By analyzing data on the level of employee satisfaction, their social status, working conditions, productivity levels and other factors, companies can predict which employees may leave the company in the near future. This allows you to take measures in advance to retain key personnel or prepare a replacement [8].

Another important aspect is the optimization of recruitment processes. With the help of big data analytics, companies can evaluate the effectiveness of various channels for finding employees, analyze which characteristics of candidates lead to better results in work, and thus adapt the recruitment strategy to the specifics of the company's activities. This approach allows you to reduce the time and resources for recruiting personnel, making this process more accurate and predictable.

Big data analytics is also used to increase labor productivity. The collected data allows you to determine the effectiveness of each employee, track their performance in different conditions, and find patterns that can be used for further training and development of employees. This approach allows you to more accurately assess the needs for training and development of personnel, as well as adjust personnel management strategies in a timely manner. The use of such technologies also helps in optimizing personnel costs. Data analytics allows you to identify inefficiently used resources or the presence of excess employees, which helps reduce salary costs and reduces the financial burden on the company [9].

To better understand the effectiveness of using big data analytics in human resource management, we present an example of Table 2 with indicators that can be obtained through such analysis.

Using big data analytics in HR processes allows companies to improve decision-making efficiency, optimize costs and reduce risks. This approach allows not only to predict future trends in HR management, but also to ensure more effective recruitment, training and development, which in turn helps to increase the productivity and competitiveness of the enterprise.

In addition to the effective use of big data analytics, the use of artificial intelligence (AI) for HR management is no

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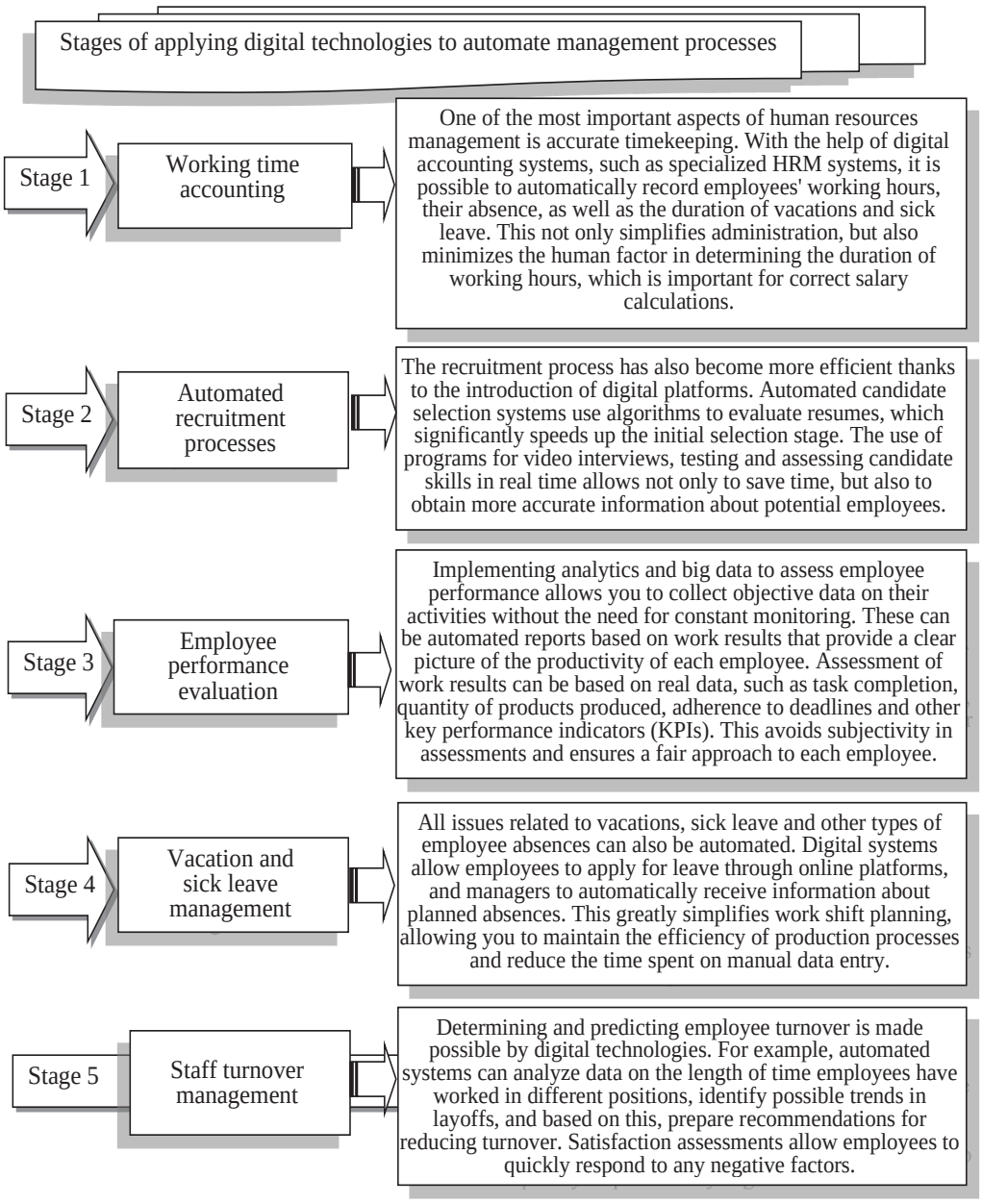

Fig. 1 – Stages of applying digital technologies to automate management processes

Table 2 – Using big data analytics for human resource management

HR Management Process	Technologies Used	Benefits
Employee turnover forecasting	Big data analytics, machine learning	Reducing employee turnover, responding to problems in a timely manner
Recruitment	Algorithms for resume analysis, interview process automation	Quick and accurate identification of suitable candidates
Performance Assessment	Data Analytics, KPI, Performance Evaluation	Accurate Measurement of Employee Productivity, Objective Assessments
Training and development of personnel	Training platforms, adaptive learning systems	Individualized training, employee training

less important. Artificial intelligence is a powerful tool for automating processes, making data-based decisions and creating personalized solutions for employee development. Thanks to AI algorithms, companies can significantly reduce the human factor in HR management, reduce costs and increase the accuracy of forecasts.

Artificial intelligence in HR management is used at various stages of processes, from the selection of

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candidates to assessing their performance. The use of such technologies allows to significantly optimize work processes and provide enterprises with better results due to a high level of automation and accuracy of decision-making. One of the most popular areas of use of AI is recruitment. Artificial intelligence algorithms are able to perform in-depth analysis of resumes, identifying the necessary skills and qualifications of candidates. They can also conduct preliminary screening interviews, providing an assessment according to various criteria, which reduces the time and resources spent on hiring. In addition, AI is actively used for assessment processes, such as analyzing employee productivity. For example, algorithms can analyze employee behavior, their interaction with colleagues, activity level, achieved results and many other indicators. This approach allows for a more objective and accurate assessment of employee efficiency. The use of AI also helps in automating the processes of training and personnel development. Intelligent systems can create individual development plans for each employee, analyzing their strengths and weaknesses, on the basis of which specialized trainings and courses are generated. AI is able to adapt training programs to the specific needs of the employee, which allows to significantly increase the efficiency of training [10].

Another advantage of using AI is the optimization of labor management costs. Thanks to accurate forecasts and recommendations of artificial intelligence, companies can carry out optimal staffing planning, minimizing excessive costs for redundant positions or inefficient use of resources. To illustrate the use of AI in labor management, we present a table that illustrates its main advantages and capabilities.

The use of artificial intelligence in human resource management processes significantly increases the efficiency of human resource management at industrial enterprises. AI provides a more accurate assessment of employee productivity, optimizes recruitment and helps in forecasting personnel needs. Thanks to such tools, enterprises are able to significantly reduce the costs of human resource management and improve the quality of decisions made. In the long term, this allows them to maintain competitiveness and adapt to changing labor market conditions.

Digital platforms for training and development of personnel have become an important element in the human resource management strategy at modern industrial enterprises. Growing competition and technological changes require companies to constantly improve the skills and qualifications of their employees. Given this, online learning platforms are becoming increasingly important as tools for increasing the efficiency and productivity of personnel.

One of the main advantages of digital platforms is a personalized approach to training. Traditional training methods often do not take into account the individual needs of employees, while online learning platforms allow for the creation of customized programs for each employee, taking into account their level of qualification, interests and professional goals. For example, platforms using artificial intelligence can automatically select courses and materials for the user, based on their previous results and personal preferences. This approach ensures a higher level of employee involvement in the learning process, as they receive exactly the knowledge and skills they need for further professional growth.

Another important advantage of digital platforms is the availability of training materials at any stage of work. Traditionally, employees had to undergo training at a certain stage of their career or at set deadlines. Now, thanks to platforms, employees can access training materials at any time when necessary, and depending on their current level of knowledge or development needs. This allows for more flexible training, which is especially important in conditions of rapidly changing technological requirements [8].

Digital platforms also enable monitoring of the learning process. With the help of such tools, managers can track the progress of employees, identify their strengths and weaknesses, and adjust training programs in a timely manner. This not only increases the effectiveness of training, but also makes it possible to optimize training costs, since it is possible to accurately determine which courses or programs produce the best results.

By using e-courses, video training, webinars, and interactive tools such as gamification, employees have the opportunity not only to gain theoretical knowledge, but also to immediately apply it in practice. This allows them to better adapt to new working conditions, as well as more quickly master new tools and technologies that become important for the effective performance of their tasks. Table 4 illustrates the main advantages of digital platforms for training and development of personnel in industrial enterprises.

Digital platforms for training and development of personnel at industrial enterprises offer great potential for improving the efficiency of employees. They allow to maintain a high level of qualification, quickly adapt

Table 3 – Use of artificial intelligence in labor management

Human Resources Management Process	Technologies Used	Benefits
Recruitment	Algorithms for CV screening, automated interviews	Fast and accurate candidate selection, reduced selection time
Labor productivity assessment	AI analytics, KPI analysis, performance monitoring	Objective and personalized assessments, rapid problem detection
Training and development of personnel	Intelligent training platforms, personalized trainings	Individualized approach to training, advanced training
Staffing Planning	Staffing Forecasting, Planning Optimization	Reducing Personnel Costs, Proper Resource Allocation

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employees to new working conditions, and also provide a personalized approach to training. This contributes to increasing labor productivity, reducing training and development costs, and improving the overall efficiency of labor resources management at enterprises.

Digital technologies in the field of labor resources management are already changing traditional methods of working with personnel, optimizing processes from recruitment to assessing their productivity. However, the rapid development of technologies opens up new horizons for further improvement of management processes. In particular, the future of labor resources management will be associated with the use of such innovations as blockchain, virtual and augmented reality, as well as adaptation to changes caused by the pandemic and global economic changes [9].

One of the most promising areas of development is the use of blockchain technologies to ensure transparency and reliability of employee data. Blockchain allows for the creation of reliable and immutable records of employees' work activities, qualifications, education and experience. This is especially important for companies operating in an international environment where it is necessary to confirm the authenticity of candidate data. In addition, blockchain can be used to automate contracts and payroll management, providing greater transparency and reducing the risk of fraud or calculation errors. These technologies allow companies to significantly improve the efficiency of human resource management, as well as ensure compliance with legal requirements. Another important innovation that can significantly change the processes of training and development of personnel is virtual (VR) and augmented reality (AR). These technologies are able to create interactive learning environments that allow employees to interact with virtual objects, simulate real-world work processes and even undergo training in conditions that are as close to real-world as possible. For example, VR can be used to train employees on specific technologies or equipment without the need for physical presence in the workplace, while AR allows providing employees with real-time information about the work being performed or navigating them in difficult environments [10].

In addition, in the post-pandemic world, where many companies have switched to remote work or hybrid models, there is a need to develop new tools for managing distributed teams. The use of technologies such as cloud platforms for collaboration, big data analytics for tracking the performance of remote workers, as well as tools for flexible project management, allows maintaining the efficiency of organizational processes even in distributed work conditions. This makes it possible to monitor employee productivity, their development and motivation, even when they work from different locations.

In the context of the development of new forms of work and adaptation to changes in the labor market, digital technologies allow for flexible management of labor resources, which contributes to a faster response to economic challenges. This also includes the introduction of electronic platforms for freelancers and temporary workers, which makes it possible to create effective models of cooperation between companies and external workers.

Table 5 presents the main prospects for the development of digital technologies in the field of labor resources management.

Rapidly evolving digital technologies offer enormous opportunities for improving workforce management. The introduction of tools such as blockchain, VR, AR, cloud platforms and big data analytics helps enterprises increase the efficiency, flexibility and transparency of their HR processes. These technologies contribute not only to improving internal processes at enterprises, but also to adapting to new working conditions that have arisen due to global changes in the world of work.

Table 4 – The impact of digital platforms on training and development of personnel

Learning and Development Direction	Digital Platforms	Benefits
Personalizing training programs	AI-based platforms, online courses	Adapting training to the needs of each employee
Accessibility of learning	Online courses, mobile platforms	Ability to learn anytime, anywhere
Progress Monitoring	Data Analytics Platforms	Progress Tracking, Curriculum Adjustments
Interactive learning methods	Webinars, game-based learning methods	Employee engagement, improved learning
Reducing training costs	E-courses, webinars	Reducing costs for organizing traditional trainings

Table 5 – Prospects for the development of digital technologies in the field of labor resources management

The technology	Potential use	Benefits
Blockchain	Management of labor contracts, verification of employee qualifications	Transparency, reduction of fraud risk, automation of processes
Virtual Reality (VR)	Employee Training, Simulation of Work Situations	Safe Training, Realistic Replication of Work Processes
Augmented Reality (AR)	Increase on-site efficiency, real-time learning	Access additional information, improve work efficiency
Cloud Platforms	Real-time Collaboration, Communication, and Project Management	Increasing Flexibility and Efficiency in Team Management
Big Data Analytics	Forecasting Employee Needs, Tracking Productivity	Improving Planning, Increasing Management Efficiency

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Conclusions

Based on the research conducted, we can note that digital technologies have become an integral part of human resources management at industrial enterprises, significantly changing approaches to the organization and optimization of personnel processes. The introduction of innovative tools, such as HRM systems, online learning platforms, big data analytics and artificial intelligence, allows you to reduce costs, increase the efficiency of personnel management and improve decision-making. These technologies allow you to automate routine operations, objectively assess employee productivity, predict staff turnover and optimize personnel selection processes. Digitalization of personnel processes helps reduce administrative costs, increase the accuracy and efficiency of management decisions, which are key factors for ensuring the competitiveness of enterprises in a global and technologically changing environment. An important direction of development is big data analytics and artificial intelligence, which allow you to more accurately predict labor needs and effectively plan personnel management strategies.

Therefore, the effective use of digital technologies in workforce management is a powerful tool for increasing the productivity and development of enterprises, allowing them to adapt to change, improve the quality of work, and maintain their competitiveness.

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THEORETICAL AND APPLIED ASPECTS OF ECONOMIC PROCESSES IN UKRAINE AND IN THE WORLD ECONOMY

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EUROPEAN PRACTICES OF DEVELOPMENT OF THE PRECIOUS METALS MARKET

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Key words:
precious metals market, innovation, regulatory policy, environmental standards, London Metal Exchange, investments, economic stability, European market, financial reserves.

The article examines the development of the precious metals market in Europe since 2000, with particular emphasis on the impact of globalization, economic crises, innovation, and regulatory changes in the Union. Particular attention is paid to the importance of precious metals for the European economy, including their role as stable investment assets. The consequences of the 2008 financial crisis and the COVID-19 pandemic in 2020, which led to an increase in demand for gold and other precious metals that served as a means of preserving capital, are considered. The role of countries such as the United Kingdom, Switzerland, Germany, and France in the functioning of the global precious metals market is highlighted, in particular through key trading venues such as the London Metal Exchange. The contribution of the European Union to improving the regulatory framework aimed at ensuring transparency, ethics, and sustainability in the precious metals trade is highlighted. The impact of EU directives on business processes and the growth of quality standards is highlighted. Attention is also drawn to the prospects of the European precious metals market, including expanding international influence through technology exports, establishing partnerships with countries implementing «green» technologies, and innovative development. The article emphasizes the importance of legislative reforms and creating conditions for attracting investment, in particular to support technological startups and the development of environmentally sustainable mining methods. In conclusion, the article presents a comprehensive analysis of the current state of the precious metals market in Europe, its key challenges and achievements, emphasizing the importance of a comprehensive approach to the implementation of innovations and regulatory changes in the precious metals market to ensure sustainable economic growth and competitiveness in the global economy.

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ЄВРОПЕЙСЬКІ ПРАКТИКИ РОЗВИТКУ РИНКУ ДОРОГОЦІННИХ МЕТАЛІВ

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Ключові слова:
ринок дорогоцінних металів, інновації, регуляторна політика, екологічні стандарти, Лондонська біржа металів, інвестиції, економічна стабільність, європейський ринок, фінансові резерви.

Стаття досліджує розвиток ринку дорогоцінних металів у Європі після 2000 року, особливо акцентуючи увагу на впливі глобалізації, економічних криз, інновацій та регуляторних змін у рамках союзу. Основна увага приділяється значенню дорогоцінних металів для європейської економіки, включаючи їхню роль як стабільних інвестиційних активів. Розглянуто наслідки фінансової кризи 2008 року та пандемії COVID-19 у 2020 році, які призвели до зростання попиту на золото та інші дорогоцінні метали які виконували роль засобів збереження капіталу. Висвітлено роль таких країн, як Велика Британія, Швейцарія, Німеччина та Франція, у функціонуванні глобального ринку дорогоцінних металів, зокрема через ключові торговельні майданчики, як-от Лондонська біржа металів. Підкреслено внесок Європейського Союзу у вдосконалення регуляторної бази, що спрямована на забезпечення прозорості, етичності та екологічності у сфері торгівлі дорогоцінними металами. Висвітлено вплив директив ЄС на бізнес-процеси та зростання стандартів якості. Також звертається увага на перспективи європейського ринку дорогоцінних металів, включаючи розширення міжнародного впливу через експорт технологій, встановлення партнерств із країнами, які впроваджують «зелені» технології, та інноваційний розвиток. Стаття акцентує на важливості законодавчих реформ і створенні умов для залучення інвестицій, зокрема для підтримки технологічних стартапів і розвитку екологічно стійких методів видобутку. Підсумовуючи, стаття представляє всебічний аналіз сучасного стану ринку дорогоцінних металів у Європі, його ключових викликів та досягнень, підкреслюючи важливість комплексного підходу до впровадження інновацій і регуляторних змін на ринку дорогоцінних металів задля забезпечення стійкого економічного зростання та конкурентоспроможності у глобальній економіці.

The article is aimed at analyzing the development of the precious metals market in Europe after 2000 and determining the impact of globalization, economic crises and the introduction of innovative technologies on its efficiency, as well as the role of regulatory policy and innovations in strengthening the competitiveness of European countries and their ability to adapt to modern economic challenges.

Analysis of recent studies and publications points to the growing role of precious metals in ensuring economic stability and investment attractiveness of European countries. Research emphasizes that the precious metals market is a strategic segment for economic development, especially in the context of globalization, economic crises and innovation [1, 2, 3, 4, 5, 6]. Many articles consider the impact of globalization on international trade, liquidity growth and market adaptation precious metals to global challenges. Such works highlight how globalization has contributed to the integration of the European market into the global economy and the strengthening of its position through technological advances and regulatory transparency, and highlight the increased demand for precious metals during times of economic instability. Gold has become a key asset for capital preservation, and European countries have confirmed their status as leaders in the trade and storage of precious metals.

The monographs also actively explore modern challenges and prospects for market development in the context of technological innovations. The paper considers automation, digitalization, recycling of precious metals, as well as environmental initiatives that strengthen the competitiveness of European countries on the world stage. The authors offer recommendations for regulators and businesses to optimize business processes, increase market

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transparency, and create an ecosystem that contributes to the sustainable development of the industry [7].

In general, recent publications show that in order to maintain a leading position in the global economy, the European precious metals market needs to actively innovate, adapt to changing conditions and use international best practices. This will ensure the stability of the market, strengthen its investment attractiveness and contribute to the sustainable development of the European economy as a whole.

Problem statement: touches on the need to improve regulatory policy and introduce innovative technologies in the precious metals market in the European Union in the context of globalization, economic crises and growing environmental awareness. European countries often face challenges that require adaptation to new realities, so the problems are the need to ensure market transparency, the introduction of environmentally sustainable mining and processing practices, as well as overcoming the risks associated with price volatility and increased international competition.

Presentation of the main material

The precious metals market in Europe after 2000 underwent significant transformations due to economic, technological and social changes, because metals themselves have always played a strategic role in the global economy, as they are used as a tool for preserving capital, a key component of industrial production or as a basis for financial stability. After 2000, the demand for precious metals increased significantly, in particular for gold and silver, which have become the main tools for preserving value in conditions of economic instability, and the main reason for such an increase in demand was globalization, which not only expanded market access, but also increased the liquidity of precious metals, making them more accessible to a wide range of investors. Interestingly, the development of the precious metals market in Europe is also due to a change in investment preferences, because gold and other metals began to be perceived not only as assets for physical ownership, but also as the basis for financial instruments such as exchange-traded funds, futures and options. This has expanded opportunities for investors and made the market more attractive, while increasing its complexity and volatility (Fig. 1).

The economic crisis of 2008 rightfully became one of the largest financial shocks in history, which significantly affected global markets, in particular the precious metals market, because if we recall those events, it arose due to the collapse of the US mortgage market, which caused the collapse of large financial institutions and grew into a global financial crisis, and it is thanks to this that precious metals Gold, in particular, has gained the status of a "safe haven" as investors have begun to look for safe assets to protect their capital from financial instability. Gold became the main asset that ensured the preservation of value in the face of the collapse of traditional financial instruments such as stocks and bonds, so the demand for it increased among both private investors and central banks seeking to increase their reserves to maintain currency stability. As a result, gold prices increased significantly, reaching record levels at that time: for example, in the period from 2008 to 2011, the price of gold more than doubled (Fig. 1) [8, 9].

A similar situation was repeated during the COVID-19 pandemic in 2020. This crisis, which was caused by a sharp slowdown in economic activity due to quarantine restrictions, disruption of global supply chains and reduced production, once again confirmed the status of precious metals as a reliable asset, which, again, became a key tool for investors during a period of high volatility in the stock markets. In addition, financial crises have affected the dynamics of the extraction and trade of precious metals. For example, during the same COVID-19 pandemic,

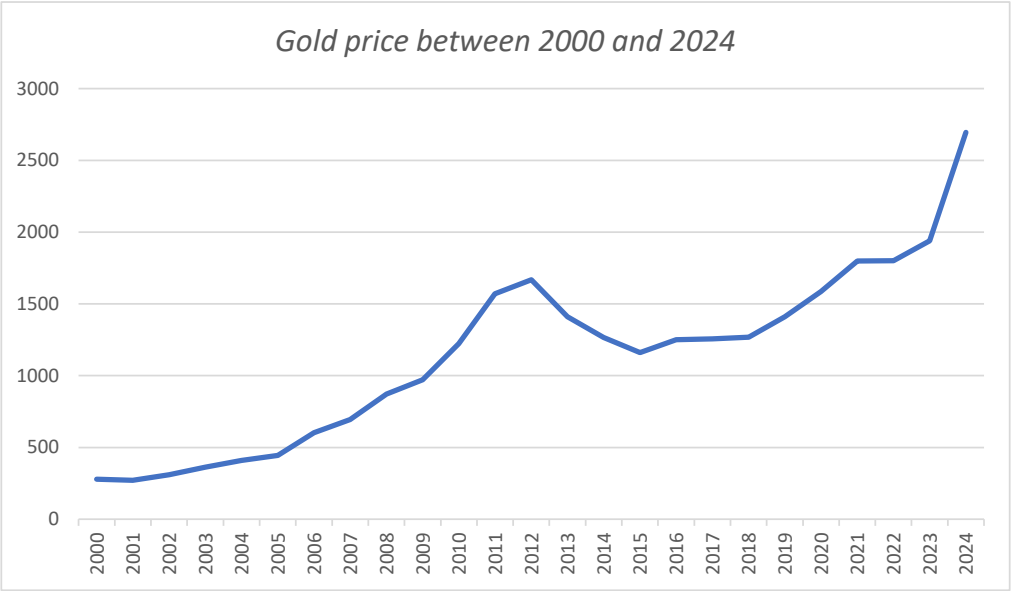

Fig. 1 – Gold price between 2000 and 2024 (source: National Mining Association: historical gold prices) [8, 9]

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production was temporarily halted in many countries due to quarantine measures, which created shortages and additional pressure on prices, but at the same time, the demand for precious metals remained stable, which further increased their value. It is also necessary to mention the role of the Central Banks of European countries, which also played an important role in stabilizing the market during these crisis periods, because their increase in their gold reserves became one of the ways to protect economies from exchange rate fluctuations and global financial instability. Germany, France and Switzerland were particularly active in this regard, which not only increased their reserves, but also kept gold as part of their economic sustainability strategy.

Since 2000, the European Union has been actively introducing a variety of legislation, which, although not primarily aimed at regulating the precious metals market, have had a significant impact on this sector and required it to be more focused on ethics, transparency and environmental responsibility. Among the main regulations are:

1. Regulation on the Responsible Supply of Conflict Minerals (2017/821): entered into force on 1 January 2021 and ensures the responsible supply of precious metals from conflict areas, preventing the financing of terrorist groups and human rights violations. Obliges importers to comply with identification, management and reporting procedures.

2. RoHS Directive (2011/65/EU, supplemented by 2017/2102): restricts the use of hazardous substances to reduce the impact on the environment and human health. The 2017 addition extended the requirements to more products and improved certification, as well as contributed to safer electronics production, improving environmental friendliness and product quality.

3. Anti-Money Laundering and Countering the Financing of Terrorism Directive (5th and 6th): strengthens the control of financial transactions to prevent criminal activity, requires customer identification, transaction monitoring and reporting of suspicious transactions. It directly affects the precious metals market due to new rules, increased control and changes in trade dynamics.

From this we can say that the EU, although it has not issued direct laws regarding the regulation of the precious metals sector, they are actively engaged in its regulation through directives that control other sectors of the Union and thanks to this approach, the EU influences numerous aspects of the work with precious metals, forming high standards of environmental safety, transparency of supply chains and ethics, which also affects their price.

Technological innovations have become a key factor in the development of the precious metals market in Europe, providing increased efficiency in mining, processing and reducing environmental impact. European companies began to actively implement automation, digital technologies or innovative metal processing methods in their business, which allowed them to remain competitive in the global market. Automation of production processes is also being actively introduced, in particular the use of robotic systems, which significantly reduces the level of manual labor and increases safety at mining facilities, along with the latest quality monitoring technologies, which allow you to accurately determine the composition and characteristics of materials, which contributes to the optimization of production cycles and cost reduction. Particular attention is also paid to precious metal recycling technologies, which help reduce dependence on the extraction of new resources and ensure the efficient use of metals from waste devices and materials, reducing the environmental footprint and costs of enterprises.

The results of the research show that a comprehensive approach to regulatory policy, the introduction of innovations and adaptation to global challenges create significant strategic advantages for the precious metals market in Europe, in particular, EU initiatives such as the Conflict Minerals Regulation and the RoHS Directive contribute to increasing transparency, environmental friendliness and responsibility of the industry. The research also confirms that during the crises of 2008 and the pandemic of 2020, precious Metals, especially gold, played a key role as a stable asset, ensuring the preservation of capital.

Conclusions

Regulatory policies and technological innovations create significant strategic advantages and new challenges for the precious metals market in Europe, in particular by showing that the implementation of EU directives such as the Conflict Minerals Regulation and the RoHS Directive has contributed to increasing market transparency, ethics and environmental friendliness, which directly affects this market. The same technological innovations such as automation, recycling and energy efficiency have also significantly increased and continue to Increase the efficiency of metal mining and processing, while reducing their impact on the environment, allowing the European market to meet high environmental standards and maintain global competitiveness. As for crisis moments, periods of economic crisis, such as the financial crisis of 2008 and the COVID-19 pandemic, confirmed the importance of precious metals as stable assets for capital preservation, which contributed to the growth of demand for gold and other metals, and the centralized increase in reserves in the EU countries was a key and important step towards stabilizing financial systems during these periods.

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INTERNATIONAL MARKETING IN THE CONTEXT OF VIRTUAL MOBILITY AS A CHALLENGE FOR UKRAINIAN COMPANIES

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Key words:
virtual mobility, international marketing, digital transformation, digital infrastructure, marketing strategies, global market.

The article carries out a comprehensive study of virtual mobility as a conceptual and practical basis for the implementation of international marketing of Ukrainian companies in the context of a full-scale war, digital transformation and destruction of the traditional economic infrastructure. It is determined that virtual mobility - as the ability of enterprises to carry out marketing, logistics and communication activities outside their geographical location through the use of digital technologies - has become a key factor in maintaining and scaling up business operations in a crisis. The article analyzes modern scientific approaches to revealing the essence of virtual mobility, digital marketing behavior and transnational communication in a globalized environment. It is substantiated that ensuring effective international marketing in the context of virtual mobility requires not only technical modernization, but also the adaptation of strategies to the cultural, behavioral and institutional contexts of target markets. On the basis of empirical data, statistical reports, industry research and cases of leading Ukrainian companies (in particular, Nova Poshta, Headway), the current practices of digital expansion to the EU and North American markets are characterized. The main challenges are highlighted: low level of fiber optic coverage, cultural heterogeneity of audiences, lack of trust in new players at the international level. The role of government initiatives (Diia. City) and external investments (IFC, EBRD) in supporting the digital environment is emphasized. Priority areas for further research are formulated, which include the development of effective models of virtual mobile marketing, indicators of the effectiveness of digital strategies and mechanisms of public-private cooperation in the field of Ukraine's digital economy.

МІЖНАРОДНИЙ МАРКЕТИНГ В УМОВАХ ВІРТУАЛЬНОЇ МОБІЛЬНОСТІ ЯК ВИКЛИК ДЛЯ УКРАЇНСЬКИХ КОМПАНІЙ

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Ключові слова:
віртуальна мобільність, міжнародний маркетинг, цифрова трансформація, цифрова інфраструктура, маркетингові стратегії, глобальний ринок.

У статті здійснено комплексне дослідження віртуальної мобільності як концептуальної та практичної основи реалізації міжнародного маркетингу українських компаній в умовах повномасштабної війни, цифрової трансформації та деструкції традиційної економічної інфраструктури. Визначено, що віртуальна мобільність – як здатність підприємств здійснювати маркетингову, логістичну та комунікаційну діяльність поза межами географічного розміщення завдяки використанню цифрових технологій – стала ключовим чинником збереження та масштабування бізнес-операцій у кризових умовах. Проаналізовано сучасні наукові підходи до розкриття сутності віртуальної мобільності, цифрової маркетингової поведінки та транснаціональної комунікації в умовах глобалізованого середовища. Обґрунтовано, що забезпечення ефективного міжнародного маркетингу за умов віртуальної мобільності вимагає не лише технічної модернізації, а й адаптації стратегій до культурного, поведінкового та інституційного контекстів цільових ринків.

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На основі емпіричних даних, статистичних звітів, галузевих досліджень і кейсів провідних українських компаній (зокрема Nova Poshta, Headway) охарактеризовано поточні практики цифрової експансії на ринки ЄС і Північної Америки. Виокремлено основні виклики: низький рівень оптоволоконного покриття, культурна неоднорідність аудиторій, дефіцит довіри до нових гравців на міжнародному рівні. Акцентовано на ролі державних ініціатив (Diia.City) та зовнішніх інвестицій (IFC, EBRD) у підтримці цифрового середовища. Сформульовано пріоритетні напрями подальших досліджень, що передбачають розробку ефективних моделей віртуально мобільного маркетингу, індикаторів результативності цифрових стратегій та механізмів державно-приватної взаємодії в сфері цифрової економіки України.

Formulation of the problem

In today's context of global instability, digital transformation of the world economy and military aggression against Ukraine, the study of international marketing mechanisms in the context of virtual mobility is of particular relevance. Virtual mobility, as the ability of companies to carry out marketing and operational activities regardless of physical location through the use of digital technologies, has become not only a forced adaptive response to external crises, but also a new paradigm for strategic management of enterprises in the global environment.

The aggravation of the geopolitical situation after Russia's full-scale invasion of Ukraine in 2022 led to a profound transformation of the business models of Ukrainian companies, which were forced to reorient their marketing strategies to digital platforms and remote interaction with target markets. According to the Ukrainian Association of the Digital Economy, in 2021-2023 alone, the share of companies actively using digital marketing and remote customer service tools increased from 45% to 83%, which confirms the scale and depth of the changes. This process was accompanied by active support from the state (in particular through the Diia.City initiative), as well as intensive attraction of foreign capital to the telecommunications sector.

In this regard, the need for a scientific understanding of the phenomenon of virtual mobility in international marketing, in particular in times of war as a special macroeconomic and geostrategic environment, is becoming more relevant. The research covers a comprehensive study of the impact of digital infrastructure, cultural barriers, global competition, and the latest marketing technologies (including AI solutions) on the ability of Ukrainian businesses to integrate into the international economic space. Thus, there is a need for a deep interdisciplinary analysis of the mechanisms, challenges, and strategies of international marketing in the context of virtual mobility, which is of significant scientific and practical value in the process of post-war economic recovery of Ukraine, development of innovative entrepreneurship, and formation of the state's digital sovereignty.

Analysis of recent research and publications

The analysis of scientific sources shows that the problem of virtual mobility in the context of international marketing is being actively studied by both Ukrainian and foreign scientists, advisory organizations, and professional associations. Thus, the work of I. Degtyareva highlights the theoretical foundations of virtual mobility of enterprises and outlines its importance in times of war as an adaptive mechanism for business functioning [1]. The reports of McKinsey & Company and the Ukrainian Digital Economy Association analyze the scale and trends of digital transformation in Central and Eastern Europe and Ukraine, which allows us to consider virtual mobility as a component of modern business models [2; 3]. The practical aspects of the implementation of the Diia.City digital ecosystem are covered in the materials of the Ministry of Digital Transformation and the Kyiv School of Economics, which emphasize the role of public policy in shaping the environment for IT companies and startups [4; 5]. Sources from Reuters, EBRD, and the World Bank Group provide analysis on the volume of foreign investment in Ukraine's telecommunications sector, which is critical to ensuring the technical basis for virtual mobility [6; 15; 16]. In the context of marketing adaptation in international markets, the works of H. Hollensen and D. Aaker, which substantiate the importance of cultural sensitivity and strategic positioning in the context of global competition [7; 9]. Also noteworthy is the statistical analytics of the Statista and Ookla platforms, which illustrates the dynamics of e-commerce development and the state of the communication infrastructure [8; 10]. Examples of the practical implementation of virtual mobility are demonstrated by the cases of Nova Poshta and Headway, which entered the EU and US markets thanks to digital strategies [11; 12]. Also important are data from Wikipedia sources on the Diia digital platform [13], OECD analytical reviews on the digital economy [14], the European Business Association's position on the effectiveness of international partnerships of Ukrainian companies [17], and marketing trends according to the HubSpot Research global report [18]. At the same time, the scientific discourse remains insufficiently developed in terms of the integration of virtual mobility into the international marketing system of Ukrainian companies in times of war, in particular: assessing the effectiveness of digital strategies for entering foreign markets, the role of state support in shaping competitive marketing models, and the prospects for sustainable development of virtual mobile business. These issues are the focus of this study.

Objectives of the article

The purpose of the article is to provide a scientific substantiation of the role of virtual mobility as a factor

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of effective implementation of international marketing of Ukrainian companies in the context of war and digital transformation.

Presenting main material

The concept of «virtual mobility» in the context of international marketing refers to the ability of companies to conduct commercial and marketing operations, regardless of physical location, through the use of digital technologies and online communications. This phenomenon has become especially relevant during the COVID-19 pandemic, and later during the full-scale war in Ukraine in 2022. According to economist I. Degtyareva, virtual mobility has allowed companies to remain competitive in international markets and minimize the cost of logistics and physical infrastructure [1]. According to a McKinsey study, more than 75% of businesses in Central and Eastern Europe have begun to actively implement digital platforms, which has enabled them to maintain operations in an unstable environment [2].

Russia's full-scale invasion of Ukraine in February 2022 had a significant impact on the business environment and forced Ukrainian companies to radically change their business strategies. With limited physical access to traditional markets, Ukrainian businesses have stepped up their use of digital channels, such as online platforms, social media, video conferencing, and cloud technologies. According to a study by the Ukrainian Association of the Digital Economy, the share of Ukrainian companies actively using digital marketing and remote work increased from 45% in 2021 to 83% in 2023 [3]. This allowed not only to maintain the companies' operations but also to ensure their international expansion, especially to the EU.

One of the key factors that ensured the rapid adaptation of Ukrainian companies to the conditions of virtual mobility was the government initiative Diia.City. Launched in 2022 by the Ministry of Digital Transformation of Ukraine, this legal ecosystem was created to promote the development of the IT sector and high-tech business. The initiative provides for a special legal regime with flexible forms of labor relations, tax benefits, and a simplified procedure for attracting foreign specialists. According to official data, as of December 2023, more than 760 companies have become Diia.City residents, including such well-known players as SoftServe, Genesis, Reface, and MacPaw, which indicates the high attractiveness and efficiency of this platform [4]. A study by the Kyiv School of Economics notes that Diia.City has reduced the fiscal burden and at the same time increased investment in the digital sector by 24% in 2022-2023 [5].

Another important factor in the digital transformation was the intensification of foreign investment in Ukraine's telecom infrastructure. In October 2024, the European Bank for Reconstruction and Development (EBRD), together with the International Finance Corporation (IFC), made the largest foreign direct investment since the beginning of the full-scale invasion - in the amount of USD 435 million - in a newly created telecommunications company formed as a result of the merger of mobile operators lifecell and Datagroup-Volia [6]. This step is aimed at strengthening the country's digital resilience, expanding access to high-speed Internet, and improving cybersecurity. Such a large-scale project allows Ukrainian businesses to ensure uninterrupted access to digital international marketing tools, including e-commerce platforms, CRM systems, online conferences, market analytics, etc.

Despite the significant benefits that virtual mobility provides to Ukrainian companies in the international market, its implementation is accompanied by a number of systemic challenges that need to be addressed comprehensively. Among the main barriers are the problems of cultural adaptation, increased competition, and technical limitations in times of war.

Cultural adaptation is a critical element of effective international marketing. Companies expanding into foreign markets have to take into account the linguistic, religious, socio-psychological and value differences of the target audience. According to the research of H. Hollensen, the success of transnational marketing campaigns depends on the ability to adapt content to the local cultural context by 80%. In the case of Ukrainian brands such as Rozetka or Liki24, adapting to the cultural expectations of consumers in Poland, Germany, and Romania has become a prerequisite for maintaining customer loyalty. In addition, the use of template approaches to promotion leads to a decrease in the effectiveness of advertising - for example, campaigns that worked well in Ukraine showed 2.5 times lower conversion rates in Eastern European countries [7].

Competition in international markets is intensifying due to the extremely high density of companies that already have established positions and strong marketing budgets. According to the Statista analytical platform (2024), more than 890 thousand active companies operate in the e-commerce sector in the EU market alone, of which approximately 30% are multinationals [8]. In such circumstances, Ukrainian companies that have moved their operating offices abroad (e.g., Grammarly, Ajax Systems) are forced to compete for consumer attention in the face of information overload. As D. Aaker in Strategic Market Management, only brands with a clearly differentiated value proposition have a chance to maintain their positions in the digital environment [9].

The technical restrictions caused by the war directly affect the quality of digital services, including internet speed, uninterrupted access to digital platforms, and data storage security. According to a report by Ookla (Speedtest Global Index), in 2022-2023, Ukraine recorded massive drops in mobile Internet speeds 12 times due to shelling of critical infrastructure, including Ukrtelecom and Kyivstar facilities. This created difficulties for companies that depend on a stable connection to cloud-based CRM systems, video communications, or e-commerce platforms. Despite the launch of Starlink, the instability of electricity supply in some regions continues to be a risk factor [10].

Despite the numerous challenges posed by the war and forced digital transformation, a number of Ukrainian companies have not only maintained their stability but also achieved significant success in international markets through virtual mobility, innovative marketing approaches, and strategic adaptation. The most prominent examples,

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such as Nova Poshta and Headway, illustrate how digital management models allow for integration into global markets even in times of war.

Nova Poshta, one of the largest logistics companies in Ukraine, has been actively implementing an international expansion strategy since the outbreak of full-scale war, focusing on the needs of the Ukrainian diaspora and cross-border e-commerce. Already in 2023, the company opened physical offices in Poland, Slovakia, Lithuania, the Czech Republic, Romania, Germany, France, Italy, Spain, and the United Kingdom. This allowed for door-to-door delivery within the European Union, minimizing dependence on national infrastructure. According to Forbes Ukraine, the volume of Nova Poshta's operations abroad grew by 61% during the year, which indicates an effective international marketing strategy based on multichannel communication, localized content, and a service approach to consumers [11]. Virtual tools for logistics management, tracking, and customer service have ensured a stable quality of service even under martial law in Ukraine.

Headway is a Ukrainian EdTech startup founded in 2019 that demonstrates a successful combination of artificial intelligence technologies and international marketing. In 2024, the company implemented personalized AI models in communication and advertising strategies, which allowed automating more than 70% of marketing activities in the mobile app. As stated in the official Headway press release (March 2024), after integrating AI tools, the company recorded a 40% increase in the efficiency of advertising campaigns and a 35% increase in user engagement [12]. Particular attention was paid to the global promotion of the product in the US, UK, the Netherlands, and Canada. Headway was included in the list of Top 100 Most Innovative Learning Platforms by EdTech Digest and won the GESAwards in the Global EdTech Startup of the Year category.

Given the extraordinary challenges posed by the war, support for the digital transformation of Ukrainian business by the state and international partners has become a crucial factor in maintaining economic stability and competitiveness on a global scale. The systematic involvement of government agencies and external institutions has helped create an environment conducive to virtual business mobility and effective integration into the international digital market.

The Ukrainian government's support for digital initiatives was manifested primarily in the large-scale implementation of the Diia digital services ecosystem. The platform, administered by the Ministry of Digital Transformation, has integrated more than 70 public services online, including business registration, obtaining documents, changing the individual entrepreneur status, etc. As of the beginning of 2024, more than 19 million Ukrainians use the Diia application, which confirms the high digital adaptability of society and business [13]. The program also contributed to the popularization of the state course on digitalization, which directly influenced the formation of a favorable climate for virtual marketing. According to the OECD Digital Economy Outlook, Ukraine ranked 11th among European countries in terms of the pace of e-Government services implementation [14].

Investments in telecommunications, in particular with the participation of international financial institutions, have become a critical source of support for Ukraine's digital infrastructure. In October 2024, the European Bank for Reconstruction and Development (EBRD), in partnership with the International Finance Corporation (IFC), made the largest foreign direct investment in Ukraine's digital sector since the beginning of the war - $435 million in a newly created telecommunications company that combined the resources of lifecell and Datagroup-Volia. The funds will be used to modernize fiber-optic communication lines, deploy secure data centers, improve cyber resilience, and scale up mobile coverage in rural areas. According to the EBRD Telecommunications Sector Strategy 2024-2028 report, such an infrastructure base ensures the technological autonomy of small and medium-sized businesses, especially in the field of international e-commerce, IT services, and marketing [15].

Conclusions

Summarizing the results of the study, it should be noted that virtual mobility is emerging not only as a response to the extraordinary circumstances of war, but also as a strategic direction for transforming the international marketing of Ukrainian companies. Its effective implementation requires a comprehensive approach that includes the modernization of digital infrastructure, the development of foreign economic cooperation, and the adaptation of marketing strategies to the global digital environment.

First, investing in digital infrastructure is a key condition for ensuring a stable presence of Ukrainian businesses in international markets. According to the World Bank Group, only 52% of Ukraine's territory has reliable fiber optic coverage, and more than 40% of small and medium-sized businesses face regular problems with network access, which limits the use of modern digital marketing and analytics tools [16]. In this context, the tasks of increasing network capacity, implementing secure data centers, maintaining energy autonomy, and developing domestic production of telecommunications technologies remain a priority.

Secondly, an important prerequisite for the effective integration of virtual mobile business into the global economy is the formation of sustainable international partnerships. According to the European Business Association, more than 60% of Ukrainian companies that have integrated into global business chains have experienced an increase in exports, and strategic alliances have reduced the cost of product promotion and distribution [17]. Further research should focus on assessing models of technology transfer and marketing innovation within such partnerships.

Thirdly, a promising area is the improvement of marketing strategies, taking into account cultural specifics and the dynamics of consumer priorities in different markets. The HubSpot Research report shows that the use of localized advertising approaches increases the conversion rate by an average of 72%, which makes it necessary to develop tools for behavioral analytics, personalization, and multichannel promotion [18]. Methodologies for evaluating

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the effectiveness of digital marketing interventions in the context of Ukrainian brands promoted during martial law require special attention.

Further research in this area should focus on formalizing models for integrating virtual mobility into the long-term marketing strategy of enterprises, identifying indicators of its effectiveness in a multi-level crisis, and developing public policy tools to support digital exports and the innovative activity of small and medium-sized businesses.

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PRINCIPLES OF SUSTAINABLE ECONOMIC DEVELOPMENT IN THE AGRICULTURAL LAND MARKET MANAGEMENT SYSTEM

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Key words:
sustainable economic development, land market management, agriculture, environmental security, social responsibility, land resources, food security, investment attractiveness.

Research on the principles of sustainable economic development within the framework of agricultural land market management.
The timeliness of the topic is determined, which is due to a set of modern issues, including the exacerbation of the ecological crisis, the instability of the agrarian sector, climate change, as well as the opening of the land market in Ukraine, which requires the formation of new effective regulatory mechanisms. It is substantiated that land resources are the basis of agricultural production, and their rational use is a core factor in ensuring food security, environmental preservation and sustainable economic growth. The authors propose their own definition of the land market. They have analyzed the evolution of the concept of sustainable development, in particular its interpretation in the works of Ukrainian and foreign scientists. Considerable attention is paid to the interdisciplinary approach, which involves the integration of economic, social and environmental factors into the system of land relations management and the basic principles of sustainable economic development in the system of land market management. Modern management tools are substantiated and generalized, including the implementation of digital technologies, such as geographic information systems (GIS), satellite monitoring, soil quality databases and other innovative solutions that make it possible to effectively control the condition of lands and predict the consequences of their use. International experience of sustainable land use in developed countries of the world is studied, specifically in Germany, France, Sweden, which have demonstrated a high level of effectiveness in the implementation of environmentally friendly practices in the agricultural sector. In Germany, digital cadastral systems, electronic document management and mechanisms of state support for ecological agriculture are extensively used. France has introduced the SAFER system (Sociétés d'aménagement foncier et d'établissement rural), which exercises control over the sale of agricultural land in order to prevent speculation and ensure its sustainable use. In Sweden, the increased focus is put to monitoring the condition of soils, restoration of degraded areas and integration of environmental standards into the land use planning system. These countries use a wide range of economic incentives: subsidies for farmers, tax remissions, grant programs for the implementation of innovative environmental technologies, and the development of the cooperative movement. Transparent land policy, an effective system of state supervision, public access to information on land resources, and active public participation in decision-making have become the guarantee to the stable functioning of the land market and ensuring environmental safety. Ways of adapting best practices to Ukrainian conditions are proposed based on the analysis of this experience with consideration to national characteristics, legal circumstances, the social structure of rural areas, and the current state of institutional support for land reform. Particularly, it is recommended to introduce electronic platforms for monitoring land transactions, improve mechanisms for state support for small and medium-sized farms, stimulate investments in soil restoration, expand access to cadastral information, and extend environmental education among the rural population. This approach will ensure a balanced combination of economic, social, and environmental purposes of sustainable development in the agricultural sector of Ukraine.

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ПРИНЦИПИ СТАЛОГО РОЗВИТКУ ЕКОНОМІКИ В СИСТЕМІ УПРАВЛІННЯ РИНКОМ ЗЕМЕЛЬ СІЛЬСЬКОГОСПОДАРСЬКОГО ПРИЗНАЧЕННЯ

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Ключові слова:
сталий розвиток економіки, управління ринком земель, сільське господарство, екологічна безпека, соціальна відповідальність, земельні ресурси, продовольча безпека, інвестиційна привабливість.

Дослідження принципів сталого розвитку економіки в контексті управління ринком земель сільськогосподарського призначення.
Визначено актуальність теми, яка зумовлена сукупністю сучасних викликів, серед яких – поглиблення екологічної кризи, нестабільність аграрного сектору, зміна клімату, а також відкриття ринку землі в Україні, що вимагає формування нових ефективних механізмів регулювання.
Обгрунтовано, що земельні ресурси є базисом аграрного виробництва, а їх раціональне використання – ключовим чинником забезпечення продовольчої безпеки, збереження навколишнього середовища та сталого економічного зростання. Запропановано авторське визначення сутності ринку землі. Проаналізовано еволюцію концепції сталого розвитку, зокрема її трактування у працях українських та зарубіжних учених. Значна увага приділена міждисциплінарному підходу, який передбачає інтеграцію економічних, соціальних та екологічних чинників у систему управління земельними відносинами та ключовим принципам сталого розвитку економіки в системі управління ринку землі. Згрунтовано та узагальнено сучасні інструменти управління, включаючи впровадження цифрових технологій, таких як геоінформаційні системи (GIS), супутниковий моніторинг, бази даних про якість ґрунтів та інші інноваційні рішення, які дозволяють здійснювати ефективний контроль за станом земель та прогнозувати наслідки їх використання. Досліджено міжнародний досвід сталого землекористування в розвинених країнах світу, зокрема у Німеччині, Франції, Швеції, які продемонстрували високий рівень ефективності впровадження екологічно дружніх практик в аграрному секторі. У Німеччині активно застосовуються цифрові кадастрові системи, електронний документообіг та механізми державної підтримки екологічного землеробства. Франція запровадила систему SAFER (Sociétés d'aménagement foncier et d'établissement rural), яка здійснює контроль за продажем сільськогосподарських земель з метою запобігання спекуляціям і забезпечення їх раціонального використання. У Швеції основна увага приділяється моніторингу стану ґрунтів, відновленню деградованих територій та інтеграції екологічних стандартів у систему планування землекористування. Зазначені країни використовують широкий спектр економічних стимулів: субсидії для фермерів, податкові пільги, грантові програми на впровадження інноваційних екологічних технологій, розвиток кооперативного руху. Прозора земельна політика, ефективна система державного нагляду, публічний доступ до інформації про земельні ресурси, а також активна участь громадськості у прийнятті рішень стали запорукою стабільного функціонування ринку земель і забезпечення екологічної безпеки.
На основі аналізу вказаного досвіду запропоновано шляхи адаптації найкращих практик до українських умов із врахуванням національних особливостей, правових реалій, соціальної структури сільських територій та поточного стану інституційного забезпечення земельної реформи. Зокрема, рекомендовано запровадити електронні платформи для моніторингу угод із землею, удосконалити механізми державної підтримки малих та середніх фермерських господарств, стимулювати інвестиції у відновлення ґрунтів, розширити доступ до кадастрової інформації та посилити екологічну освіту серед сільського населення. Такий підхід дозволить забезпечити збалансоване поєднання економічних, соціальних і екологічних цілей сталого розвитку в аграрному секторі України.

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The purpose of the study is to formulate the principles of sustainable development and substantiate the possibilities of their integration into the national system of agricultural land market management, which became the basis for improving legislation, developing state strategies, increasing the participation of local communities in management processes, increasing the transparency of land relations and introducing environmental standards of land use. This, in its turn, will contribute to a long-term balance between economic interests, social stability and environmental protection.

Problem statement

Under current conditions of socio-economic transformation and environmental challenges, the issue of effective management of the agricultural land market is becoming particularly topical. The opening of the land market in Ukraine, the exacerbation of the ecological crisis, soil degradation, climate change and social inequality in access to land resources require the formation of new approaches to the regulation of land relations. Traditional management models do not fully take into consideration the necessity to integrate economic, environmental and social aspects, which necessitates the implementation of the principles of sustainable development as a basis for the formation of a balanced and effective agricultural policy. It is also timely to study international experience in innovative land use mechanisms and the possibility of their adaptation to Ukrainian circumstances in an effort to ensure food security, preserve the environment and improve the quality of life of the rural population.

The issue of agricultural land market management is challenging for the moment and very important under the current conditions of economic and environmental crises. The use of sustainable development principles will increase the efficiency of land resource use without harming future generations and is of particular importance in the framework of opening the land market in Ukraine. In this context, it is important to consider Seventeen Sustainable Development Goals defined by the United Nations, which cover economic, social and environmental aspects, particularly, poverty reduction, ensuring food security, responsible use of natural resources, protection of ecosystems and promotion of sustainable economic growth. Their integration into land resource management policy will facilitate the formation of a balanced agricultural policy and sustainable development of rural areas.

Analysis of recent research and publications

The issue of sustainable economic development and effective land resource management remains in the focus of attention of both domestic and foreign scientists. The papers of Cherep A. V. are of significant scientific value. [1], who in its research consistently substantiates the necessity to integrate the principles of sustainable development into the system of financial and economic management, drawing attention to balancing economic, environmental and social factors. Her papers serve as a theoretical basis for further scientific research in the field of improving the institutional structure of the agricultural market, in particular under the conditions of the implementation of the agricultural land market in Ukraine.

Research by domestic scientists, including M. D. Bilyk [2], I. V. Prokop [3], I. V. Chukin [4], focuses on the analysis of the functioning of the land market, legal and economic aspects of the transfer of land titles, problems of institutional support and the need to improve land legislation. Foreign researchers, such as Alain de Janvry [5], Frank Place [6], Hans Binswanger-Mkhize [7], Klaus Deininger [8], Roy Prosterman [9], specifically from Germany, France, and Sweden, place special emphasis on the practical aspects of implementing environmentally friendly practices, the development of digital technologies (GIS, satellite monitoring), as well as the formation of public policy focused on the sustainable development of rural areas.

The timeliness of this trend is emphasized in the publications of such international organizations as OECD, FAO, World Bank, which accentuate the importance of transparency of land relations, effective management of natural resources and communities' participation in decision-making. For the purposes of these approaches, the experience of adapting global principles of sustainable development to national conditions, which is the subject matter of this article, is of special significance.

Findings. Sustainable development is defined as a holistic and continuous process of ensuring economic growth, improving the quality of life of the population, expanding opportunities for human self-realization under the condition of efficient utilization of natural resources, preserving ecological balance, biodiversity and the environment in the interests of both current and future generations. This approach involves the harmonization of economic, social and environmental goals, which is essential to the formation of a stable and responsible model of social development.

The main aspects include economic, environmental and social components, this is shown in Table 1. [10]

Table 1 – Core Aspects of Sustainable Development [developed by the authors]

Component of Sustainable Development	Key Goals	Main activities and areas
Economic	– Sustainable economic growth – Productivity improvement – Competitiveness	– Job creation – Entrepreneurship development – Infrastructure investment – Innovation and technology
Environmental	– Environmental protection – sustainable utilization of natural resources – Pollution reduction	– Energy efficient technologies – Ecosystem restoration – Emission reduction – Waste management
Social	– Social equality – Access to resources and services – Improving the quality of life	– Decent work – Education and health – Social dialogue – Community participation in decision-making

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The economic component of sustainable development is oriented toward achieving stable and long-term economic growth based on innovation, efficient resource management and entrepreneurship. It includes the creation of a favorable business environment, support for small and medium-sized enterprises, infrastructure development, investment in human capital, and the creation of new jobs. One of the basic tasks is to increase labor productivity and introduce technologies that contribute to resource conservation. Particular importance with this background is ensuring the competitiveness of the national economy in the global market while adhering to the principles of environmental and social responsibility is of [11].

The environmental component focuses on the preservation, protection and restoration of the natural environment for current and future generations. Its main tasks are the efficient use of land, water resources, minerals, forests, as well as the reduction of harmful emissions, the fight against soil degradation and climate change. An important trend is the introduction of environmentally safe, resource-saving and energy-efficient technologies in all sectors of the economy, particularly in agriculture, industry and transport. Modern management practice requires the integration of environmental criteria into the processes of planning, production and consumption, with due regard to international standards and obligations in the field of environmental protection.

The social component of sustainable development involves achieving social equality, fair distribution of benefits, ensuring access of the population to quality health care services, education, housing, potable water and infrastructure. The basic priorities are poverty overcoming, ensuring decent employment, reducing social inequality, and protecting vulnerable groups of the population. The close involvement of citizens in decision-making is of great importance, especially in matters related to the natural resources utilization and the development of local communities. The development of human potential, supporting an inclusive society and promoting social dialogue are important prerequisites for achieving sustainable development in general. It has been established that the principles of sustainable economic development in the land market management system were formed on the basis of key international documents, global challenges and theoretical concepts that combine environmental, economic and social aspects. Having studied Seventeen Sustainable Development Goals, we have generalized and grouped them according to key features – economic, social and environmental, which is visualized in Fig. 1.

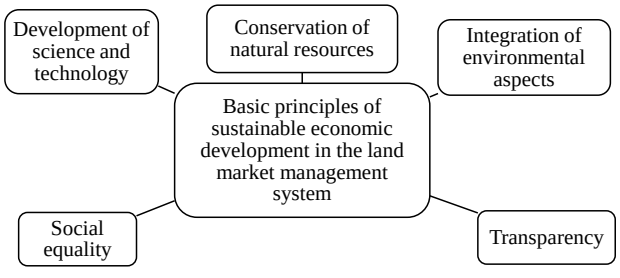

Fig. 1 – Basic principles of sustainable economic development in the land market management system [developed by the authors]

– conservation of natural resources: a key task of sustainable development is to ensure the long-term, balanced use of land, water, forest and other natural resources. This involves not only avoiding their depletion, but also introducing measures to restore and protect them. It is important to take into consideration the ecological capacity of territories in order to preserve the opportunities for life and management of future generations;

– integration of environmental aspects: environmental criteria should become an integral part of the process of making managerial and legislative decisions. In particular, when developing land utilization policy, it is necessary to assess the potential impact on the environment, biodiversity, climate stability and resilience of ecosystems. This approach makes it possible to avoid negative long-term consequences for the environment;

– social equality: achieving rightfulness in access to land resources is one of the priorities of sustainable development. This means creating conditions for equal participation of all segments of the population in land utilization, with particular attention to supporting small farmers, households and local communities. Ensuring social balance contributes to strengthening well-being, reducing inequality and conflicts in rural areas;

– transparency: openness and accessibility of information on land transactions, contracts, cadastral data and decision-making procedures are important elements of effective land management. Transparency enables to increase public trust in government institutions, reduces the risks of corruption and ensures compliance with the rights of all participants in land relations;

– development of science and technology: innovative approaches and modern scientific achievements are crucial for ensuring effective and environmentally balanced land utilization. Specifically, the widespread use of geographic information systems (GIS), remote sensing, digital modeling and analytical platforms makes it possible to accurately monitor the condition of lands, predict changes, and optimize their planning and use taking into consideration sustainable development.

We believe that the principles of sustainable development enable us to ensure a balance between economic requirements, environmental safety and social justice. In the framework of land resources, this means creating conditions for effective management, restoration of degraded areas and improving the quality of life of the population.

The land market is an important component of the economic system that ensures the redistribution of rights to use, own and dispose of land plots between business entities, the population and the state. It functions with the involvement of various institutions, including state bodies, financial institutions, private owners and tenants.

In the scientific literature, there are different approaches to interpreting the concept of “land market”. Thus, the Ukrainian economist Petrenko N. O. [4] defines the land market as “a set of economic and legal relations regarding the transfer of land titles according to market mechanisms”. I. V. Prokopa [3] considers it as a tool for forming an effective land utilization model that ensures

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the rational utilization of land resources. Meanwhile, I. V. Tadanik [15] emphasizes the functional role of the land market in stabilizing the agricultural sector and stimulating investment activity.

Taking into consideration current conditions in Ukraine, especially after the opening of the agricultural land market, it is important to form a integrated understanding of this phenomenon, which takes into consideration not only economic, but also social, legal and environmental aspects.

We consider it appropriate to define the essence of the "land market", and propose to further regard it as an institutionally regulated system of economic, legal and social relations, within which the transfer of ownership rights and land plots utilization is carried out on the basis of free competition, in an effort to ensure effective, fair and environmentally responsible system of land tenure.

After the opening of the land market in Ukraine, new regulatory mechanisms were introduced to ensure transparency, legality, and efficiency of land purchase and sale processes. However, this stage was accompanied by a number of challenges and problems that require a systemic solution [12].

Start with, the underdevelopment of financial instruments to support farmers makes it difficult for agricultural producers, especially small ones, to access financing for land purchases. The lack of flexible credit programs, land banks, or effective subsidies leads to the concentration of land in the hands of large agricultural holdings and deepens social inequality.

For another thing, the lack of data on the qualitative characteristics of land creates risks for investors and users who do not have complete information on the condition of soils, the level of fertility, the presence of pollution, or erosion processes. This reduces the efficiency of land utilization and complicates long-term planning of agricultural production.

In the third place, the lack of transparent mechanisms for monitoring transactions contributes to the shadowing of land market transactions, complicates state and public control, and generates distrust in institutions. The availability of informationless schemes, malpractices, and the lack of open access to cadastral information weakens the potential for sustainable development of land relations.

Therefore, despite positive developments, the implementation of the land market requires further institutional and technological improvements to achieve transparency, fairness, and environmental responsibility in land management. Currently, due to these problems, many agricultural lands remain unallocated or have an unregulated legal status. This complicates their circulation on the market and creates opportunities for corruption. It is worth noting that a significant share of land is concentrated in large agricultural holdings, which creates a risk of monopolization and influence on prices. Meantime, small farmers face limited access to finance and resources.

Increase in land value in some regions is supported by risks for low-income farmers to lose access to land resources. And according to statistics, more than 80% of land deals are concluded without a full assessment of the ecological condition of the soils. The availability of such gaps in the management system creates risks for long-term sustainable development.

Moreover, the process of introducing the land market is accompanied by problems of public awareness. Many farmers bump up against difficulties due to the complexity of the purchase and sale procedure, which may result in social tension in rural regions.

Having considered the current state of the land market in Ukraine and paying attention to the main problems, we face the following basic challenges, which are depicted in Fig. 2.

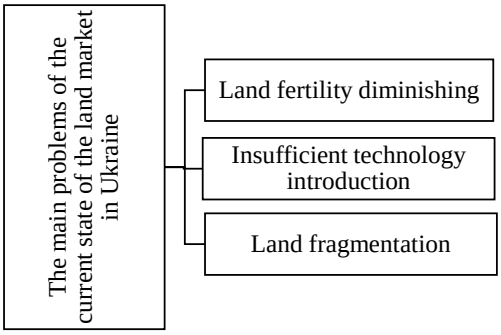

Fig. 2 – Main problems of the current state of the land market of Ukraine [developed by the authors]

– land fertility diminishing – intensive land utilization without observing crop rotation, the use of organic fertilizers and agro-ecological measures results in soil degradation. In many regions of Ukraine, up to 20% of yield is lost due to erosion, which threatens food security;

– insufficient technology introduction – the lack of modern monitoring systems, such as GIS, satellite data, remote sensing and digital cadaster, limits the possibilities of operational management and control over the soil condition;

– land fragmentation – the availability of small, scattered and plots of complex configuration complicates effective land utilization, increases logistics costs and makes it impossible to mechanize processes;

– low level of awareness of land share owners – lack of proper legal, economic and agrarian literacy among land owners creates risks of their undervalued utilization and contributes to fraud on behalf of disreputable tenants;

– imperfection of the legislative framework – numerous changes to land legislation, contradictions between laws and regulations, as well as the lack of accurate procedures complicate administration of law;

– corruption risks – bureaucratic hurdles and informal requirements when registering titles, agreeing boundaries and making changes to cadastral information create favorable conditions for malpractice;

– limited access to financing – farmers, especially small and medium-sized ones, do not have real access to profitable credit resources, which limits their involvement in the land market and the development of farms;

– nontransparency of market information – limited access to current data on prices, transaction volumes, land concentration and actual utilization leads to information asymmetry and market shadowing;

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– problems with registration of property rights – technical errors, lack of documents or incomplete registration procedures make it impossible for plots to fully participate in the market;

– regional inequality of the market development – different regions of Ukraine have significant differences in demand, prices, and activity of market participants, which results in economic imbalance and distortion of competition;

– failure to comply with the intended purpose of land – in many cases, agricultural land is used for other needs, which contradicts environmental standards and reduces the effectiveness of control;

– problems with the functioning of the State Land Cadaster – the availability of errors, duplications, missing or incorrect records creates difficulties in the process of registering titles and causes legal conflicts;

– low interest in long-term use of land – orientation towards short-term benefits on the part of tenants reduces motivation to invest in sustainable development, maintaining fertility, and modernizing production;

These challenges are directly related to the deterioration of climatic conditions, such as the increase in average temperature and drought, which significantly affect soil fertility. Excessive use of chemical fertilizers and the lack of crop rotation worsen soil quality. This causes a decrease in yield and an increase in the cost of growing crops.

It is also important to note that Ukraine faces the problem of unauthorized utilization of land, which reduces the overall level of market transparency and trust in its institutions.

The experience of EU countries shows us the importance of state support through subsidies, as well as the creation of cooperatives to reduce farmers' expenditures. For example, in Germany, electronic document management systems are effectively used to increase the transparency of transactions.

France has introduced the SAFER system, which controls land sales to ensure their efficient utilization and avoid speculative activity. Sweden uses land utilization control systems with an emphasis on the restoration of degraded areas.

In countries such as Poland and Lithuania, governments actively support farmers through subsidies for sustainable development. These programs include financing organic farming and measures to prevent land degradation.

In its turn, the Netherlands uses digital cadastral systems that allow integrating satellite data to monitor soil conditions and process land utilization applications.

Analyzing international experience in regulating the land market, we consider it necessary not to forget that EU countries also have quite a few problems in this area. However, they demonstrate a fairly significant breakthrough in innovations, reforms, and a high level of state support, which may set the pattern for Ukraine [13].

Considering the findings of the analysis of land market management and the problems associated with it, we consider it appropriate to study the integration of sustainable development principles by introducing economic instruments that will be an important step in stimulating the sustainable utilization of land resources. Such instruments include:

– tax incentives for farmers who implement environmentally sound practices, in particular organic farming;

– grants and subsidies for the implementation of innovative technologies, such as precision agriculture;

– state support for cooperatives that ensure the far-sighted use of resources [14].

A positive example is the creation of environmental investment funds that appropriate resources to projects to preserve soil and increase productivity. This approach reduces the burden on farmers and will stimulate innovations.

Far-sighted utilization of land resources under the conditions of the functioning of the land market is a fundamental condition for ensuring stable economic growth, increasing the productivity of the agricultural sector and strengthening the country's food security. It provides not only for environmentally sound land utilization, but also for the economic appropriateness and investment attractiveness of the territories. The main areas that have a direct impact on the economy include:

– restoration of degraded lands by attracting capital to reclamation projects allows returning to economic circulation significant areas that were previously unutilized or provided minimal income. This creates new opportunities for expanding agricultural production and increasing rental potential.

– prevention of soil erosion and maintenance of its fertility directly affect the economic effective output from land. The introduction of effective crop rotations, minimum tillage and agrotechnical measures allows increasing yields and reducing expenditures for soil restoration;

– replacing chemical fertilizers with organic ones may reduce the cost of agricultural production in the long term, as well as increase the competitiveness of products in the organic agricultural market, which has a higher added value;

– the use of cover crops and green manure crops helps reduce dependence on imported fertilizers, reduces expenditures for plant protection, improves soil quality and, accordingly, increases the economic efficiency of crop cultivation [15];

– investments in digital technologies and precision agriculture (in particular, GPS monitoring, GIS systems, satellite observation) provide expenditures optimization, increased cultivation accuracy, control over resource utilization and increased profitability of enterprises;

– optimization of the land utilization structure through the consolidation of small plots contributes to reducing transaction expenditures, increasing the capitalization of land assets, more effective management of production and logistics;

– water management in agricultural production enables reducing irrigation expenditures, increasing crop resistance to droughts and ensuring the stability of profits even in risky climatic conditions;

– formation of long-term land value through the implementation of land utilization quality standards

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ensures an increase in the market value of land plots, enhances their investment attractiveness and promotes the development of mortgage lending in the agricultural sector;

– reduction of shadowing of land turnover through the implementation of transparent monitoring tools (electronic cadaster, public registers, digital platforms for concluding transactions) enables increasing budget revenues and reducing economic losses from illegal operations;

– increase of the efficiency of agricultural production through a systematic approach to system of land tenure stimulates the creation of added value, the development of agricultural exports, increasing employment in rural areas and strengthening local budgets through tax revenues.

Satellite monitoring systems used in many countries of the world make it possible to effectively assess the state of land on a real-time basis. Therefore, close cooperation with these countries, or an innovative leap that will result in the introduction of such technologies in Ukraine, may significantly improve control over the state of land resources.

Let us consider the social aspects of sustainable development, which are an integral part of successful land market management. The main directions include:

– conducting educational campaigns for the population on the importance of sustainable land utilization.

– ensuring transparency of land transactions through open electronic platforms.

– creating support programs for young farmers who seek to be engaged in ecological agriculture.

It has been established that an important element is the involvement of local communities in the processes of planning and implementing sustainable land utilization projects. This approach ensures public trust in reforms and contributes to increasing social cohesion [16].

Another important element is to stimulate public initiatives aimed at preserving natural resources and raising environmental awareness. Involvement of private companies and non-governmental organizations in joint sustainable development projects will also contribute to strengthening socio-economic stability.

Conclusions

The study has shown that the integration of economic, environmental and social approaches is a basic factor in achieving balanced and sustainable development of the land market in Ukraine. Effective land management is impossible without systematic consideration of the relationship between economic efficiency, environmental safety and social responsibility. Specifically, the implementation of modern digital technologies for monitoring and assessing the state of land (including GIS systems, satellite sensing and analytical platforms) is of paramount importance, which enables ensuring transparency, control and adaptability in land utilization processes.

Special attention should be paid to creating a favorable environment for financial support of small and medium-sized agricultural producers. Providing affordable loans, developing a land banking system, introducing crop insurance mechanisms, and other financial instruments will help reduce socio-economic inequality and increase the investment attractiveness of the agricultural sector.

The development of social responsibility in the field of land utilization is no less important – the point is the involvement of local communities in the decision-making process, openness of land policy, consideration of the interests of vulnerable groups of the population. Against this background, environmental education programs, information campaigns and the formation of a culture of responsible attitude to natural resources among the population become significant.

The study has also confirmed the importance of international cooperation aimed at exchanging experience and adapting the best global practices in the field of land market regulation. The introduction of innovative solutions, in particular precision agriculture, intelligent land utilization planning and monitoring using high-tech tools, may significantly increase the effectiveness of management decisions at the national and local levels.

Therefore, sustainable development of the land market is possible only under the condition of an integrated approach that combines economic feasibility, environmental balance and social orientation. The guidelines and recommendations proposed in the article are aimed at increasing the efficiency and transparency of land relations, preserving soil fertility, supporting farms, and expanding community involvement in policymaking. Their implementation will provide conditions for a long-term positive impact on the agricultural economy, the environment, and the well-being of Ukrainian citizens.

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FINANCE AND MONEY TURNOVER

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GLOBAL EXPERIENCE OF USING CRYPTOCURRENCIES AS A FINANCIAL INSTRUMENT IN AGRICULTURE

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Key words:
blockchain, cryptocurrency, agribusiness, agriculture, agro-startup.

This article explores the integration of cryptocurrencies into the global agribusiness sector, positioning them as a new financial instrument. The study examines the main advantages of cryptocurrencies in agriculture, including the simplification of financial operations, reduction of transaction costs, increased transparency in supply chains, and access to alternative sources of financing. Based on the analysis of international cases, the research reviews key projects and platforms implementing blockchain solutions in the agricultural sector. Special attention is given to the challenges and risks associated with cryptocurrency adoption, such as regulatory restrictions, the volatility of digital assets, and the need for technological adaptation within agricultural operations. The study provides an assessment of the potential of cryptocurrencies in agricultural financial systems and offers recommendations for their effective implementation. The stages of cryptocurrency development and their adaptation within the agricultural sector are analyzed. The main areas of digital currency application in agriculture are identified, including financing of farming enterprises through crowdfunding platforms, conducting international settlements for agricultural products, crop insurance, and optimization of logistics chains. Particular attention is devoted to examining regulatory approaches to the implementation of cryptocurrencies in the agricultural sector and analyzing risks related to market volatility, cybersecurity threats, and legal uncertainty. The international experience of digital technology integration into the agricultural sector, along with the challenges and prospects for the integration of cryptocurrencies into agri-financial systems, is explored. The article emphasizes the importance of developing state policies that stimulate innovation in agriculture and ensure the financial stability of farming enterprises. It concludes that the use of cryptocurrencies in the agricultural sector holds significant potential for improving access to financing, enhancing transaction transparency, and increasing agricultural production efficiency.

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СВІТОВИЙ ДОСВІД ВИКОРИСТАННЯ КРИПТОВАЛЮТ ЯК ФІНАНСОВОГО ІНСТРУМЕНТУ В СІЛЬСЬКОМУ ГОСПОДАРСТВІ

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Ключові слова:
блокчейн, криптовалюта, агробізнес, сільське господарство, агро-стартап.

У цій статті досліджується інтеграція криптовалют у світовий агробізнес, позиціонуючи їх як новий фінансовий інструмент. У дослідженні розглядаються основні переваги криптовалют у сільському господарстві, включаючи спрощення фінансових операцій, зниження транзакційних витрат, підвищення прозорості ланцюгів поставок і доступ до альтернативних джерел фінансування. Спираючись на аналіз міжнародних кейсів, у дослідженні розглядаються ключові проекти та платформи, які впроваджують блокчейн-рішення в аграрному секторі. Особливу увагу приділено викликам і ризикам, пов'язаним із впровадженням криптовалют, таким як регуляторні обмеження, волатильність цифрових активів і необхідність технологічної адаптації в рамках сільськогосподарських операцій. Дослідження надає оцінку потенціалу криптовалют у фінансових системах сільського господарства та рекомендаціями щодо їх ефективного впровадження. Проаналізовано етапи розвитку криптовалют та їх адаптацію в аграрному секторі. Визначено основні напрями застосування цифрових валют у сільському господарстві, зокрема фінансування фермерських господарств через краудфандингові платформи, здійснення міжнародних розрахунків за сільськогосподарську продукцію, страхування врожаїв та оптимізацію логістичних ланцюгів. Окрему увагу приділено вивченню регуляторних підходів до впровадження криптовалют у аграрному секторі, аналізу ризиків, пов'язаних з волатильністю ринку, кіберзагрозами та правовою невизначеністю. Досліджено міжнародний досвід, який активно впроваджується через цифрові технології в аграрну галузь, а також проблеми і перспективи інтеграції криптовалют в аграрні фінансові системи. В статті підкреслюється важливість розвитку державної політики, яка стимулює впровадження інновацій у сільському господарстві та забезпечує фінансову стабільність фермерських господарств. Зроблено висновок про те, що використання криптовалют в агросекторі має значний потенціал для підвищення доступу до фінансування, прозорості операцій та підвищення ефективності аграрного виробництва.

Statement of the problem

Agriculture is a cornerstone of the global economy, playing a vital role in ensuring food security and promoting societal resilience. However, the sector faces numerous challenges, including access to financing, supply chain opacity, and significant reliance on traditional financial instruments. Against this backdrop, the use of cryptocurrencies as a financial instrument in the agricultural sector is gaining increasing popularity.

Blockchain technology and cryptocurrencies open up new opportunities for agribusiness by facilitating rapid transactions, reducing financial operating costs, and increasing the transparency of market participants' interactions. They also contribute to farmers' access to alternative sources of financing, in particular through decentralized finance (DeFi) platforms, crowdfunding, and asset tokenization. An analysis of global experience in integrating cryptocurrencies into agriculture allows for the identification of key advantages, challenges, and prospects for the development of this financial technology. The article examines current practices of cryptocurrency use in various countries, their impact on agricultural production efficiency, and the risks associated with their implementation. Special attention is paid to regulatory issues, adaptation of agricultural businesses to new technologies, and future trends in the digital transformation of the agricultural sector.

Analysis of recent studied publications

In modern scientific literature and reports of international organizations, considerable attention is paid to the implementation of blockchain technology and cryptocurrencies in agriculture. Studies show that the use of cryptocurrencies contributes to reducing transaction costs, increasing transparency in the supply chains of agricultural products, and expanding farmers' access to financial resources. Among the main authors who have dedicated their time to studying cryptocurrencies in general and in specific sectors of the economy are: Kunishnikova O. (cryptocurrency as a financial market instrument), Bezverkhyi K. (the essence of cryptocurrencies), Ryadinska V. (financial and legal analysis of cryptocurrencies), Dyachuk M., Oginok S. (risks and opportunities of cryptocurrencies), Mazur V. (use of cryptocurrency as a financial instrument). Among foreign experts, the works of the following authors were studied: Kumar K., Lahza H.

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(cluster-based agriculture using blockchain), Bhat S., Huang N. (development of precision agriculture through artificial intelligence and big data), Sivaganesan D. (smart farming through blockchain technologies), and Neeta M., Sushila Sh. (use of cryptocurrencies in agriculture).

Research by AgriDigital demonstrates the effectiveness of blockchain solutions in grain logistics, while GrainChain offers smart contracts for automating settlements in the farming business. Other studies emphasize risks such as cryptocurrency volatility, regulatory restrictions, and technological barriers to implementation in agricultural practices..

Objectives of the article

Is to examine the global experience of using cryptocurrencies as a financial instrument in agriculture, to determine their impact on the financial stability of agribusiness, and to assess the prospects for their implementation in the context of the digital transformation of the agricultural sector. The goal of the study is to analyze the advantages, limitations, and potential risks of cryptocurrency application in agribusiness, as well as to develop recommendations for the effective integration of these technologies into the financial system of agricultural enterprises in Ukraine, based on global experience.

The main material of the research

Despite the significant spread of crypto technologies across various industries, they remain relatively new to most users. The foundation for introducing cryptocurrencies and blockchain technologies is the digital literacy of potential beneficiaries in this field. According to the general economic approach, cryptocurrencies are decentralized digital (virtual) assets, also referred to as "currency," protected by cryptographic methods (mathematical methods ensuring confidentiality). Kuvshinnikova O. defines cryptocurrency as a public digital asset created using cryptography to ensure transaction confidentiality and control over the issuance of virtual units [1].

The key functional features of cryptocurrencies are their anonymity and lack of regulation by state authorities. At the same time, this anonymity has attracted interest from regulatory bodies worldwide, as cryptocurrencies are unfortunately known for their potential to evade taxes and mandatory fees, be invested in dubious projects, and sometimes even finance terrorist groups. Similar to more conservative financial instruments, cryptocurrencies face the problem of high volatility in the digital asset market and dependence on global financial and trade policies. The creation of cryptocurrency is not subordinated to any state or government authority, since the principle behind the creation of these virtual currencies lies in the operation of a system known as "blockchain" (from English – "a chain of blocks") [2]. Interestingly, the name "blockchain" itself immediately reflects the principle of its operation: distributed across thousands of points around the world (the so-called "nodes"), the system looks like a long chain with computing machines – “miners” – connected to it, whose task, via electronic calculations, is to process existing blocks and write new ones. The data is thus represented in the system only once, i.e., as a unique entry, which automatically prevents duplication and protects it from forgery. An additional advantage of the blockchain system is equal access for all its participants, with the ability to validate data. It is appropriate to analyze the schematic principle of a cryptocurrency transaction through the lens of the blockchain system’s operation (Fig. 1).

Thus, the following conclusion can be drawn: the main advantages of cryptocurrencies are their security, decentralization, transaction irreversibility, and the ability to operate without intermediaries, based on the peer-to-peer (P2P) principle.

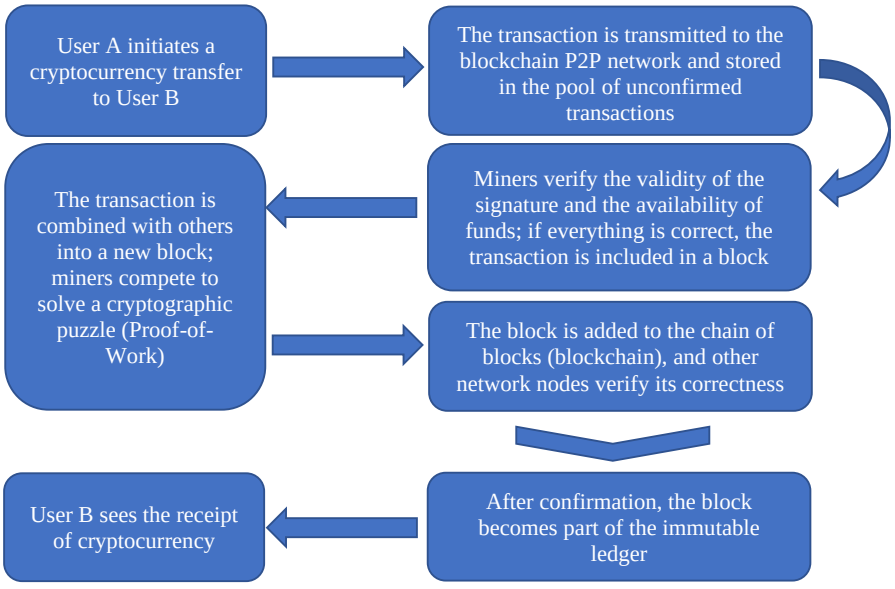

Fig. 1. – Cryptocurrency Transaction System in the Blockchain (created by the authors)

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The aforementioned approaches, specifically their economic advantages, have found application in various sectors of product manufacturing and service provision, mainly in the IT sector. However, in our opinion, given such a secure, transparent, and advanced system of data exchange and storage, limiting blockchain and cryptocurrency transactions solely to the digital sphere is a waste of their high potential.

One of the most stable and conservative branches of the economy has been and remains agriculture. Global experience in the use of cryptocurrencies in agriculture (and the agro-industrial complex in general) shows that there is demand for revolutionary approaches to attracting financial instruments, and that this demand is actively developing. Entrepreneurs seek to automate production and trade processes, as well as to conclude more transparent and fair transactions.

If we turn to the statistical indicators of the capitalization of the sustainable agricultural market that utilizes blockchain technology and actively employs cryptocurrency transactions in its operations, we can observe that in 2023 the global blockchain market in sustainable agriculture was valued at $188.90 million. It is expected to reach $294.97 million by 2031, with a compound annual growth rate (CAGR) of 5.9% during the forecast period (Figure 2) [3].

Given this data and the growth rate of market capitalization, we can conclude that the driving factors behind such indicators include the growing demand for transparent and traceable supply chains, the desire to reduce operational costs, and the increasing investment in agricultural startups worldwide.

Among the main drawbacks and "barriers" to conducting agricultural activities on the blockchain are, of course, the high entry threshold for the average farmer or producer, the cost of implementing blockchain technologies, and transitioning to cryptocurrency-based payments.

A significant challenge for those seeking to shift their agricultural business to cryptocurrency transactions and smart contracts is the dependency of producers on existing digital literacy skills and the geographical location of farms and production facilities, especially considering the availability of high-speed digital telecommunications in remote rural areas.

Over the past ten years, there has been a significant growth in the world of crypto assets – from a niche financial instrument to a massive global market. Bitcoin and Ethereum are vivid examples of digital currencies that represent the revolution of decentralization in finance, radically transforming key concepts related to transactions, value protection, and the engagement of economic players.

These digital currencies are based on blockchain technology, which ensures decentralization, enhanced transparency, immutability of data, and security. The existence of cryptocurrencies on financial markets is now undeniable; however, the range of opportunities that this technology offers is far broader. According to researcher Kumar K. R., rural enterprises powered by blockchain combined with intelligent systems can bring significant benefits and also reshape how governments manage rural territories [4].

Despite the key role agriculture plays in food security, the rural economy remains one of the least developed sectors in the global economic system. A strong infrastructure, a large base of smallholder farms, and access

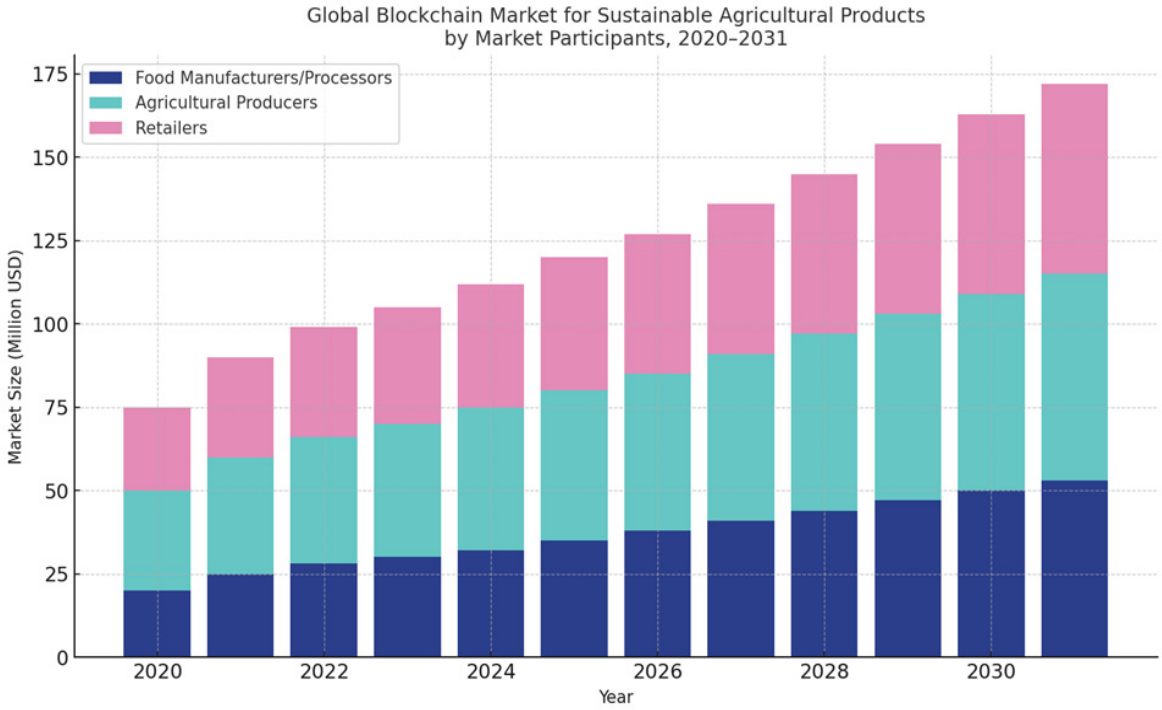

Fig. 2. – Global blockchain market for sustainable agricultural products by market participants, 2020–2031 (based on [3])

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to financial assets – in combination with technological advancement – complement each other in enhancing digital capacities within the innovation sphere. These factors also hold the potential for large-scale transformations [4].

Blockchain, digital tokens, the Internet of Things (IoT), and the progressive development of artificial intelligence (AI) are all examples of tools that can support the advancement of rural economies.

A key component in the development of blockchain technologies may be the chain-based structural approach. The majority of the global population is unable to fully verify the variety of products they purchase. This creates uncertainty, especially in cases of organic products, compliance with environmental regulations, and decision-making processes.

The use of blockchain technology allows for the creation of a permanent, open ledger (a connected chain of records) that covers all stages of production – from farm to retail [4]. Every step – from harvest dates, storage conditions, transportation methods, certification procedures – can be recorded on the blockchain and made accessible for verification by all interested parties.

This fosters mutual trust among all participants in the supply chain: from farmers to postal workers, distributors, and business partners in general. Moreover, it significantly reduces the risk of fraud or manipulation by unscrupulous market players. Farmers thus go beyond traditional ethical standards while remaining competitive in the market [5].

A core feature of the cryptocurrency system is smart contracts – computer programs programmed to autonomously manage transactions linked to corresponding legal actions by new parties [5, 8]. For example, after signing a contract between a farmer and a postal service provider, the parties can agree on a deferred payment that occurs only after the receipt of goods is confirmed. A smart contract formalizes this agreement without human intervention, and the payment is automatically executed once all terms are fulfilled. This system reduces the role of intermediaries, simplifies transaction processes, and lowers the risk of breach of contract or misconduct.

Such contracts can be useful not only for financial operations but also for risk management. For instance, insurance payouts to farmers can be tied to meteorological data from weather stations or sensors (using Internet of Things – IoT technology) [5, 7]. Upon submitting a claim, the smart contract automatically initiates an insurance payout without the need for additional claim verification.

Technological advancements in systems based on the Internet of Things are increasingly transforming the agricultural sector. Sensors can track a wide range of variables, such as air temperature, soil moisture, air humidity, crop growth rates, and even sunflower activity.

All of this data can be easily entered into the blockchain, ensuring its preservation, analysis, and use in decision-making processes [5, 7].

For example, artificial intelligence-based algorithms driven by this data can:

- determine the optimal time for sowing or harvesting;
- signal the need for intervention or irrigation;
- detect risks or plant diseases.

This process allows for the efficient use of resources, reduces losses, increases productivity, and mitigates the negative impact on profits.

The use of cryptocurrencies and blockchain in the agro-industrial sector contributes to environmental sustainability. Through efficient monitoring and automation, farmers can maximize water use efficiency, ensure healthy yields, and save energy. This not only helps minimize waste but also conserves natural resources, reduces greenhouse gas emissions, and prevents pollution of soil and aquatic ecosystems.

Additionally, there is significant potential for implementing incentive schemes. For example, farmers who support sustainable agricultural technologies – such as crop rotation, organic farming, and lawful use of chemicals – may receive rewards from local authorities in the form of tokens or cryptocurrencies [5]. If implemented, this trend creates substantial added value in the agricultural sector, promoting the development of sustainable production.

One of the main obstacles faced by farmers, especially in developing countries, is limited access to financial services. Banks are often reluctant to lend to small agricultural enterprises due to high risks and lack of collateral. In this context, decentralized finance (DeFi) platforms based on blockchain may become a viable alternative to traditional banking systems [6].

Agricultural producers can receive loans, insurance, and investments without intermediaries. It is expected that data about their activities – yields, contracts, environmental responsibility – recorded in a blockchain-based digital portfolio, will improve their creditworthiness.

Overall, the aforementioned areas of crypto-economy development are transforming its internal nature, which has made it vulnerable to marginalization within the traditional financial system due to the internal unpreparedness of economic actors to adopt new and more rational rules of the game.

Another advantage of cryptocurrencies is their ability to facilitate access to international markets. Small-scale farmers have faced numerous difficulties when trying to enter global markets due to intermediaries, high transaction fees, and complicated logistics [7, 8]. Cryptocurrencies allow such farmers to receive payments directly from consumers around the world with minimal fees and high liquidity. This contributes to the growth of the local economy, the farmer's income, stimulates employment, and increases the level of innovation.

Despite its enormous potential, the development of cryptocurrencies in rural areas is accompanied by a number of challenges:

- A significant portion of rural territories lacks permanent access to the Internet, complicating the implementation of digital technologies.
- Most farmers lack sufficient knowledge about cryptocurrencies, blockchain, or IoT, which slows the adoption of new technologies.
- The protection of data and digital assets is critically important to building trust in new systems.
- The crypto economy has medium-level legal recognition, but only in developed countries, which still complicates its use in official business operations [8].

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All of this requires the involvement of the private sector, the state, and the international community. Investment is needed in infrastructure, educational projects, the development of regulatory systems, and support for innovative initiatives.

Conclusions

The integration of blockchain and cryptocurrencies into rural communities represents a unique opportunity to transform these vital components. Enhanced awareness, operational efficiency, sustainability, access to finance, and automation of procedures have the potential to significantly improve the functioning of the rural economy while ensuring environmental sustainability and resilience of the agricultural sector itself.

Research into overcoming the barriers shows that the advantages far outweigh the risks. The future development of agriculture depends on the proper implementation of innovative principles, where cryptocurrencies will play a key role.

The future of rural entrepreneurship is not only in traditional agriculture, but also in smart contracts, the development and accumulation of personal crypto-assets for proper investment in one's own enterprise, decentralized financial structures, and a global virtual network based on trust.

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BANKING SYSTEMS OF UKRAINE AND POLAND: A COMPARATIVE ANALYSIS ON THE PATH TO THE EUROPEAN UNION

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Key words:
banking system, NBU, NBP, financial sector, economic policy, stress testing, assets, stability.

To improve the solvency and liquidity of banks and to respond promptly to contemporary realities, there is a constant need to identify effective methods for regulating and supervising Ukraine's banking system. Since the banking systems of Ukraine and Poland demonstrate both similar and somewhat different approaches to the development of financial institutions, Poland's experience may be of interest to Ukrainian banking institutions. Each country independently forms its banking system, relying on its beliefs, historical experience, and economic and political development conditions. Comparing the banking systems of different countries allows for an understanding of strengths and weaknesses, identification of differences in regulatory approaches, definition of areas of responsibility for stakeholders, and evaluation of the effectiveness of such solutions (approaches). Despite differences in the functioning of central banks and regulatory mechanisms, both systems share common goals: supporting the stability of the banking sector and fostering economic development while considering heightened risks of political and military instability.

БАНКІВСЬКІ СИСТЕМИ УКРАЇНИ ТА ПОЛЬЩІ: ПОРІВНЯЛЬНА ХАРАКТЕРИСТИКА НА ШЛЯХУ ДО ЄВРОПЕЙСЬКОГО СОЮЗУ

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Ключові слова:
банківська система, НБУ, NBP, фінансовий сектор, економічна політика, стрес-тестування, активи, стабільність.

З метою покращення платоспроможності, ліквідності банків та вчасного реагування на реалії часу постійно виникає необхідність виявлення дієвих методів регулювання та нагляду за банківською системою України. Оскільки банківські системи України та Польщі демонструють як схожі, так і дещо відмінні підходи до розвитку фінансових інституцій, досвід Польщі може бути цікавим для українських банківських установ. Кожна країна самостійно формує банківську систему, спираючись на власні переконання, історичний досвід, економічні та політичні умови розвитку. Порівняння банківських систем різних країн дозволяє зрозуміти сильні та слабкі сторони, виявити відмінності у підходах до регулювання, визначити зони відповідальності сторін та оцінити ефективність функціонування таких рішень (підходів). Попри відмінності у функціонуванні центральних банків та регуляторних механізмах, обидві системи мають спільні цілі – підтримку стабільності банківського сектору та розвиток економіки зважаючи на посилені ризики політичної та військової нестабільності.

Statement of the problem

In the modern world, an increasing number of processes require enhanced analysis, control, and supervision, especially in the economic sphere, where such processes impact the stability of the state. One of the main components of the financial system is the banking sector. It ensures the flow of capital, has the capacity to support businesses, and maintains economic resilience.

Considering this, neighboring countries such as Poland and Ukraine provide interesting examples for comparative analysis, as they exhibit several similarities and some differences in the development of their banking systems.

Analysis of recent studies and publications

Research on the stability of Ukraine's banking system is a popular topic, leading to a continuous increase in the number of scholars exploring this issue. Notable among

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them are O. Dzyublyuk [1], A. Moroz [2], M. Krupka, Ye. Andrushchak [3], I. Dzyuba [4], N. Sytnyk [5], B. Lutsiv, M. Savluk, B. Adamyk, I. Ivanets, M. Shchepansky, M. Khmeliarchuk, T. Hirchenko, O. Serdyukova, N. Hongalo, Y. Prytsak, O. Vinnytska, L. Chvertko, and others.

Objectives of the article

The purpose of this article is to describe the structure and status of the banking systems of Poland and Ukraine, their dynamics, and responses to political and economic challenges over recent years. It also aims to review regulatory bodies and attempt a comparison of the results of stress tests conducted in these countries, which are currently available in the public domain.

The main material of the research

The efficiency of financial institutions is one of the key components for maintaining the stability of a state's economic framework. As mentioned earlier, the state oversees numerous spheres, one of which is the financial system. Within its structure, banks and their "lifespan" occupy a special place. Therefore, to better understand the topic, it is essential to delve into the essence of the banking system.

The website of the Encyclopedia of Modern Ukraine defines the concept of a banking system as: "...a set of various types of banks and banking institutions in their interconnection, functioning within the territory of Ukraine" [4]. A similar but more detailed definition is provided in the textbook on the banking system by N.S. Sytnyk, which states that it is: "...a legislatively defined, clearly structured, and subordinated set of financial intermediaries that engage in banking activities on a permanent professional basis and are functionally interconnected into an independent economic structure" [5].

Turning to the perspective of Polish online communities, some describe this system as a complex (a holistic entity) of banking institutions along with the standards that define their mutual relationships and interactions with the environment [6]; others define it as a logical and coherent whole, created by the banking and financial institutions of a particular country and governed by its norms [7]. Thus, summarizing the above, the banking system includes all banking institutions present in a country with legalized operational confirmation, operating according to the standards applicable within that territory.

There are concepts of one-tier, two-tier, and three-tier banking systems. According to the legislation of both Poland and Ukraine, their structures can be attributed to a two-tier system with a clear distinction between the tasks of the central bank, which performs only specific functions in accordance with the monetary policy, and those of independent operational banks that operate on commercial principles. This system significantly differs from a one-tier structure characteristic of a centralized economy and from a three-tier structure, where a third tier is allocated for non-banking financial institutions (credit, financial, insurance, investment companies, etc.).

Referring to official sources, Article 4 of the Law of Ukraine "On Banks and Banking Activities" mentions the levels of the system, stating: "The banking system of Ukraine consists of the National Bank of Ukraine and other banks, as well as branches of foreign banks established and operating within the territory of Ukraine in accordance with the provisions of this Law and other laws of Ukraine" [8].

The first tier is the National Bank of Ukraine (NBU), which carries out regulation and banking supervision through prudential norms and regulatory and legal support for banking operations.

In Ukraine, banks can independently determine their areas of activity and specialization. The NBU has the authority to define the types and procedures for a bank to acquire the status of a specialized bank; however, there are currently no narrowly specialized banks.

The banking system of Ukraine includes several systemically important banks, comprising both state-owned and commercial banks. The NBU determines the list of such banks based on factors such as the size of the bank, the degree of financial interconnections, and areas of activity.

Similarly, the structure of the banking system in Poland is also two-tiered but has its own features enshrined in legislation and adapted to European Union standards. According to sources, the system is often further divided into three groups of institutions: stabilizing, market-forming, and auxiliary (Fig. 2).

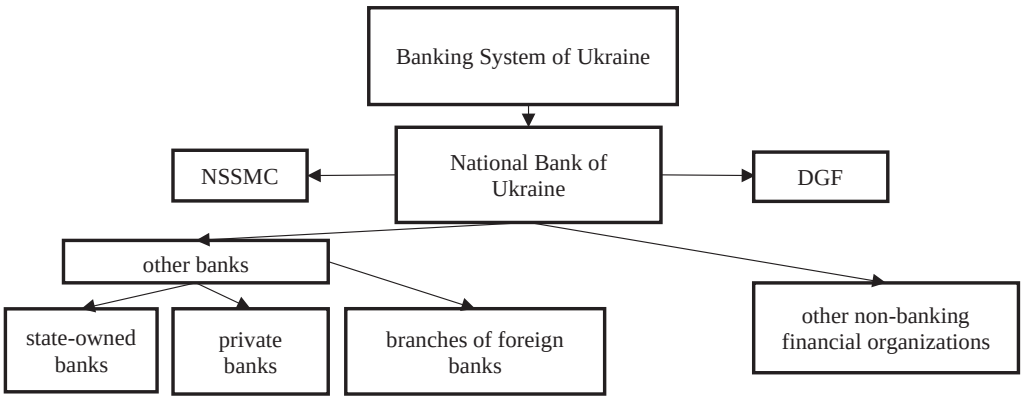

Fig. 1. – Diagram of Ukraine's Banking System [2]

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The first, stabilizing component includes: Narodowy Bank Polski (National Bank of Poland, NBP), Komisja Nadzoru Finansowego (Financial Supervision Authority), and Bankowy Fundusz Gwarancyjny (Bank Guarantee Fund). This is where similarities and differences begin to emerge. Similarities can be found in certain activities and the scope of powers held by the central bank.

In both Ukraine and Poland, the central bank is responsible for regulating activities, controlling the liquidity of banks, and maintaining financial stability in the banking sector.

They equally perform functions in the area of currency issuance, act as a "bank of banks," and serve as the state's bank. Additionally, they have the authority to manage gold and foreign currency reserves and handle cash operations related to the state budget [9].

However, there are important differences stemming from the varying approaches to regulating financial systems. For instance, unlike the NBP, the NBU does not manage the state budget; this responsibility lies with the Ministry of Finance of Ukraine. Another distinction concerns supervisory functions. The NBP does not have the authority to issue licenses for banking activities or directly supervise banks, insurance companies, or other financial institutions. These functions are assigned to an independent regulator – the KNF, which serves as the central supervisory authority for both banking and non-banking structures. In Ukraine, the supervision of banks and the issuance of licenses remain the responsibility of the NBU, which centralizes these functions within a single body. Meanwhile, the non-banking sector is regulated by other institutions, such as the National Securities and Stock Market Commission.

The final component of the institution, the BFG, is functionally similar to the Deposit Guarantee Fund in Ukraine, with the main difference lying in its foundation, standards, and legislation, which are derived from the European Union (Poland) and the IMF alongside the World Bank (Ukraine) [10, 11].

The second institution, the market-forming one, includes the banking sector, representing the total number of banks that constitute the market. The third institution, the auxiliary one, encompasses all other entities that do not engage in deposit and lending activities: insurance institutions, National Depositories of Securities (KDPW), the National Clearing House (KIR, which oversees transaction flows, online payments, and e-signature technology), the Credit Information Bureau (BIK), and non-banking issuers of payment cards [9].

According to research, the Polish banking system exhibits a more detailed division among existing institutions. The banking sector plays a key role in this division, with the central bank overseeing it and making decisions to improve the system. Therefore, let us focus on the quantitative dynamics of banks in the two countries in recent years for a better understanding of the system's condition.

Table 1 – Number of Solvent Banks in Ukraine and Poland

Years	Number of Solvent Banks		Difference (Deviation)
	Ukraine	Poland	
2017	96	64	32
2018	82	63	19
2019	77	62	15
2020	75	66	9
2021	74	67	7
2022	71	64	7
2023	67	63	4
2024	63	62	1
2025	61	62	-1

Sources: 12,13

Let us first examine the changes separately for each country. In Ukraine, a trend of decreasing the number of solvent banks can be observed. Over the past nine years, the number of banks has decreased by 35, which accounts for 36.5%. Unlike Ukraine's rather sharp dynamics, Poland shows moderate changes, with no abrupt fluctuations or

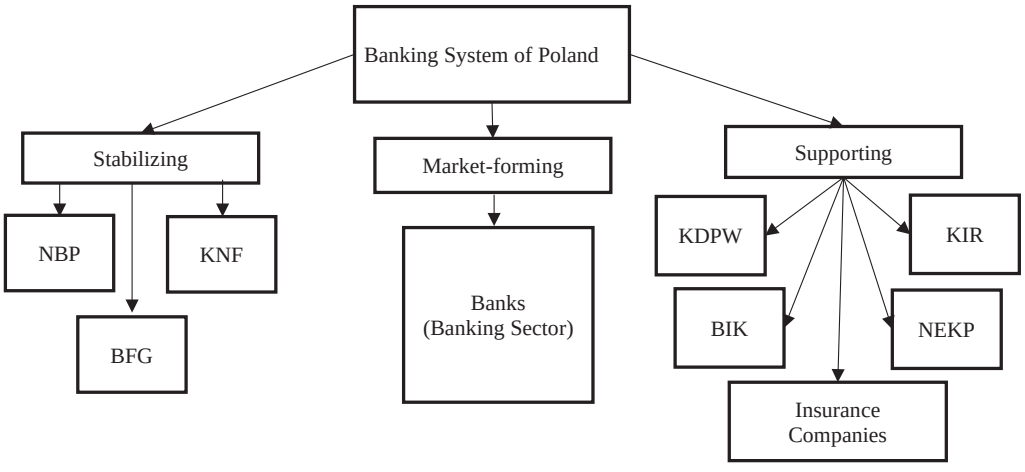

Fig. 2. – Brief Scheme of the Composition and Functioning of Poland's Banking System [6, 7, 9]

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unexpected jumps. The indicators remain stable and do not exceed variations between -3 and +4 banks during the period.

This trend demonstrates that overall year-to-year changes in Poland are also gradually declining. At the beginning of the analyzed period (in 2017), the difference in the number of banks was 32 in favor of Ukraine. However, as of January 1, 2025, the number of banks in Poland exceeded that of Ukraine by one.

The reduction in the number of banks in both countries indicates the cleansing of the market from insolvent banks. However, this indicator alone is insufficient to assess real financial stability. An important aspect for analysis is the total assets of banks and their annual dynamics. These figures reflect the scale of activity and, to some extent, the level of readiness to face economic challenges.

Table 2 reflects the dynamics of changes in total assets over the years in the countries and the percentage change relative to the previous year. Ukrainian banks demonstrate a sharp annual increase in assets. This trend is especially noticeable in 2023-2024, and compared to 2017, the total assets have increased 2.72 times. In Poland, the situation is similar, with the total assets in the banking sector growing moderately each year. The most significant growth occurred in 2019 and in recent years.

In Ukraine, the number of solvent banks decreases annually, but the Polish banking market demonstrates greater stability. However, when comparing the total assets, we observe that despite the decline in the number of Ukrainian banking institutions, total assets tend to grow.

In our opinion, attention should be paid to such indicators as inflation and the key policy rate. Total bank assets are measured in monetary equivalents, and inflation directly affects their real value. For example, if assets grow nominally but there is high inflation, the real growth of this indicator may be insignificant or even negative.

The data in Figure 3 illustrate the dynamics of changes in inflation and key policy rates in Ukraine and Poland. In Ukraine, inflation fluctuated within the range of 104-113% (the maximum increase, 15%, to a level of 126.6, was observed in 2022). The National Bank of Ukraine's (NBU) key policy rate underwent significant changes during the analyzed period, reaching a low of 6% in 2020 and a high of 25% in 2022. The dynamics of these indicators demonstrated that between 2018 and 2020, the country's economic situation stabilized, while the indicators for 2022–2024 were influenced by the full-scale invasion by russia.

In Poland, effective economic policies up until 2022 were confirmed by inflation and key policy rate indicators. For example, inflation remained acceptable (101-103%) until 2020, considering the country aims to maintain a 2.5% benchmark, as is common in developed economies. However, starting in 2022, inflation rose significantly, prompting the central bank to increase the key policy rate by 5.4 times, reaching 6.75%. This situation in Poland is also linked to the challenging macroeconomic and economic environment caused by Russia's war in Ukraine.

These indicators are presented with the understanding that they are interdependent. Initially, the state (authorized bodies) monitors factors such as the level of money supply in circulation, transactions, and other indicators, establishing the inflation rate. If inflation rises, the central bank increases the key policy rate to control price levels (in Poland, this is analogous to the reference rate, "Stopa referencyjna," which determines the minimum allowable interest rate on bank loans. Different approaches apply to non-bank institutions). This is done to reduce the money supply in the economy. Accordingly, higher interest rates set by banks make loans more expensive, reducing consumer capacity and willingness to invest. Simultaneously, deposit rates are raised to attract resources to banks and encourage savings.

Conversely, when inflation decreases, as the country aims for, prices stabilize. Loan rates decrease, encouraging businesses and individuals to take loans, purchase real estate, and invest overall. At the same time, deposit rates may decline when banks no longer need additional funds, making deposits less attractive.

Comparing the tables reveals that the dynamics of banking assets correlate with changes in inflation and key policy rates. In both Ukraine and Poland, inflation

Table 2 – Dynamics of Total Bank Assets in Ukraine and Poland

Years	Total bank assets			
	Ukraine (million UAH)	Deviation from the previous year, %	Poland (million PLN)	Deviation from the previous year, %
2017	1 260 617	-	1 612 359	-
2018	1 333 831	5,8%	1 689 646	4,79%
2019	1 359 703	1,94%	1 780 157	5,36%
2020	1 493 298	9,83%	2 106 036	18,31%
2021	1 822 841	22,07%	2 307 868	9,58%
2022	2 053 232	12,64%	2 466 160	6,86%
2023	2 351 678	14,54%	2 720 449	10,31%
2024	2 945 030	25,23%	3 022 519	11,1%
2025	3 422 600	16,22%	3 374 413	11,64%

Sources: 14,15

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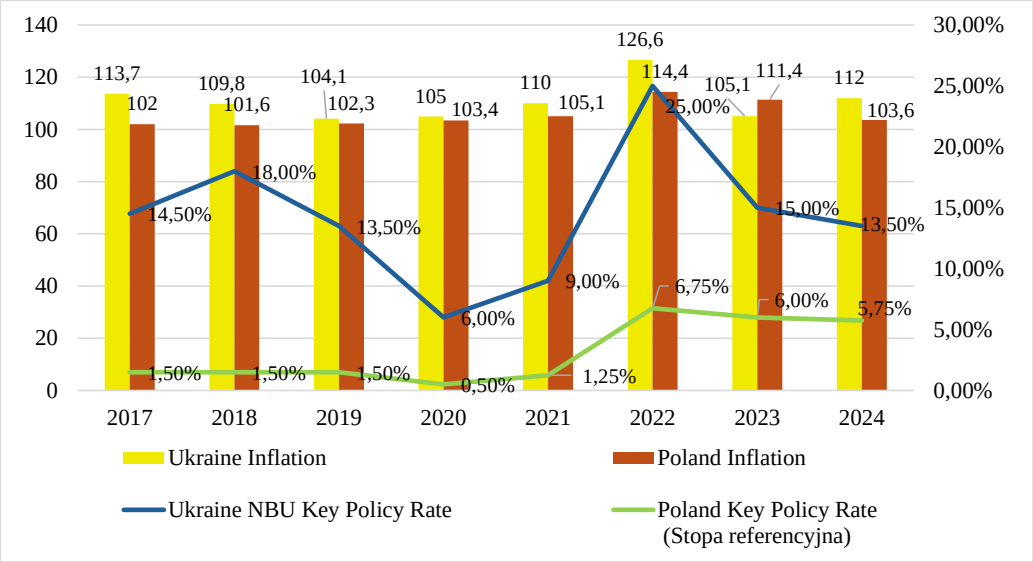

Fig. 3. – Dynamics of Inflation and Key Policy Rates in Ukraine and Poland
Sources: 16,17,18,19

indicators are interconnected with all sectors of the national economy, including the banking sector, and have a direct impact. However, their consequences differ.

On one hand, the NBU employs strict high-rate methods to curb inflation, but these actions lead to higher loan costs, which can negatively affect the real growth of banking assets. On the other hand, the NBP maintained lower rates for an extended period, focusing on forecasting and facilitating the gradual development of the financial system. The spikes in 2022 and 2023 were necessary temporary measures to combat inflation.

Quantitative indicators of the banking system, such as asset volumes or the number of solvent banks, are undeniably important. However, they are not synonymous with "quality," as the resilience of these banks to crises and shocks is equally significant. To assess these factors, banks undergo stress testing, which helps determine their preparedness for unexpected crises.

In Ukraine, annual stress testing is conducted under the NBU's supervision. To assess the resilience of banks, a baseline macroeconomic scenario is applied. It consists of three stages that determine the required level of capital adequacy norms (with a focus on bank liquidity). Under the baseline scenario, it is assumed that:

- Bank balance sheets are static, affected by changes in asset quality and exchange rates.
- Current profits are capitalized throughout the forecast period.

According to the NBU, stress testing this year will involve 21 banking institutions, accounting for over 90% of the banking system's assets. These banks were selected based on three criteria: the size of risk-weighted assets, the volume of deposits attracted from households, and the volume of net loans provided to households.

The list of banks includes: JSC "PrivatBank," JSC "Oschadbank," JSC "Ukreximbank," JSC "Ukrgasbank," JSC "Sense Bank," JSC "Raiffeisen Bank," JSC "UkrSibbank," JSC "OTP Bank," JSC "Credit Agricole Bank," JSC "ProCredit Bank," JSC "KredoBank," JSC "Pravex Bank," PUMB, JSC "Bank Pivdenny," JSC "Tascombank," JSC "Universal Bank," JSC "Credit Dnipro," JSC "Bank Vostok," JSC "A-Bank," JSC "MTB Bank," and JSC "AKB Lviv."

In contrast, Polish banks undergo more rigorous stress tests prescribed by European Central Bank standards. The latest test occurred in 2024 under the supervision of the previously mentioned KNF, in collaboration with the NBP. The objective was to assess the impact of negative macroeconomic and market shocks and the cost of foreign-currency-denominated housing loans. The analysis is conducted using two scenarios: a reference (baseline) scenario and a shock scenario.

The reference scenario, based on the 2022 macroeconomic inflation forecast report, assumed moderate real GDP growth under stable interest rates. The shock scenario was designed using NBP's macroeconomic forecasting models and historical data on macroeconomic variables during financial crises in other countries. It assumes GDP stagnation and declining market interest rates, among other restrictive factors.

Summarizing the stress test results for the banking sectors in Ukraine and Poland, generally positive indicators of banking resilience and performance can be noted.

In Ukraine, among the 20 institutions analyzed, only a few demonstrated a capital adequacy ratio below the minimum threshold. Nevertheless, most banks confirmed their ability to function stably even under the war and economic crisis conditions.

In Poland, all banks successfully passed the reference (baseline) scenario tests, meeting capital requirements. However, as emphasized by the NBP, the implementation of the shock scenario could have a significant negative impact on the banking system, primarily due to high levels of foreign-currency-denominated housing loans,

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which pose specific risks in the context of macroeconomic changes.

Conclusions

Thus, the study analyzed the banking systems of Ukraine and Poland and provided a comparative characterization. The gathered information allowed for identifying key similarities and differences influenced by a range of factors. It is essential to consider that Ukraine is currently in a state of war.

Although both countries have a two-tier structure of the banking system, which includes the central bank and other banks (state, private, mixed, foreign), the regulation mechanism, functions, and shares of responsibility differ somewhat. The National Bank of Ukraine (NBU) plays the primary role in Ukraine, focusing on supervision, control, and analysis. In contrast, in Poland, these functions, especially the oversight of the banking system, are decentralized and involve an additional institution – the KNF.

The quantitative dynamics of institutions in the two countries show different trends. Over the past decade, Ukraine's banking sector has undergone significant cleansing from insolvent banks due to reforms, stricter regulatory requirements, and economic instability in the market. In Poland, this indicator remains stable, reflecting the relative resilience of the system.

The general analysis of total assets showed significant growth in both Poland and Ukraine, despite the difference in the number of institutions. In Ukraine, this growth is particularly notable even since 2022, the start of the full-scale invasion. Partially, this may be explained by the fact that a larger share of assets is concentrated in large banks. At the same time, it is necessary to consider factors that may have influenced this increase, one of which is inflation. Inflation in Ukraine is significantly higher, which could reduce the real value of assets.

In analyzing stress test reports for banks, the focus was on conclusions: in cases of deviations from regulatory indicators, financial institutions were given a certain period to address the situation and recommendations for developing strategies to improve financial stability.

However, if Ukraine aims to meet European Union standards and integrate into the European financial system, it must not only fulfill basic requirements defined at the local level but also implement additional mechanisms for assessing bank resilience. One such step could be the gradual expansion of additional stress-testing practices, particularly the adoption of modern methodologies used by leading EU countries.

Implementing more in-depth risk analysis and modeling and adapting to methods based on European approaches will provide an objective assessment of the state of the banking sector. This will allow comparisons of the performance of Ukrainian banks with institutions in more developed countries, help identify "weak spots," and reveal opportunities for developing gap-bridging strategies. Additionally, an in-depth analysis of stress resilience will foster increased trust in Ukrainian banks among investors and organizations at the international level. Thus, improving new approaches to stress testing could contribute not only to enhancing the stability of the financial system but also to improving the country's economic condition.

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PECULIARITIES OF LENDING TO AGRICULTURAL BUSINESS IN UKRAINE AND ABROAD

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Key words:
agricultural sector, agricultural lending, financial position, commercial banks, state support, farms, european standards.

In the current environment, agricultural enterprises are strategically important for Ukraine, as they ensure the country's food security. The agricultural sector of Ukraine is one of the key sectors of the country's economy, providing a significant portion of exports and employment. The level of development of the agricultural sector is directly proportional to the amount of money invested in its development. Currently, bank loans are one of the sources of meeting the credit needs of agricultural producers. They help to balance the need for capital with available own funds. However, agricultural enterprises in Ukraine face a number of challenges in obtaining loans, including high interest rates, lack of sufficient collateral, and an unstable legal and economic environment. Compared to developed countries, where the agricultural sector is actively supported through government programs, subsidies and concessional lending, Ukrainian farmers are often forced to rely on their own resources or look for alternative sources of financing. The introduction of new financial instruments such as crop receipts, leasing, and risk insurance is also important. To increase the availability of credit resources in Ukraine, it is necessary to improve the financial infrastructure, strengthen government support for the agricultural sector, and create favorable conditions for attracting investment. Comparison with international experience allows us to identify the most effective approaches to the development of the agricultural credit system.

ОСОБЛИВОСТІ КРЕДИТУВАННЯ АГРАРНОГО БІЗНЕСУ В УКРАЇНІ ТА ЗА КОРДОНОМ

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Ключові слова:
аграрний сектор, агрокредитування, фінансовий стан, комерційні банки, державна підтримка, фермерські господарства, європейські стандарти.

В сучасних умовах аграрні підприємства є стратегічно важливими для України, адже задовольняють продовольчу безпеку країни. Аграрна галузь України є одним із ключових секторів економіки країни, що забезпечує значну частину експорту та зайнятості населення. Рівень розвитку аграрної галузі прямо пропорційний сумі вкладених у її розвиток грошей. У даний час банківські кредити є одним з джерел забезпечення потреб сільськогосподарських виробників у кредитних ресурсах. З їх допомогою відбувається збалансування потреби в капіталі з наявними власними коштами. Однак, аграрні підприємства в Україні стикаються з низкою проблем при отриманні кредитів, зокрема високими процентними ставками, відсутністю достатнього забезпечення, а також нестабільністю законодавчої та економічної ситуації. У порівнянні з розвиненими країнами, де аграрний сектор активно підтримується через державні програми, субсидії та пільгове кредитування, українські аграрії часто змушені покладатися на власні ресурси або шукати альтернативні джерела фінансування. Важливим аспектом є також впровадження новітніх фінансових інструментів, таких як аграрні розписки, лізинг та страхування ризиків. Для підвищення доступності кредитних ресурсів в Україні необхідне вдосконалення фінансової інфраструктури, посилення державної підтримки аграрного сектору та створення сприятливих умов для залучення інвестицій. Порівняння з міжнародним досвідом дозволяє визначити найефективніші підходи до розвитку системи аграрного кредитування.

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Statement of the problem

Lack of financing is one of the main problems of the agricultural sector in Ukraine. The lack of sufficient funding prevents agricultural enterprises from modernizing and improving their technical facilities.

Banks and investors are now very cautious about the agricultural sector, which limits access to credit for businesses.

The lack of financing can be overcome by financial instruments such as loans and grants. It is important to actively use government programs and subsidies to develop the agricultural sector.

Analysis of recent studies and publications

Research on the issues of ensuring the efficiency of lending to the agrarian sector was done by many scientists. The problem of financing agricultural enterprises through bank loans is widely considered and analyzed in the scientific works of O. Chernobay, V. M. Gomza, O. S. Nakonechnaya, L. I. Galas [1].

Objectives of the article

The purpose of the article is to study the peculiarities of agricultural business lending in Ukraine and abroad, to identify the main problems of access to financial resources for agricultural enterprises, and to compare the domestic experience with international practice in order to formulate recommendations for improving the agricultural lending system in Ukraine.

The main material of the research

In Ukraine, lending to agricultural businesses is implemented through several main mechanisms, including government support programs, commercial bank financing, and cooperation with international financial institutions. State support includes programs for partial compensation of interest rates on loans, subsidies for the purchase of machinery and equipment, and grant programs for agricultural enterprises. These measures are aimed at reducing the financial burden on farmers, stimulating their activity and attracting investment in the agricultural sector.

Agribusiness lending programs in Ukraine and abroad are an important tool for ensuring financial stability, development and competitiveness of the agricultural sector. These programs are aimed at supporting farmers, agricultural enterprises and cooperatives that ensure food security, rural development and export potential. They differ from country to country, depending on the level of economic development, legislative framework, and the specifics of the agricultural sector.

The mechanism of bank lending to agricultural enterprises is a lending procedure that each commercial bank carries out independently in accordance with the established credit policy.

The requirements for borrowers to obtain a bank loan include good financial standing, profitability, positive credit history, availability of collateral, regular cash flows to current accounts, sources of repayment, additional costs and insurance of the collateral.

Prior to the full-scale invasion of Russia, the share of loans granted to domestic agricultural enterprises remained quite low and amounted to only 9% of the total [1]. Agricultural enterprises mainly invest their own funds in their operations. For comparison, in developed countries, the share of bank lending reaches 70% of the working capital of the agricultural sector. The main obstacles to obtaining loans by agricultural companies are: high risks and interest rates, stricter collateral requirements from lenders, insufficient interest of banks in lending to startups and small and medium-sized enterprises, limited experience in agribusiness, dependence of borrowers' solvency on natural and climatic factors, as well as availability, condition and depreciation of fixed assets.

However, since 2023, the Ukrainian banking system has increased lending to the agricultural sector. Figure 1 shows the structure of the bank loan portfolio by type of economic activity as of 11 months of 2024.

Agricultural enterprises received the largest share of loans, accounting for 45%. The second place went to trade enterprises, which received 24% of all loans. Lviv, Kharkiv, Dnipropetrovs'k, Odesa, Kyiv, Vinnytsia regions and the city of Kyiv were the leaders in terms of loan volumes.

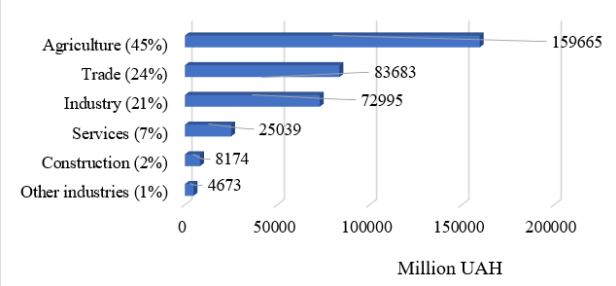

Fig. 1 – Volume and structure of the bank loan portfolio as of 01.12.2024 p

Note: compiled on the basis of [4]

Let us consider the current offers of domestic commercial banks to provide agricultural loans.

State-owned banks are the key players in providing loans. In 2023, PrivatBank became the leader in agricultural lending, providing UAH 6.4 billion in loans to farmers. This year, the bank is also not losing its position. As of the end of 2024, JSC CB PrivatBank provided financing to more than 3 thousand agricultural companies in the amount of UAH 10.6 billion as part of the program of credit support for agricultural producers.

At JSC Oschadbank, lending to the agro-industrial complex is also one of its priority areas. The bank ranks second among all Ukrainian banks by the number of loans granted. In 2023, the bank provided about 3.4 thousand loans worth more than UAH 5 billion to agrarians representing MSMEs [2]. As of October 1, 2024, loan agreements in the agricultural sector amounted to UAH 9.9 billion.

More than 30% of all loans received by farmers are provided by banks with state guarantees, which greatly simplifies access to bank financing for enterprises. The

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Table 1 – Proposals of domestic commercial banks in terms of lending to agricultural enterprises as of 01.12.2024 року

№ s/n	Bank	Average interest rate	Loan disbursement fee	Maximum loan term, months
1	JSC Oschadbank	18,70%	from 0,5% to more	36
2	JSC CB PrivatBank	19,50%	1-1,5%	60
3	JSC "Credit Agricole Bank"	16,50%	0,01%	60
4	OTP Bank JSC	16,95%	1-1,5%	36
5	JSC Ukreximbank	22,00%	0,20%	84
6	JSB "Ukrgasbank"	20,15%	0,5-1,0%	60
7	JSC Agroprosperis Bank	21,75%	0,5%	84
8	JSC "Bank Credit Dnipro"	21,00%	1,5%	36
9	JSC Raiffeisenbank	18,65%	0,5-0,99%	60
10	JSC Globus Design Bureau	16,00%	from 0,5-1%	60

state plays a key role in agricultural financing programs through the 5-7-9% program and state guarantees.

The state support program "Affordable Loans 5-7-9%" [3] helps agricultural enterprises gain access to the necessary financial resources and provides low-interest loans for agricultural enterprises. Thanks to the program, the agricultural sector is able to operate. With the loan funds, farmers can buy seeds, fertilizers, fuel and lubricants to prepare for sowing and harvesting, pay salaries to employees, and restore farms.

It is worth noting that agricultural enterprises in Ukraine received the largest number of loans through the government program "Affordable Loans 5-7-9%". Since its launch in February 2020 until December 2024, farmers have taken out loans totaling UAH 160 billion [4].

Currently, the Affordable Loans 5-7-9% program allows entrepreneurs to receive up to UAH 90 million in one tranche. The interest rate is 0% during martial law and for one month after its termination.

The program was extended by the government even during the war, maintaining its relevance for small businesses. At the same time, the adopted State Budget for 2025 provides more than UAH 6 billion to support the agricultural sector [5]. Thus, since budget funding for farmers has been limited since 2022, bank lending has become one of the main sources of financing for current projects of agricultural enterprises.

In Ukraine, the Fund for Partial Guaranteeing of Loans in Agriculture was launched in 2023. The Fund's activities are aimed at supporting small, small and medium-sized farmers who cultivate land of up to 500 hectares. This is a support for small farmers to be able to get loans. The Fund will guarantee to Ukrainian banks to cover up to 50% of loan obligations.

Borrowers can receive investment loans for up to 7 years, loans for the purchase of land for up to 10 years, and working capital for up to 3 years, with a maximum loan amount per borrower of UAH 30 million [6].

For comparison, it is worth considering the specifics of lending to farmers in the EU. In the EU, agricultural enterprises have free access to credit resources thanks to government and banking support programs. The main focus of such programs is to increase competitiveness, preserve ecosystems, efficiently use natural resources, support economic and social revitalization of rural areas, and promote adaptation to climate change and prevent natural risks.

Among the European Union countries, Germany, France and Poland can be distinguished as having well-developed agricultural lending systems. In Germany, state-owned banks play a key role in offering long-term loans to farmers to modernize production facilities.

France provides farmers with financial support through a loan guarantee system, which reduces risks for creditors and makes financing more affordable. France has a special tax regime for rural producers that reduces the tax burden. Farmers who buy agricultural machinery can receive compensation of up to 40% of its cost. In addition, there is a special "tax credit" that allows you to pay only 60% of the tax, and the rest is compensated by the state. The interest rate for farmers producing organic products is only 2% per annum. For buyers of agricultural machinery, banks provide loans at 2-3% per annum, with no interest paid for the first year [7].

Credit Agricole Bank is a partner for the majority of French farmers, providing financing and support to agricultural production regardless of the market. It provides special financing and additional services for organic producers, including deferred loan repayment, additional funds for the purchase of machinery and special offers for crop insurance against climatic influences.

Poland also actively supports its farmers as part of its rural development program, including subsidies per hectare of sown area and special programs for young farmers. In addition, the government reduces the cost of agricultural machinery by 80%. In Poland, banks are actively financing farmers by providing long-term loans (up to 25 years) at low interest rates (3-5% per annum), which allows farmers to use cheap financial resources. Land is most often used as collateral for such loans. Poland actively uses the resources of the European Union to develop agricultural infrastructure and support farms.

In the Netherlands, there are government programs that provide guarantees for farmers for part of the loan. This applies to both small and medium-sized enterprises, including young farmers under 39 years of age, who can receive loans to optimize production, improve product quality or animal welfare conditions [7].

The main advantages of European lending programs are low interest rates, long loan repayment terms, and the

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availability of grants and subsidies, which can significantly reduce the financial burden on farmers. At the same time, the procedure for obtaining financing can be quite complicated due to high reporting requirements, compliance with environmental standards and other regulatory norms [8].

Comparing Ukrainian and European programs, it is worth noting that in Ukraine, the level of state support for agribusiness is lower and the interest rates on loans are much higher. At the same time, international programs operating in Ukraine are gradually adapting European practices.

The effectiveness of agricultural business lending programs depends on a comprehensive approach that includes the availability of financial resources, technical support, a favorable regulatory environment, and infrastructure development. Given the experience of the European Union, Ukraine has significant potential to improve its programs by introducing new financial instruments and expanding international cooperation.

Ukraine's agricultural sector faces numerous challenges, such as high dependence on seasonality, limited access to long-term investment resources, volatile markets, and infrastructure constraints. In this context, the development of modern lending programs is critical to ensuring sustainable growth. The European experience can serve as a basis for reforming the Ukrainian agribusiness financing system [1].

One example of the successful use of international financial mechanisms is the EU Credit for Small and Medium Enterprises program, which is implemented through a number of Ukrainian banks with the support of the European Investment Bank [9]. This program allows agricultural producers to obtain loans on favorable terms, with reduced rates and long maturities, which facilitates the implementation of investment projects to modernize and expand production. However, access to such resources requires farmers to have a high level of financial literacy, business transparency, and compliance with international reporting standards.

Among the examples of European loan programs that could be adapted in Ukraine are the financing mechanisms in Poland. Here, farmers have access to concessional loans through the Agency for Restructuring and Modernization of Agriculture, which offers subsidies for interest payments. Such loans are aimed at updating the technical park, setting up processing plants, building agricultural infrastructure, and implementing environmental projects. The advantage is the simplicity of procedures and active support from local administrations.

In Germany, agricultural business lending programs are based on cooperation between the state, banks, and regional support funds. For example, KfW Bank offers low-interest loans for investing in farm development, digital technologies, and renewable energy sources. An important aspect is the long-term support of projects aimed at reducing dependence on fossil fuels and increasing production efficiency [10].

Comparing these approaches to domestic lending, it can be noted that long-term financing mechanisms are currently underdeveloped in Ukraine. The bulk of loans provided by Ukrainian banks are short-term and aimed at seasonal needs, such as the purchase of fertilizers, fuel, or seeds. This limits the ability of farmers to implement large-scale investment projects that require significant financing and a long payback period.

To further develop the agricultural lending system in Ukraine, it is advisable to adapt the best practices of European countries. In particular, the creation of state and regional loan guarantee funds will reduce risks for banks and expand access to finance for small and medium-sized farmers. In addition, intensified cooperation with international financial institutions opens up opportunities for attracting profitable loans and grant funding.

Equally important is the work to simplify the procedures for obtaining loans and ensure transparency of financial mechanisms. This will help increase confidence in the lending system and encourage farmers to actively attract investment to develop their farms.

A key factor in the successful adaptation of Ukraine's agricultural lending system to European standards is the creation of a favorable institutional environment. This includes improving legislation, developing financial instruments, and raising the level of financial literacy among farmers.

One promising area is the introduction of specialized credit lines for small farmers. European experience shows that such programs provide equal access to finance for all categories of farmers, regardless of their size or specialization. For example, Poland has programs targeted specifically at small farmers who face difficulties in raising capital due to limited resources or low creditworthiness. These programs are supported not only by public funds, but also by EU structural investment funds, such as the European Agricultural Fund for Rural Development [11].

Financial instruments for cooperatives are common in Europe. In Denmark and the Netherlands, farmers' cooperatives receive loans under state guarantees to develop processing plants, build warehouses and logistics centers. This approach allows small producers to share resources, reducing the cost of individual investments. However, dependence on the cooperative model can be a barrier for farms that operate independently.

Infrastructure projects financed through loans play an important role in increasing the competitiveness of the agricultural sector. In France and Germany, farmers receive financing for the construction of warehouses, cooling systems, and transportation of products. Such projects are supported by national funds or through direct EU investment. Despite the significant positive impact on farm efficiency, infrastructure projects take a long time to implement and pay off.

It is worth noting that the Ministry of Agrarian Policy and Food of Ukraine, with the assistance of the EU, has established and put into operation a state automated information system for collecting, recording, storing, and processing information on agricultural producers - the State Agrarian Register (SAR). The State Agrarian Register provides online access to support programs for all registered agricultural producers, regardless of their legal form. The information system is similar to the registers of agricultural producers that exist in all EU member states [12].

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Conclusions

Thus, compared to European programs, the Ukrainian lending system focuses on partial compensation of interest rates on commercial loans, which does not meet the long-term needs of farmers. Lending rates in Ukraine are significantly higher than in the EU, which limits access to finance. In addition, environmental and innovative projects, which are prioritized in European programs, are not yet sufficiently supported in Ukraine.

Ukrainian farmers also face less support for cooperative structures. While in the EU, cooperatives are an important tool for accessing financing and implementing large projects, in Ukraine this model is developing slowly, which reduces the competitiveness of small producers. Another important difference is the lack of a significant amount of grant programs that could support innovative solutions.

However, Ukraine has prospects for integrating European experience. Active cooperation with international financial organizations, such as the EBRD and the European Investment Bank, creates conditions for adapting EU best practices. Expanding state guarantees, supporting long-term loans, promoting sustainable development, and improving the cooperative system could significantly increase the availability of financing for Ukrainian farmers.

Today, Ukraine's agricultural business is supported by financial assistance programs, compensation for the restoration of infrastructure and equipment, grants for the development of horticulture and greenhouses, and tax benefits. These measures have become important tools to support the industry, especially in times of war.

In order to restore and further develop the agricultural sector, it is necessary to continue adapting Ukraine's agricultural policy to European standards and legislation, which will facilitate the country's integration into the European Union and strengthen the competitiveness of Ukrainian agribusiness in international markets.

Foreign experience shows that agricultural sector support policies aimed at stabilizing the financial condition of farmers and ensuring their competitiveness in international markets are extremely important in the context of globalization.

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STATE OF THE BANKING SECTOR AND THE ROLE OF BANKING MANAGEMENT

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Key words:
banking sector, digitalization, financial performance indicators, cashless transactions, bank management, strategy.

In modern conditions, banking management is one of the most dynamic areas of the economy. Technological changes, rising inflation, increased competition and stricter regulatory requirements have led to the development of more aggressive management strategies in banks, which increases the level of risks. As risk management becomes increasingly complex, this can lead to a deterioration in the asset structure and a decrease in the efficiency of operations, which potentially threatens crisis situations. Therefore, it becomes critically important for bank management to develop effective approaches to identifying and minimizing risks in order to ensure profitability, protect depositors' funds and maintain the stability of the bank's operations.

Recently Ukraine's banking sector has demonstrated extraordinary resilience, remaining a reliable support for the real economy. There has been no outflow of deposits from the banking system, and access to cash has been ensured even during winter power outages, highlighting the effectiveness of digital technologies and backup mechanisms. The high level of capital adequacy ratio (CAR) and significant liquidity buffers show that the banking system is ready to cope with current challenges. This level of stability is comparable to the experience of countries that have rebuilt their financial systems after crises, such as Finland after the Great Depression.

In addition to important reforms implemented since 2014, comprehensive measures of the National Bank of Ukraine and a high level of digitalization played a key role in the stability of the banking sector.

СТАН БАНКІВСЬКОГО СЕКТОРУ ТА РОЛЬ БАНКІВСЬКОГО МЕНЕДЖМЕНТУ

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Ключові слова:
банківський сектор, цифровізація, показники фінансових результатів, безготівкові операції, банківський менеджмент, стратегія.

У сучасних умовах банківський менеджмент є однією з найбільш динамічних сфер економіки. Технологічні зміни, зростання інфляції, загострення конкуренції та жорсткіші регуляторні вимоги спричинили розвиток більш агресивних управлінських стратегій у банках, що підвищує рівень ризиків. Оскільки управління ризиками стає дедалі складнішим, це може призвести до погіршення структури активів і зниження ефективності операцій, що потенційно загрожує кризовими ситуаціями. Тому для керівництва банків стає критично важливим розробляти ефективні підходи до виявлення та мінімізації ризиків, аби забезпечити прибутковість, захистити кошти вкладників і підтримувати стабільність роботи банку.

Останнім часом, банківський сектор України демонструє надзвичайну стійкість, залишаючись надійною опорою для реальної економіки. Не було зафіксовано відпливу депозитів з банківської системи, а доступ до готівкових коштів був забезпечений навіть під час відключень електроенергії взимку, що підкреслює ефективність цифрових технологій та резервних механізмів. Високий рівень нормативу адекватності капіталу (CAR) та значний запас ліквідності показують, що банківська система готова впоратися з поточними викликами. Цей рівень стабільності можна порівняти з досвідом країн, що відновлювали свої фінансові системи після кризових ситуацій, як-от Фінляндія після Великої депресії.

Окрім важливих реформ, реалізованих з 2014 року, ключову роль у стабільності банківського сектору відіграли комплексні заходи Національного банку України та високий рівень цифровізації.

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Statement of the problem

The country's economy is heavily dependent on international financial assistance, the volume of which is constantly decreasing and irregular, which threatens macroeconomic stability. Despite this, the banking sector is operating stably, showing significant profits, and its role in the economy is growing. This has become possible thanks to the concerted efforts of banks, the rapid response of the National Bank of Ukraine to market changes, as well as the successful reform of the system, which has been ongoing since 2015. As a result, banks entered the crisis with a large capital and liquidity reserve, which allows them to effectively withstand operational risks and implement plans in case of negative events.

Analysis of recent research and publications

The issues of banking management have been actively studied by both Ukrainian and foreign scientists and economists. Among Ukrainian researchers, it is worth noting Anatoly Galchynsky, Viktor Mishchenko and Oleksandr Berezin, who studied the issues of effective bank management in times of crisis. Among foreign scientists, a significant contribution was made by Peter Drucker, Frederick Mishkin and Merton Miller, who studied the issues of risk management and financial stability of banks at the international level. Their works helped to shape approaches to managing banking operations and risks in times of economic instability.

Objectives of the article

The purpose of this article is to study and describe the current situation in the banking sector of Ukraine with an emphasis on economic instability. The task is to better understand the current situation in the country, based on the analysis, to examine the changes that have occurred over the past year, to identify key trends and opportunities for the development of the sector. In addition, the article provides for the development of substantiated forecasts regarding the need to implement certain measures to improve the work of banking management in Ukraine.

The main material of the research

The main objectives of bank management are:

– The key goal is to generate profit from banking operations and financial services. This is necessary to ensure the stable functioning of the bank and protect the funds of depositors and creditors. Profitability is the main indicator of the effectiveness of any banking institution.

– Ensuring reliability – maintaining a high level of reliability of the bank, which depends on the amount of aggregate risk it faces. Minimizing risks is an important task of banking management.

Thus, the main indicators of the effectiveness of banking management are profitability and risk, which must balance each other.

According to the National Bank of Ukraine (Fig. 1), the number of banks in all categories did not change significantly from 2020 until the beginning of 2022. Prior to this period, there was a slight decrease of one unit in solvent, state-owned and private banks. Since the beginning of 2022, the indicators have begun to decline more rapidly in all categories by an average of 3 units. Despite the difficult situation in the country during such a period, these indicators are not critical for the country's banking system.

Net assets of solvent banks increased by 4,7% in 2025 (Fig. 2), of which 1% was due to exchange rate revaluation. The largest increase was observed in the amount of funds

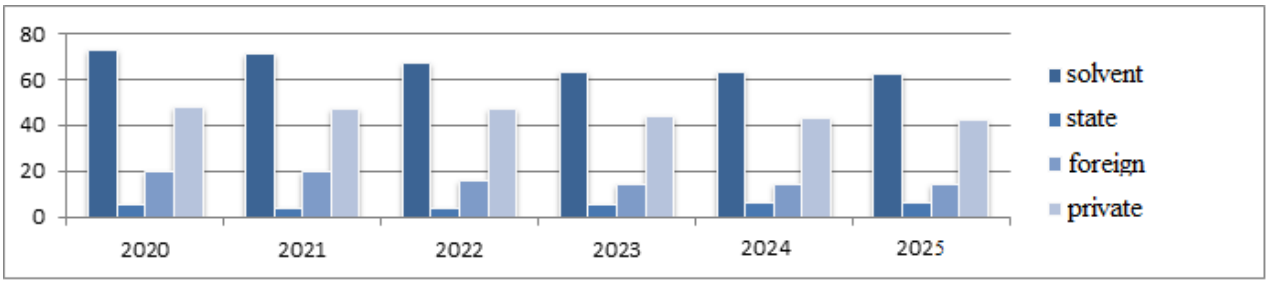

Fig. 1 – Dynamics of the number of banks during 2021-2025

Compiled based on [1]

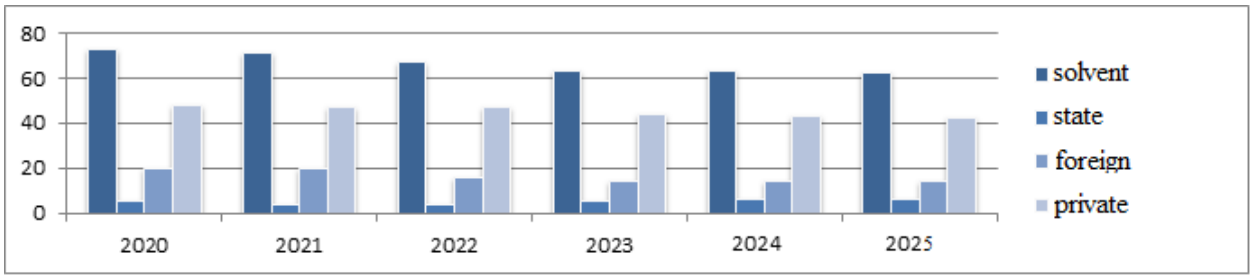

Fig. 2 – Changes in general balance sheet indicators during 2017-2025, billion UAH

Compiled based on [1]

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that banks place on the accounts of the National Bank of Ukraine (since the growth of liabilities requires an increase in mandatory reserves), on correspondent accounts with other banks, as well as in domestic government loan bonds of Ukraine (DGLB). Ukrainian government loan bonds of Ukraine (DGLB) are government securities that are placed exclusively on the domestic stock market and confirm Ukraine's obligations to reimburse the bearers of these bonds for their nominal value with the payment of income in accordance with the terms of the bond placement. At the same time, banks' investments in the National Bank of Ukraine deposit certificates are decreasing, compared to 2024, having decreased by 7.1% in 2025. In addition, net loans to customers increased by 6,8 % in 2025, and their share in assets also increased. Figure 3 shows the financial results and profitability of the banking sector. Return on assets (ROA) for 2025 is 5%, which is a high indicator for the banking sector. This may indicate extremely efficient work of banks. Return on equity (ROE) for the same period is 0,48. This means that the company receives 48 kopecks of profit for every hryvnia of equity. ROE at 48% is extremely strong, which may indicate highly efficient activities or the presence of one-time profits. The financial results of solvent banks for 2024 and 2025 are stable at UAH 26,1 billion and UAH 22,2 billion. The National Bank of Ukraine's prompt and comprehensive anti-crisis actions played a key role in stabilizing the sector. The measures taken became decisive in early 2022, as the level of financial stress exceeded that observed in early 2014 and early 2020 (Fig. 4). During the crisis, the NBU took a number of measures to ensure liquidity, including refinancing banks and introducing strict capital controls. The exchange rate was fixed and the decision on the discount rate was suspended, and the NBU financed the budget by UAH 400 billion, which caused inflation. In 2023, the National Bank of Ukraine stopped financing the budget, liberalized capital controls, and began lowering interest rates due to lower inflation. Since October, it has returned to a more flexible exchange rate, indicating renewed confidence in the economy.

In the fall of 2023, the National Bank of Ukraine presented the Financial Sector Development Strategy to prepare the industry for its future role in ensuring macroeconomic stability and economic recovery. Important elements are improving corporate governance, adapting to European Union standards, and assessing sustainability. In the world, banks usually finance economic growth, but this has not yet been implemented in Ukraine. The goals and objectives of this strategy are related to financial stability, macroeconomic stability, modern financial services, ensuring the smooth operation of regulators, and the Deposit Guarantee Fund (DGF), which should work to boost the Ukrainian economy [3]. The methodological features of the

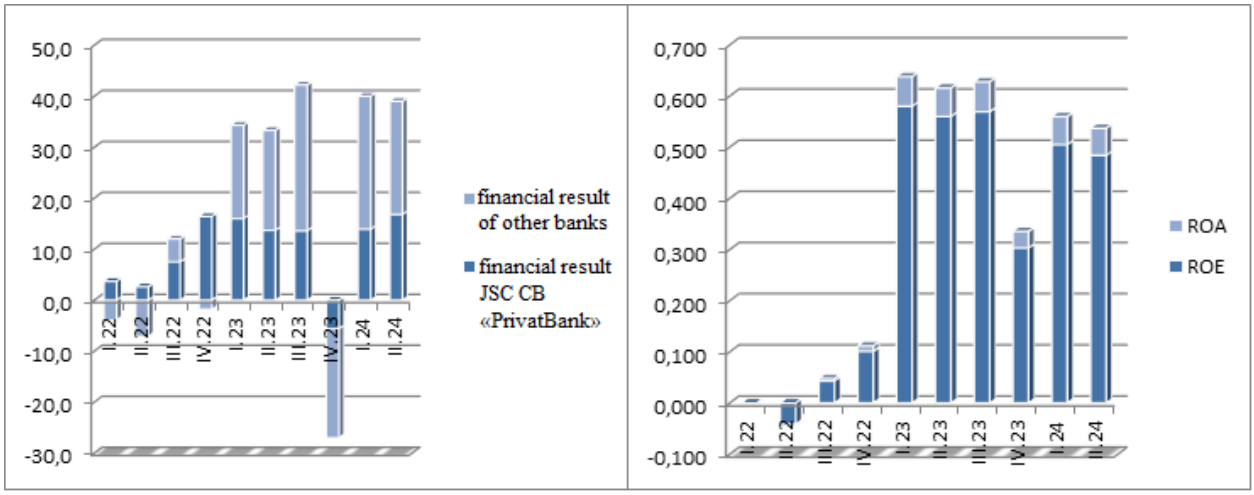

Fig. 3 – Financial performance and profitability of capital and assets of banks

Compiled based on [1]

Fig. 4 – Financial stress index for the banking sector

Compiled based on [1]

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Financial Sector Development Strategy to prepare the sector for its future role in ensuring macroeconomic stability and economic recovery are due to the uncertainty under which it was created. In this regard, flexibility is a key principle for both strategic planning and further implementation of measures. The Strategy provides for a long-term effect, until the completion of all planned measures, and may be revised in the event of significant changes in external conditions. In addition to direct measures provided for in the Strategy, references to measures from other strategic documents (reference measures) may also be included.

The digital transformation of the banking sector, which accelerated significantly in early 2020, has been one of the key reasons for its stability. Contactless payments and the use of Near Field Communication (NFC) technologies, which allow users to make transactions, exchange digital content, and connect electronic devices with a single touch, have grown dramatically (Fig. 5 – statistics were not collected during February-April 2022), and most banks have integrated Apple Pay. This has contributed to improving access to banking services and supporting the economy, especially in early 2022, when mobility became extremely relevant for Ukrainians. Digital technologies play a crucial role in ensuring the smooth operation of the sector and strengthening trust in it. At the end of 2023, a total of 7,91 billion transactions were made using payment cards issued by Ukrainian banks. The total volume of such transactions reached UAH 6,14 trillion. The majority of these transactions were carried out in Ukraine (almost 92% in number and 90% in amount). Total, 7,39 billion non-cash transactions were carried out outside and within Ukraine for the amount of UAH 3,98 trillion, with 65% of these transactions being non-cash transactions with cards. The number of ATMs also increased by 2%, reaching 15,8 thousand. It is worth noting the growth in the popularity of tokenized payment cards (NFC technology), the number of which increased by 57% to 12,4 million.

The most common non-cash transaction using payment cards is payments with terminals (Fig. 6). Of all the amounts of non-cash transactions, it accounts for 46% (451,0 billion UAH) and 72% (1 328,7 million items) of the number of non-cash transactions, the average check is 339 UAH. Also, an equally popular operation is a card-to-card transfer – 32% (317,6 billion UAH) of the amount and 9% (165,1 million items) of the number, the average check is 1 923 UAH. And of course, paying for goods and services on the Internet is one of the biggest advantages of non-cash transactions and digitalization in general – 14% (140,1 billion UAH) of the amount and 14% (264,0 million items) of the number, the average check is 3 357 UAH. In 2023 and early 2024, despite the ongoing full-scale war, the majority of payment card transactions in Ukraine were carried out cashless. This is confirmed by statistical data for the year analyzed by the National Bank as part of its function of supervising the payment infrastructure, which covers transactions with cards issued by Ukrainian banks and financial institutions (Fig. 6).

Conclusions

Based on the analysis, it can be concluded that the banking sector of Ukraine, despite the challenges associated with economic instability, demonstrates high resilience and adaptability. The main goals of banking management remain ensuring profitability and reliability of banking operations. This is achieved through effective risk management and maintaining stable profitability.

In recent years, the number of banks has decreased only slightly, which indicates the absence of a critical impact on the structure of the banking sector. Positive trends are also observed in key financial indicators: net assets of solvent banks are increasing, the volume of non-cash transactions is growing, and a high level of profitability of assets and capital is maintained.

Key factors of stability were the prompt anti-crisis measures taken by the National Bank of Ukraine.

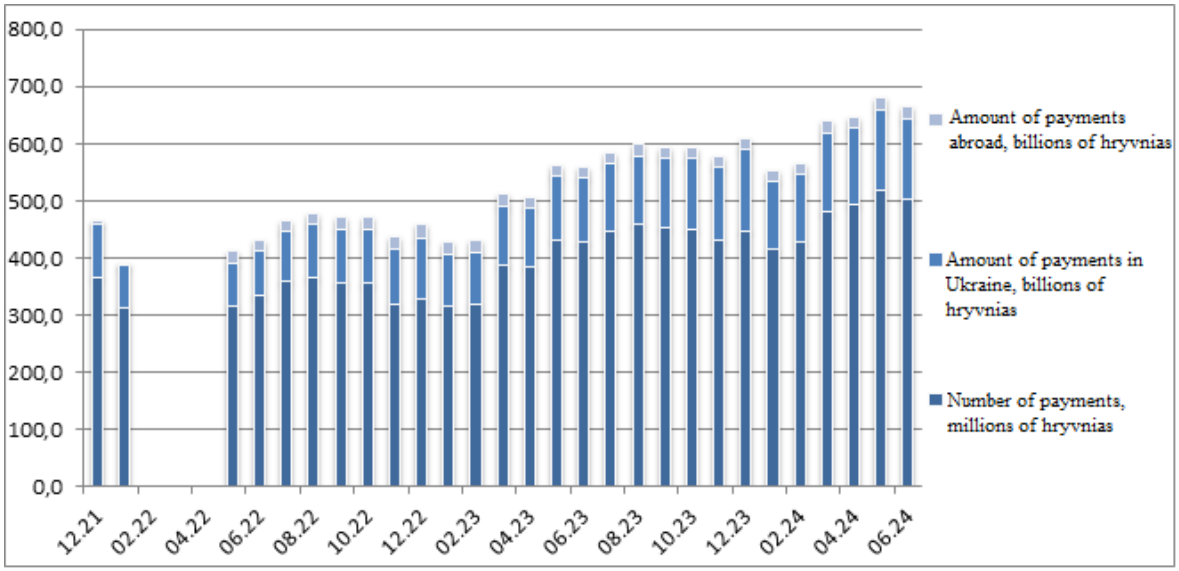

Fig. 5 – Payment cards in the retail network

Compiled based on [1]

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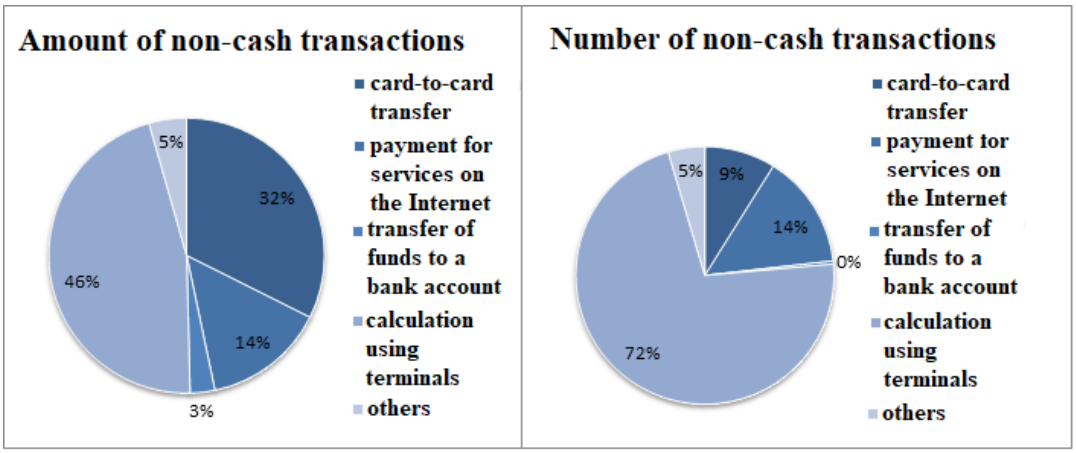

Fig. 6 – Amount and number of non-cash transactions using payment cards at the beginning of 2024
Compiled based on [1]

This includes both supporting banks' liquidity through refinancing and strict control over capital flows during the most stressful periods. Digital transformation, in particular the development of contactless payments and the use of NFC technologies, also significantly contributed to supporting the banking system during this difficult period.

Thus, the coordinated actions of bank management and the state regulator ensured the stable operation of the banking sector, which allows not only to support the country's economic activity, but also creates prospects for the further restoration and development of the financial system of Ukraine.

The need to continue strategic reforms, in particular towards integration with European standards, as well as maintaining macroeconomic stability are key tasks to ensure the long-term sustainability of the sector.

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SWAPS AND THEIR FEATURES OF TRADE IN THE EU

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Key words:
interest rate swap, currency swap, commodity swap, equity swap, debt-equity swap, total return swap, credit default swap, Eropean Union.

The foreign exchange market size is expected to see strong growth in the next few years. It will grow to $1106.49 billion in 2029 at a compound annual growth rate (CAGR) of 7.2%. The growth in the forecast period can be attributed to political and geopolitical developments, commodity prices and resource exports, pandemic recovery and risk appetite, inflationary pressures, emerging market dynamics. Major trends in the forecast period include rise of retail forex trading, enhanced risk management strategies, global economic recovery impact, focus on ESG (environmental, social, governance), technological infrastructure investments. The surge in international transactions is significantly contributing to the growth of the foreign exchange market going forward. International transactions refer to transactions involving two or more related businesses in which at least one party is a non-resident. Increased global trade and international transactions increase the size and activity of the foreign exchange market. For instance, in August 2024, according to Convera Corporation, a US-based Web services corporation, the wholesale cross-border payments market is projected to grow by 54%, from $146 trillion in 2023 to $225 trillion by 2030. In contrast, non-wholesale (retail) payment flows are expected to rise by 45%, reaching $65 trillion. Therefore, a surge in international transactions will drive the foreign exchange market. The increasing terrorism threats is expected to propel the growth of the foreign exchange market going forward. Terrorism threats refer to the potential risks and dangers posed by individuals, groups, or organizations that engage in acts of terrorism. Terrorism events can lead to a rise in safe-haven demand for currencies, increased geopolitical and economic risks, monetary policy responses, international cooperation and information sharing, counter-terrorism financing initiatives, and flight to safe havens. For instance, in February 2024, according to the Institute for Economics and Peace, an Australia-based non-profit think tank, in 2023, deaths from terrorism in Israel reached an all-time high, with 1,210 people killed and 4,537 injured as a result of 20 terrorist attacks. Therefore, the increasing terrorism threats is driving the growth of the foreign exchange market.

СВОПИ ТА ОСОБЛИВОСТІ ЇХ ТОРГІВЛІ В ЄС

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Ключові слова:
відсотковий своп, валютний своп, товарний своп, своп на акції, своп на борг, своп на загальну дохідність, своп кредитного дефолту, Європейський Союз.

У статті досліджено роль та значення валютного ринку у формуванні цін на світові валюти; досліджено сутність поняття «міжнародний валютний ринок» та його структурні елементи. З'ясовано роль європейського валютного ринку на міжнародному валютному ринку. З'ясовано, що очікуваний розмір ринку іноземної валюти значно зросте в наступні кілька років, що можна пояснити політичними та геополітичними подіями, цінами на сировину та експортом ресурсів, відновленням пандемії та схильністю до ризику, інфляційним тиском, динамікою ринків, що розвиваються. Досліджено, що основні тенденції в майбутньому включають зростання роздрібної торгівлі валютою, покращені стратегії управління ризиками, вплив глобального економічного відновлення, зосередження на ESG (екологічні, соціальні, управління), інвестиції в технологічну інфраструктуру. Розкрито тлумачення визначення «своп» з різних точок зору. Досліджено типи свопів та з'ясовано їх економічне значення. Проаналізовано тенденцію торгівлі свопами EURIBOR між учасниками ринку єврозони, яка почала активізуватися в 2021 р. на тлі нормалізації монетарної політики ЄЦБNote. Виявлено, що чистий ризик свопів IRR значною мірою відображає потреби хеджування, пов'язані з зазначеною бізнес-моделлю. Зазначено, що зростання міжнародних операцій значною мірою сприятиме зростанню валютного ринку в майбутньому.

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Statement of the problem

Note that foreign exchange means the exchange of one currency for another at a predetermined exchange rate or foreign exchange rate. The foreign securities market, which has a nominal value of trillions of dollars, consists mainly of foreign exchange markets. They are used in currency pairs that are priced against each other. The main counterparties in foreign currency are reporting dealers, other financial institutions and non-financial clients. Reporting dealers refer to financial institutions that are active participants in the local and international derivatives and foreign exchange markets. There are some trade finance instruments, such as currency swaps and currency options, with some end users including individuals, retailers, corporate institutions and governments.

Analysis of recent studies and publications

A study of the peculiarities of the European currency market was conducted by prominent foreign experts: Alain Chaboud, Dagfinn Rime and Vladyslav Sushko [7], David Hudson [8]. Domestic scientists who studied the international currency market are Odinokova A. O., Grynko I. M. [9] and Shapran N.S. [10]. The issue of developing and substantiating areas of competent management of virtual asset trading using swap operations, which is currently not fully explored. Therefore, in view of this, there is a growing need to continue to improve and clarify the mechanism of conducting various swap operations on the European currency market in order to transfer the experience to the Ukrainian currency market.

Objectives of the article

The purpose of the article is to study the peculiarities of the European currency market and the company's accounts payable, justifying the need for a balanced management of them.

The main material of the research

The foreign exchange (FX) market, where the relative prices of the world's currencies are determined, is essential for international transactions in goods, services and financial assets. In addition, FX is often viewed as an asset class on its own. The end-users of the FX market are therefore comprised of a wide variety of financial and non-financial customers around the globe. The trading activity of these agents and their interaction with market intermediaries drives the process of exchange rate determination, which has an impact on virtually all international economic activity. As a result, the FX market is the largest financial market in the world. FX trading volumes are, for example, much larger than global equity market activity.

Measuring global trading activity presents a challenge as the global FX market is obviously not under a single jurisdiction. However, a comprehensive and authoritative source of information, albeit infrequent, is the Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity (the «Triennial»). The Triennial provides a snapshot of daily FX trading activity every third year in the month of April.2 The data for the Triennial are collected by central banks from bank-dealers in their jurisdictions and then aggregated, analyzed and published by the Bank for International Settlements (BIS). More frequent estimates can be obtained by using data from surveys conducted twice a year by foreign exchange committees (FXCs), industry groups sponsored by central banks in various countries [7, p. 3].

To fulfill the tasks, it is advisable to study the essence of the concept of «international currency market» and consider its structural elements. The international currency market is a system of currency relations within the framework of the world community, which is established by interstate agreements. The international currency market contains the following elements: functional forms of world money (reserve currencies); regime of mutual convertibility of currencies; regulation of the components of international currency liquidity (that is, the components of the country's gold and currency reserves, gold and the reserve position in the IMF); regulation and unification of forms of international accounts; interstate institutions that regulate currency relations within the framework of the world community; a network of international and national banks that carry out international settlements and credit operations [9, p. 41].

Foreign exchange markets are actually made up of many different markets, because the trade between individual currencies - say, the euro and the U.S. dollar - each constitutes a market. The foreign exchange markets are the original and oldest financial markets and remain the basis upon which the rest of the financial structure exists and is traded: foreign exchange markets provide international liquidity, preferably with relative stability [8].

A foreign exchange market is a 24-hour over-the-counter (OTC) and dealers' market, meaning that transactions are completed between two participants via telecommunications technology. The currency markets are also further divided into spot markets - which are for two-day settlements - and the forward, swap, interbank futures, and options markets.

The European foreign exchange market represents a complex network of tools and services designed to optimize the flow of capital, reduce risks and ensure the stability of the region's economy. One of such complex instruments is swaps. Therefore, to begin with, we will consider the essence of swap operations on the stock market from a theoretical point of view. Notably, interest rate derivative notional trade in the EU increased by 30.2% to $19.2 trillion in the first quarter of 2024, compared to $14.7 trillion in the first quarter of 2024. USD in the first quarter of 2023, which is 34.6% of the total European interest rate derivative that is conventionally traded [1, p.3].

Note that the concept of «swap is a derivative contract by which two parties exchange cash flows or obligations from two different instruments. Simply put, it is a contract to hedge risk through the exchange of payments. Such a contract can be concluded both on the organized market and outside it [2]».

In addition, the term «swap» is interpreted as «a financial exchange agreement under which one of the parties promises to make a series of payments with a set frequency in exchange for receiving another set of

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payments from the other party. These flows typically respond to interest payments based on the notional amount of the swap [3]».

Also in finance, the definition of «swap» is considered as «a derivative contract under which two parties agree to exchange cash flows or obligations from two different financial instruments. Swaps typically provide for cash flows based on a notional principal, such as a debt or security, but the underlying instrument can vary significantly [4]».

In our opinion, a swap is an arrangement in the form of a derivative contract entered into between two parties, where one of the parties undertakes to pay a series of payments in the form of cash flows or obligations at a fixed frequency based on a notional principal amount, such as debt or security, but the underlying instrument may differ significantly.

There are the following types of swaps: interest rate swap, currency swap, commodity swap, equity swap, debt-equity swap, total return swap and credit default swap. Therefore, each of them was considered in more detail in the table. 1 shows the types of swaps and their economic essence.

Interestingly, swaps can be traded over-the-counter (OTC), meaning they are negotiated and executed directly between two parties, rather than on an exchange. This allows for greater flexibility and customization of the swap contract, allowing parties to tailor the contract to their specific risk management strategies. These positive aspects may not be possible with standard exchange-traded derivatives.

Due to recent economic developments in the stock market in the EU, the use of currency swaps has become widespread. Interest rate swap activity in the euro area has increased sharply since 2021, reflecting the critical role of derivatives in managing interest rate risk as monetary policy expectations change. Interest rate swaps ("swaps") account for the largest share of the eurozone derivatives market. Between March 2021 and September 2022, and the gross notional EURIBOR swaps are the most traded and liquid derivatives used to hedge interest rate risk for euro-denominated exposures - increased by around 50% (Figure 1, panel a). While previous work identified how eurozone banks use swaps in part to manage their interest rate risk (IRR), this unit uses trade repository data on individual EURIBOR swaps between 2019 and 2022 to determine how risk is distributed across sectors in the swaps market or, in other words, who will pay the margin, to whom the rates should change. Eurozone banks are among the most active counterparties to EURIBOR swaps due to their role as market makers or the need to hedge interest rate risk. Banks tend to be net buyers of floating-rate payments, hedging exposure to their fixed-rate assets (Figure 1, panel B). Due to the clearing obligations for EURIBOR swaps, a significant proportion of trades are brokered by significant institutions, which in some cases also clear members of central clearing counterparties (CCPs). Almost all Eurozone banks are active in the EURIBOR swaps market; this is defined as the market makers of 26 large banks, which collectively exceed approximately 90% of the gross notional volume held by significant institutions.

Collectively, banks use swaps to hedge their interest rate exposures. Derivatives positions of ECB-supervised banks that experienced a negative IRR impact in the aggregate increase in value relative to market makers, non-euro CCPs and ECB-supervised banks that experienced a positive IRR impact after increase in interest rates.

Market makers are the main counterparty of SSM banks that were negatively affected by IRR (Figure 2, panel a). A parallel shift of 100 basis points in the yield curve results in a capital transfer (equivalent to a margin call) of around €33 billion from market makers to IRR-affected banks.

Accordingly, the derivative positions of ECB-supervised banks with a positive IRR effect on the aggregate depreciated compared to ECB-supervised banks with a negative IRR effect, non-euro area banks and other entities after the upgrade interest rates.

Investment funds, insurance companies and pension funds will have to make margin payments in case of rising interest rates. This is consistent with the latter sectors having maturity mismatches due to long-term liabilities

Table 1 – Types of swaps and their economic essence

Type of swaps	Meaning
Interest rate swap	An agreement between two parties to exchange different interest payments (calculated at fixed and floating interest rates) in the same currency during the term specified in the contract. The amount of the interest payment is calculated based on the amount, the interest rate and the corresponding interest period.
Currency swap	An agreement involving the exchange of cash flows denominated in different currencies agreed upon by the parties.
Commodity swap	It is used to exchange cash flows that depend on the price of the product. Since the price of goods is variable, the fixed price of the goods (for today) is exchanged for a floating price.
Equity swap	An agreement to exchange future cash flows between two parties, where one party generates a cash flow based on equity and the other party generates a notional fixed cash flow based on, for example, LIBOR.
Debt-equity swap	An agreement involving the exchange of cash flows generated by equity and debt capital.
Total return swap	An agreement in which the return on a particular asset is exchanged for a fixed interest rate. The party paying the fixed rate assumes the risk of a certain asset (including shares). For example, an investor may pay a party a fixed rate in exchange for access to shares, realizing capital gains and receiving dividends, if any.
Credit default swap	An agreement concluded for the purpose of hedging credit risk (default by the counterparty), although the buyer of protection may not bear the credit risk or bear it indirectly. This instrument belongs to the third wave of derivatives - credit derivative instruments, and will be discussed in the next publication.

Note: Compiled on the basis of [2]

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and relatively short-term assets, which means they use swaps to hedge basis interest rate risk. These sectors are net payers mainly of market makers and banks. Due to the over-the-counter nature of the swaps market, insurers and pension funds are primarily exposed to market makers. Foreign banks and CCPs are also important players in the swaps market. Large net transfers from market makers to foreign banks will occur after interest rates rise. Market makers and CCPs should be market neutral, but the former are relatively large and hedge their risks associated with banking activities.

When looking at stable sectoral risks, IRRs reflect the specifics of each sector's business model, but large margin payments during periods of low liquidity can pose risks to financial stability. This finding seems to indicate that most sectors use swaps to hedge their IRR. ECB-supervised banks with negative or positive IRR exposure (in their non-derivative banking book) hedged accordingly, while insurers and pension funds have negative net IRR exposure, with long-term liabilities and relatively shorter assets (Figure 2, panel b). Sudden changes in interest rates that cause margin payments can create financial stability

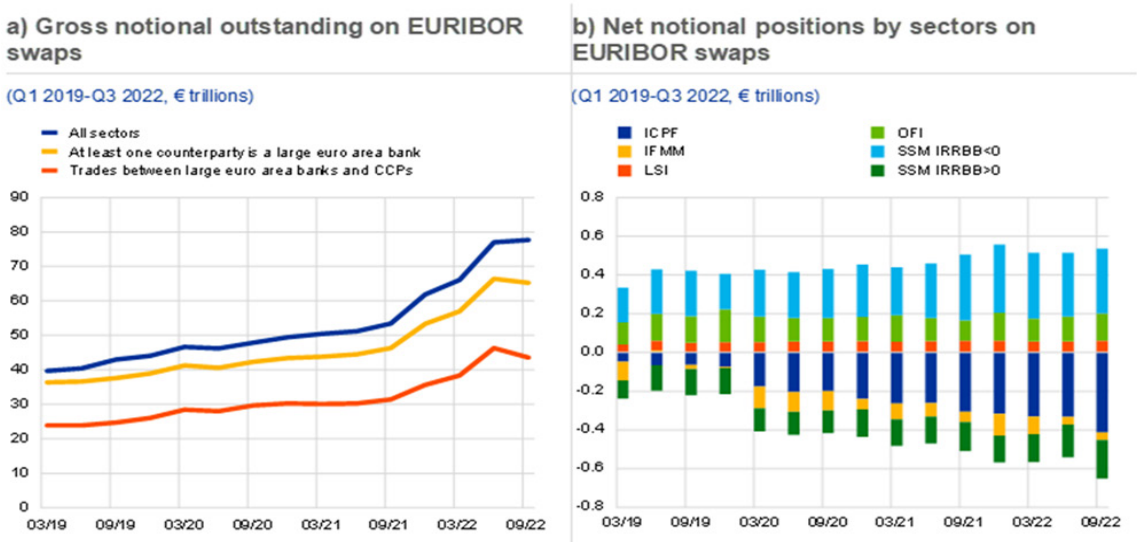

Fig. 1 – Trading in EURIBOR swaps between eurozone market participants began to intensify in 2021 against the backdrop of ECB monetary policy normalization

Note: Compiled on the basis of [5]

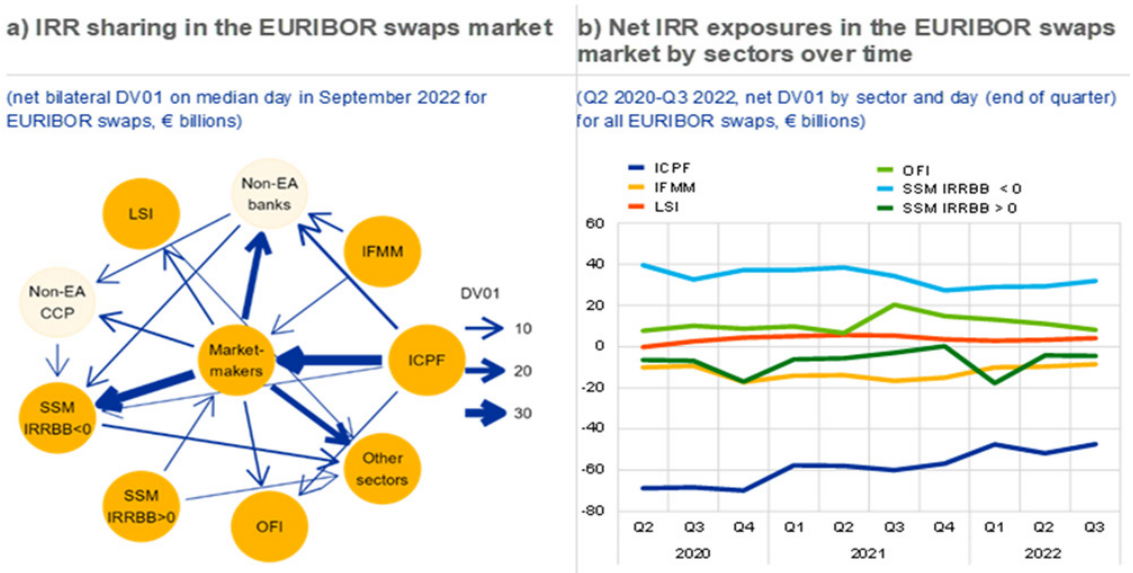

Fig. 2 – The net exposures of IRR swaps largely reflect the hedging needs associated with the business model

Note: Compiled on the basis of [5]

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problems in times of low market liquidity and if entities do not have access to sufficient liquidity.

According to the Euro Risk Free Rate Statement as of December 2, the CFTC's Market Risk Advisory Committee (MRAC) published Part II of the first cross-currency swap RFR initiative, which recommends the use of SOFR instead of USD LIBOR in all new cross-currency swaps beginning December 13, 2021 on the interdealer market at the LIBOR rate in US dollars [6].

There is currently a EUR Risk Free Rates Working Group (EUR RFR WG) which supports this initiative, recommends alignment with Part II in EU inter-dealer foreign exchange swap markets and recognizes that this helps market participants meet the objective of ending new use US dollar LIBOR rates at the end of 2021 (subject to certain risk management exceptions) as directed by the US and UK authorities.

In addition, the EUR RFR Working Group also recommends the adoption of €STR for cross-currency EUR-USD swaps in the EU interdealer market as of 13 December 2021.

After that, the periodicity of 7-day operations to ensure liquidity in US dollars as of May 1, 2023 was considered. Due to improved US dollar funding conditions and low demand for recent US dollar liquidity operations, the Bank of England, the Bank of Japan, the European Central Bank and the Swiss National Bank, after consultation with the Federal Reserve System, jointly decided to return the frequency of their 7-day operations from daily to once a week. This operational change became effective on May 7, 2023, and 7-day operations will be conducted according to published schedules [5].

Therefore, it can be concluded that central banks are ready to reconsider the provision of liquidity in US dollars, as market conditions require. Swap lines between these central banks are available permanent instruments and serve as an important liquidity support to ease the strain on global funding markets, thereby helping to mitigate the effects of such strains on the supply of credit to households and businesses both domestically and abroad.

Conclusions

The foreign exchange market size has grown strongly in recent years. It will grow from $792.43 billion in 2024 to $838.54 billion in 2025 at a compound annual growth rate (CAGR) of 5.8%. The growth in the historic period can be attributed to globalization and international trade, interest rate differentials, government policies and monetary interventions, speculation and investment flows, balance of payments and economic indicators.

The foreign exchange market size is expected to see strong growth in the next few years. It will grow to $1106.49 billion in 2029 at a compound annual growth rate (CAGR) of 7.2%. The growth in the forecast period can be attributed to political and geopolitical developments, commodity prices and resource exports, pandemic recovery and risk appetite, inflationary pressures, emerging market dynamics. Major trends in the forecast period include rise of retail forex trading, enhanced risk management strategies, global economic recovery impact, focus on ESG (environmental, social, governance), technological infrastructure investments.

The surge in international transactions is significantly contributing to the growth of the foreign exchange market going forward. International transactions refer to transactions involving two or more related businesses in which at least one party is a non-resident. Increased global trade and international transactions increase the size and activity of the foreign exchange market. For instance, in August 2024, according to Convera Corporation, a US-based Web services corporation, the wholesale cross-border payments market is projected to grow by 54%, from $146 trillion in 2023 to $225 trillion by 2030. In contrast, non-wholesale (retail) payment flows are expected to rise by 45%, reaching $65 trillion. Therefore, a surge in international transactions will drive the foreign exchange market.

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THE ROLE OF LOCAL GOVERNMENT BODIES IN ENSURING THE EFFECTIVENESS OF THE STATE PROGRAM FOR COMPENSATION OF COSTS FOR HUMANITARIAN DISTRIBUTION: LEGAL AND MANAGEMENT ANALYSIS

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Key words:
mine action, cost compensation, local governments, land relations, humanitarian demining, state agrarian register.

The article is devoted to the study of the legal, institutional and management aspects of the participation of local governments in the implementation of the state budget program for compensation of costs for humanitarian demining of agricultural lands. In the conditions of post-war reconstruction of Ukraine, this Program is one of the key mechanisms for returning potentially explosively contaminated lands to economic circulation, especially in communities that have suffered the direct consequences of hostilities. The article substantiates the relevance of expanding the role of local governments in this process, given their proximity to the needs of the population, the availability of information on the structure of land use and the ability to perform local coordination functions. The author analyzes a number of management barriers, in particular the so-called "chess fragmentation" of fields, restrictions on access to the Program of individual landowners who are not registered in the state agrarian register, and the absence of a mechanism for representing their interests. The methodological basis of the study is the comparative legal, functional and systemic approaches, as well as an analysis of the practice of applying the Resolution of the Cabinet of Ministers of Ukraine No. 284 of March 12, 2024. As a result, two options for a normative solution to the identified problems were formulated: 1) authorization of local governments to submit applications for the inclusion of additional areas in the specifications of contracts with mine action operators; 2) ensuring the right to consolidated participation of individual landowners through the representation of local governments.

РОЛЬ ОРГАНІВ МІСЦЕВОГО САМОВРЯДУВАННЯ У ЗАБЕЗПЕЧЕННІ ЕФЕКТИВНОСТІ ДЕРЖАВНОЇ ПРОГРАМИ КОМПЕНСАЦІЇ ВИТРАТ ЗА ГУМАНІТАРНЕ РОЗМІНУВАННЯ: ПРАВОВИЙ І УПРАВЛІНСЬКИЙ АНАЛІЗ

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Ключові слова:
протимінна діяльність, компенсація витрат, органи місцевого самоврядування, земельні відносини, гуманітарне розмінування, державний аграрний реєстр.

Стаття присвячена дослідженню правових, інституційних та управлінських аспектів участі органів місцевого самоврядування у реалізації державної бюджетної програми компенсації витрат за гуманітарне розмінування земель сільськогосподарського призначення. В умовах післявоєнного відновлення України дана Програма є одним із ключових механізмів повернення до господарського обігу потенційно забруднених вибухонебезпечними предметами земель, особливо у громадах, які зазнали безпосередніх наслідків бойових дій. У статті обґрунтовано актуальність розширення ролі органів місцевого самоврядування в цьому процесі з огляду на їхню близькість до потреб населення, наявність інформації про структуру землекористування та можливість виконання функцій локальної координації. Автор аналізує низку управлінських бар'єрів, зокрема так звану «шахматну фрагментацію» полів, обмеження доступу до Програми індивідуальних землевласників, які не зареєстровані в державному аграрному реєстрі, та відсутність механізму представництва їх інтересів. Методологічну базу дослідження становлять порівняльно-правовий, функціональний та системний підходи, а також аналіз практики застосування постанови Кабінету Міністрів України № 284 від 12 березня 2024 року. У результаті сформульовано два варіанти нормативного вирішення ідентифікованих проблем: 1) уповноваження органів місцевого самоврядування на подання клопотань про включення додаткових ділянок до специфікацій договорів з операторами протимінної діяльності; 2) забезпечення права на консолідовану участь індивідуальних землевласників через представництво органів місцевого самоврядування.

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Statement of the problem

In the context of the full-scale armed aggression of the Russian Federation against Ukraine, the issue of humanitarian demining has acquired critical importance not only as an element of national security, but also as a prerequisite for the economic and social recovery of the affected territories. According to the Ukrainian government, as of the beginning of 2025, more than 139 thousand square kilometers of territory are potentially contaminated with mines and explosive devices [5]. About a third of these territories are agricultural lands, which poses a serious threat to the agricultural sector, the state's food security and the livelihoods of rural communities.

In response to these challenges, the Government of Ukraine has introduced the program "Compensation of Expenses for Humanitarian Demining of Agricultural Land" (hereinafter referred to as the Program), approved by the Resolution of the Cabinet of Ministers of Ukraine dated March 12, 2024 No. 284 "On Approval of the Procedure for the Use of Funds Provided in the State Budget for Compensation of Expenses for Humanitarian Demining of Agricultural Land", which allowed for increased participation of national mine action operators. However, an analysis of the practical experience of implementing the Program reveals a number of legal and managerial problems that limit its effectiveness.

Formulation of the article's objectives

The purpose of this study is to determine the place and potential role of local governments in the implementation of the Program, analyze legal conflicts arising in the area of the distribution of powers, as well as formulate proposals for improving the regulatory model with the participation of territorial communities in the implementation of mechanisms for compensating for humanitarian demining costs.

The main material of the research

As noted, a separate subject of mine action whose competence will be focused on within the framework of the study is local governments.

Competence is one of the main properties of state executive bodies, local self-government and their officials. As is known, partial compliance or non-compliance with these constitutional principles during the formation and exercise of state power entails political and legal instability caused by contradictions and conflicts between the branches of power, higher, central and local authorities. The importance of qualitatively and precisely defined competence of state authorities and local self-government is undeniable [6, p. 32].

Executive and local self-government bodies are the largest group of public authorities that carry out executive and administrative activities in managing economic, administrative-political and socio-cultural sectors in the state, in order to ensure the rights and legitimate interests of citizens in various spheres of public life. The peculiarity of the executive branch of government is that it is in the process of its implementation that the real implementation of laws and other regulatory acts of the state, the practical application of all levers of state regulation and management of important processes of social development takes place [3, p. 22].

When analyzing the competencies of mine action subjects, it is necessary to focus especially on the specifics of determining the relevant powers of local state administrations and local self-government bodies.

As noted by V. Sokolov and D. Khyzhnyak, the Constitution of Ukraine has established two systems of local government, which is an established fact: local state administrations, which are local executive bodies, and local self-government as a public authority of territorial communities. These are different in their legal nature of local government systems, primarily in terms of functions and powers. The Constitution of Ukraine guarantees local self-government and thus does not allow its replacement by local state administrations [10, p. 144].

However, in the process of lawmaking, this distinction between local state administrations and local self-government bodies was ignored and as a result, local state administrations and local self-government bodies are endowed with the same competencies, in particular, the latter, in cooperation with central executive bodies, other state bodies and the national mine action body within the limits of their powers:

1) facilitate training in the risks associated with explosive objects;

2) facilitate the provision of medical care to injured persons and their medical rehabilitation;

3) inform the population about possible threats from explosive objects and measures that must be taken to avoid danger to the life and health of the population;

4) inform the population about the hazardous area marking systems installed in the relevant territories and the measures that must be taken to avoid danger to the life and health of the population, as well as monitor the condition of the installed hazardous area marking systems and their maintenance and inform the mine action center and the humanitarian demining center about cases of their damage, destruction, theft or other cases that make it impossible to further effectively use the hazardous area marking systems [9].

We, in turn, support the position I. V. Georgievsky, who indicates that before determining and consolidating the competence of state executive bodies and local self-government bodies, a theoretical model of the distribution of management functions should be developed, because only doctrinal analysis is able to take into account objective phenomena that affect and influence the transformation of the functional structure of these bodies. When determining the range of management functions that should be assigned to state executive bodies and local self-government bodies, it is advisable to take into account their affiliation with functions aimed at ensuring regional self-government, or functions that are delegated. The latter is associated with the process of decentralization of management, and the development of self-government functions means the redistribution of powers between central and regional subjects of management on a contractual basis [1, p. 35]. In general, the list of tasks indicated above contains duplication, unclear formulations and overlap

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of competencies of various authorities. Competencies in the field of training on the risks of explosive objects and general public information about threats partially overlap, so it would be advisable to define their boundaries, for example: training as organized activities, and information as the dissemination of general information. Similarly, information about threats and about hazardous area designation systems belong to related competencies and can be combined to avoid repetition.

The wording “facilitate” is too general and does not specify the mechanisms for implementing the competencies, which makes these tasks declarative. It is worth clarifying how the relevant competencies are implemented - through financing, organizing events, information support, etc.

The competence for providing medical care and rehabilitation belongs to the field of health care, so it is necessary to determine what exactly the role of local authorities is - in coordination, ensuring access, etc.

The implementation of the competence for monitoring hazardous area designation systems should include a clearly defined mechanism for its implementation. In particular, the procedure for transmitting information about damage or absence of marking signs should be standardized. For effective monitoring, it is necessary to provide access to relevant registers or databases containing information about the locations of such signs.

In fact, the Unified State Civil Protection System [4] already provides for the implementation of measures to identify, designate dangerous areas, inform the population about risks and maintain relevant warning signs in good condition. If the above measures are carried out precisely within the Unified Civil Protection System, it is worth assessing the need to separate this issue in the Law of Ukraine “On Mine Action in Ukraine”. In general, the analyzed competencies potentially coincide with the tasks of the civil protection system, which indicates duplication of norms and the need to harmonize legislation to avoid legal uncertainty.

Thus, the study of the competencies of local governments in the field of mine action reveals not only regulatory uncertainty and duplication of powers with other public authorities, but also the absence of clearly defined mechanisms for the implementation of these powers in practice. These problems are especially evident in the process of implementing state policy within the framework of the budget Program implemented by the Ministry of Economy of Ukraine as the main administrator of budget funds, and at the executive level - through the Humanitarian Demining Center. It has already proven itself as one of the effective tools for supporting the agro-industrial complex in the field of humanitarian demining.

The cumulative effect of the specified Program is not only in restoring the economic capacity of the agrarian sector, which is strategically important for Ukraine, but also stimulates the socio-economic recovery of the territorial communities of Ukraine affected by military aggression.

Another important result of the Program is that it stimulated the active formation of the Ukrainian national sector of mine action operators and the Ukrainian industry for the production of equipment and supplies for demining. In a short period of time, an effective part of the national mine action operators have proven their organizational, technological, financial capacity and efficiency.

At the same time, the analysis of the practice of its implementation allows us to identify a number of organizational and institutional barriers that prevent the achievement of the full effect.

One of such obstacles is the so-called fragmentation ("chess") of territories submitted by agricultural producers for demining work within the framework of the Program.

It is generally known that the cultivation of land plots by agricultural producers is carried out in whole arrays (fields), which almost always include land plots of several landowners or land users. This specificity of agricultural activity is taken into account in most legislative acts regulating land row, lease or sublease relations between land users and allow agricultural producers to exchange land plots to optimize and consolidate production efforts. At the same time, not all such consolidation actions undergo registration processes in the State Register of Real Rights to Real Estate (hereinafter – SRRE) [7] and, as a result, in the State Agrarian Register (hereinafter – SAR) [2; 8]. Thus, within the geographical boundaries of specific fields cultivated by one land user, there may be land plots registered under several other landowners or land users.

The process of non-technical survey of territories to determine areas suspected or contaminated with explosive objects (hereinafter referred to as NTO) does not depend on these circumstances, since NTO is focused on the presence of direct or indirect evidence of contamination of the territory and is carried out within the boundaries of the landfill contours (arrays, fields), which include all land plots that are “geographically” located on the corresponding landfill (field, array), without identifying certain land users. Such landfills may include not only cadastral land plots, but also the adjacent territory (field roads, ravines, forest belts, unidentified land plots without cadastral numbers, etc.).

At the same time, the work on demining (clearing) of land plots, which is provided for by the terms of the Program, is built on the principle of accurate identification of land users by means of SAR and SRRE. Agricultural producers can apply for inclusion in the Program only for those plots that are registered directly under them in the SAR (clause 9 of the Procedure). Thus, only a part of the land plots that are geographically located within the boundaries of one field (polygon, array, etc.) can be included in the application for demining.

For example, the geographical boundaries of a field with a total area of 20 hectares include 6 plots within the specific cadastral numbers of one land user and 4 - of another, while only one of these land users expressed a desire to participate in the Program. As a result, only a part (in our example - 6 out of 10) of the land plots that are actually located within the boundaries of one field (polygon, array, etc.) fall into the specification of the Demining Agreement with the relevant operator. In most cases, these “program” plots do not even always border each other, which creates the so-called “chess” effect.

In the above case, even after the complete completion of demining/clearance works, the field as a whole may

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remain unusable, since the demined areas actually border and alternate with the contaminated areas.

Given the above, it is possible to come to an obvious conclusion that a certain part of the lands that were demined within the framework of the Program are actually not returned to full-fledged use, or their use poses a threat to the life and health of at least the workers of the agricultural producer who cultivate it.

Thus, the goal of the Program to restore agricultural production on demined land plots is not fully achieved.

In turn, in order to fully achieve the goal of the Program, it is necessary to resolve the issue of finding a legal mechanism for including land plots located within the geographical boundaries of the field, but whose land users are persons who do not participate in the Program, among the areas included in the Specifications of contracts with mine action operators.

Taking into account the above, we propose to consider possible ways to resolve this issue, providing for the involvement of local governments in the Program, in particular:

1. Provide for the possibility of submitting applications by the executive body of local government to include land plots located within the geographical boundaries of the field, but whose land users are persons who do not participate in the Program, among the plots included in the Specification of Agreements with Mine Action Operators.

Organizationally, such an application can be sent in the form of scanned copies attached to the application of a specific land user in the SAR system, by direct submission by the local government to the Center or in response to the Center's request.

The basis for the formation of a petition from the executive body of local self-government may be a corresponding appeal of the land user, with justification of the belonging of the land plots to the boundaries of the relevant field (local self-government bodies have the necessary information for the unambiguous identification of each land plot, its belonging to the relevant field (polygon, array) and its relation to cultivation by a particular land user).

2. Provide the opportunity for an agricultural producer participating in the Program to enter "in manual mode" in the SAR system (requires technical refinement of the SAR system interface) additional land plots located within the geographical boundaries of the field, but the land users of the latter are persons who do not participate in the Program, to the number of plots included in Specifications of contracts with mine action operators (a document confirming this fact can be attached to the materials submitted for participation in the program, a certificate issued by the relevant executive body of local government confirming the location of individual plots within the relevant field).

In addition, involving local governments in participation in the Program can solve another important problem.

Today, many land plots (landfills, fields) are cultivated by landowners (so-called "shareholders") who are not agricultural producers or persons qualified for inclusion in the SAR.

According to official statistics, as of the end of 2024, almost 18 percent of agricultural land is cultivated by individual or family landowners, who, in turn, are not included in the number of entities that can participate in the Program. In addition, even if such an opportunity were provided to them, it would lead to the formation of a large number of applications for demining of areas with a total area of no more than 2-5 hectares.

In our opinion, the individual participation of such entities in the Program has a dubious organizational and economic feasibility, as it would lead to a significant increase in the cost of demining work. At the same time, this category of persons should not be deprived of the right to participate in the Program.

Summarizing the above, we consider it reasonable to foresee the possibility of consolidated participation of individual landowners who are not agricultural producers or persons qualified for inclusion in the SAR in the relevant Program. The representative entity of such consolidated participation may be the executive body of local government.

Conclusion

Thus, the effective implementation of state policy in the field of humanitarian demining requires not only the technical capacity of mine action operators and the availability of funding, but also an established mechanism of interaction between public authorities, in particular local governments. The analysis showed that these bodies can play a significant role in overcoming barriers associated with fragmentation of the land fund, limited access to the Program for individual landowners, and the lack of comprehensive coverage of fields. The proposed expansion of the powers of local governments — by granting them the right to submit petitions and represent the interests of persons who are not formally covered by the Program mechanisms — corresponds to the logic of decentralization and will contribute to a more complete achievement of its goals. Such an approach will not only increase the efficiency of the use of budget funds, but also ensure the real return of demined territories to economic use and the restoration of community life.

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LABOUR ECONOMICS, PERSONNEL MANAGEMENT AND MARKETING

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CLASSIFICATION OF SCIENTIFIC METHODS: A MODERN VIEW

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Key words:
research, methods, models, trends, digital technologies, techniques, science, development, enterprise.

The article reveals modern approaches to the classification of scientific methods in the context of global transformations in science and technology. It is noted that the existing classifications need to be revised to take into account interdisciplinarity, digital research tools and the subjective factor in the cognitive process. The author emphasizes the need to integrate quantitative, qualitative and digital methods to create adaptive hybrid methodologies. Examples of the use of Big Data, machine learning and interdisciplinary approach in the activities of leading companies (Amazon, Netflix, Google) are analyzed. The expediency of updating the methodological foundations through the development of new classification models that meet the challenges of the XXI century is substantiated. Ways to solve the problem of inconsistency between traditional approaches to methodological practice and the modern scientific environment are proposed. It is emphasized that only through a meaningful rethinking of the methods of cognition can science meet the dynamics of modern society, maintain openness to new knowledge and remain an effective tool for understanding complex reality. The article also emphasizes the role of the researcher's methodological culture as an important resource for adapting to the changing conditions of scientific activity and the effective use of interdisciplinary and digital potential.

КЛАСИФІКАЦІЯ НАУКОВИХ МЕТОДІВ: СУЧАСНИЙ ПОГЛЯД

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Ключові слова:
дослідження, методи, моделі, тенденції, цифрові технології, техніки, наука, розвиток, підприємство.

Розкрито сучасні підходи до класифікації наукових методів у контексті глобальних трансформацій у сфері науки та технологій. Зазначено, що наявні класифікації потребують перегляду з урахуванням інтердисциплінарності, цифрових інструментів досліджень і суб'єктивного чинника у пізнавальному процесі. Акцентовано увагу на необхідності інтеграції кількісних, якісних і цифрових методів задля створення адаптивних гібридних методологій. Проаналізовано приклади застосування Big Data, машинного навчання та інтердисциплінарного підходу у діяльності провідних компаній (Amazon, Netflix, Google). Обґрунтовано доцільність оновлення методологічних засад через розробку нових класифікаційних моделей, що відповідають викликам XXI століття. Запропоновано шляхи вирішення проблеми невідповідності традиційних підходів до методологічної практики сучасного наукового середовища. Підкреслено, що лише шляхом осмисленого переосмислення методів пізнання наука може відповідати динаміці сучасного суспільства, підтримувати відкритість до нових знань і залишатися ефективним інструментом пізнання складної реальності. У статті також акцентовано на ролі методологічної культури дослідника як важливого ресурсу адаптації до змінних умов наукової діяльності та ефективного використання міждисциплінарного й цифрового потенціалу.

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Statement of the problem

Despite the many attempts to create a single and universal system of classification of scientific methods, there is a problem of ambiguity in their interpretation and use in the context of modern scientific realities. This requires new approaches to the classification and synthesis of traditional and innovative methods.

Analysis of recent research and publications

A significant contribution to the classification of scientific methods was made by R. Merton, who developed the concept of "middle-range theories" [1], and T. Kuhn, who identified the concept of scientific paradigms [2]. The foundations of the modern systematization of scientific methods were developed in the works of F. Bacon [3], who described the empirical approach in science. Among Ukrainian researchers, it is worth noting S. Prysyazhnyuk, who dealt with the structure of scientific research [4], and T. Bichek, who studied the methods of systematic analysis [5].

Formulation of the objectives of the article

The purpose of the article is to highlight the current approaches to the classification of scientific methods, to identify their varieties and problems of interpretation in the context of modern scientific activity.

Summary of the main research material

Establishing a clear classification of scientific methods is an important factor in ensuring scientific credibility and innovation in research in the 21st century. Established classifications need to be adapted to changing realities, such as interdisciplinary research, digital technologies, and globalization processes.

Science as a form of human activity is characterized by strict requirements for research methods. The modern methodology considers the classification of scientific methods as a means of generalizing their meaning and role in scientific knowledge.

Modern scientific methods are conditionally classified according to various criteria:

1. By levels of scientific knowledge:

1) empirical methods (observation, experiment, measurement):

– observation is used in modern cognitive science research (e.g., observation of neural activity) [6]. For example, a system of observations at Nestlé of consumer behavior when testing new product flavors.

– experiment – widely used in creating virtual environments for testing hypotheses [7];

– measurement – is actively used in bioinformatics for accurate estimates of genomic changes [8]. For example, a system for measuring energy consumption at Tesla when testing new batteries.

2. Theoretical methods (analysis, synthesis, modeling, abstraction):

– analysis – used to decipher complex systems, for example, in big data analysis [9]. For example, big data analysis at Amazon to optimize supply chains;

– synthesis – used to collect and combine data in scientific visualizations [10]. For example, combining consumer data at Samsung to create new product models;

– modeling – is actively used to create artificial neural networks [11]. For example, creating models of consumer behavior at Netflix using artificial neural networks.

2) Abstraction – used to create a theoretical framework in meta-analysis [12]. For example, creating theoretical models of risks in the financial activities of Goldman Sachs.

2. By the nature of the research:

1) qualitative (descriptive, symbolic) methods: qualitative methods are focused on a deep understanding of the essence of phenomena and focus on texts, symbols and interpretations. For example, content analysis of customer reviews at Starbucks or analysis of evaluative comments by users of the Airbnb service [13];

2) quantitative (statistical, data processing methods) methods: quantitative methods are based on numerical data and statistical analyzes. For example, Facebook's use of A/B testing to evaluate the effectiveness of new features or Netflix's use of big data analysis to predict the success of movie productions [14].

3. By means of general logical cognition: analytical and synthetic methods:

– Analytical methods are used to break down complex phenomena into parts. For example: analysis of Amazon's sales by market segments [15];

– Synthetic methods ensure that parts are combined into complete systems. For example: synthesizing different data at Microsoft to create new services [16].

2) Induction and deduction:

– Induction is based on the accumulation of individual facts and their generalization. For example, a general conclusion about seasonal sales trends at Zara [17];

– deduction is used to apply general principles to specific cases. For example, the use of general supply models by Apple to organize its supply chains.

Modern trends in the development of science emphasize interdisciplinary methods, digital research techniques (big data, machine learning), and the awareness of the role of subjectivity in scientific knowledge:

– Interdisciplinary methods combine knowledge from different sciences to study complex problems in a comprehensive manner. For example, Google applies interdisciplinary approaches, combining computer science, psychology, and design in the development of user interfaces [18].

– digital research techniques:

1) Big Data: Amazon uses big data analysis to personalize recommendations and optimize logistics, which allows it to effectively predict consumer demand [18; 22];

2) machine learning: Netflix uses machine learning algorithms to create recommendation systems that predict viewer preferences based on their previous views [20; 21].

Modern science recognizes that complete objectivity is unattainable: data interpretation always has elements of subjectivity. At Airbnb, data analysts take into account subjective factors in customer reviews when assessing the quality of services and formulating proposals for service improvement [20].

Despite the existence of numerous classifications of scientific methods, there is a problem of their insufficient compliance with modern scientific challenges. Most

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traditional classifications do not take into account the development of digital technologies, an interdisciplinary approach and the subjective factor in the process of scientific knowledge, which creates difficulties in choosing adequate methodological tools for researchers, reduces the efficiency of research work and complicates interdisciplinary knowledge integration.

Based on the above, we can suggest ways to solve the problem:

1. Update the classifications of scientific methods to reflect the latest advances in digital technologies and interdisciplinary research.
2. Introduction of flexible and adaptive methodological models that allow combining quantitative, qualitative and digital methods.
3. Institutionalization of courses on the methodology of modern scientific knowledge in higher education programs.
4. Development of integrated research platforms that facilitate the use of Big Data, machine learning and interpretive methods simultaneously.

Thus, the classification of scientific methods is a necessary tool for orienting a researcher in a complex system of scientific knowledge. The modern approach requires taking into account the latest technological tools and interdisciplinary connections.

Conclusions

As a result of the study of current trends in the classification of scientific methods, it is established that traditional approaches no longer meet the dynamic conditions of modern scientific practice. The need to revise the methodological foundations is due to the active introduction of digital technologies, the strengthening of the interdisciplinary approach and the recognition of the role of the subjective factor in the cognitive process. The urgency of integrating qualitative, quantitative and digital methods emphasizes the importance of creating new hybrid methodologies.

In particular, the successful application of Big Data and machine learning methods at enterprises (e.g., Amazon, Netflix, Google) demonstrates the effectiveness of combining analytical tools with a deep understanding of human behavior. Companies that implement an interdisciplinary approach are better able to adapt to the complex environment of the modern market.

Therefore, further development of science requires not only the adaptation of existing methods but also the development of new classification models that can take into account the complexity of research objects, the digital transformation of knowledge, and the interconnection of objective and subjective factors.

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MODERN CHALLENGES AND PROSPECTS FOR THE FORMATION OF A STRATEGY FOR WORKING WITH PERSONNEL IN THE CONTEXT OF DIGITALIZATION[1]

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Key words:
Personnel management strategy, digitalization, personnel, human resource management, HR tools, digitalization of management processes.

The article reveals the current challenges and prospects for forming a strategy for working with personnel in the context of digitalization. Attention is focused on the importance of adapting HR practices to the rapidly changing digital environment, which significantly affects approaches to HR management. The key factors that determine the success of the introduction of digital technologies in the field of human resources management are analyzed, in particular, the development of digital literacy skills among employees, the use of the latest HR tools to automate processes, as well as the integration of digital platforms for effective communication and teamwork. The potential of digital solutions to improve recruiting, training, performance evaluation, and maintaining a healthy climate in the organization is identified. The risks arising from insufficient preparation of employees for digital changes and the need to constantly monitor the results of technology implementation to ensure their effectiveness are revealed. Based on the analysis, recommendations are made for organizations seeking to optimize their HR strategy in the context of digitalization.

СУЧАСНІ ВИКЛИКИ ТА ПЕРСПЕКТИВИ ФОРМУВАННЯ СТРАТЕГІЇ РОБОТИ З ПЕРСОНАЛОМ В УМОВАХ ЦИФРОВІЗАЦІЇ

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Ключові слова:
Стратегія управління персоналом, цифровізація, персонал, управління персоналом, HR-інструменти, цифровізація управлінських процесів.

Розкрито сучасні виклики та перспективи формування стратегії роботи з персоналом в умовах цифровізації. Акцентовано увагу на важливості адаптації кадрових практик до швидко змінюваного цифрового середовища, яке суттєво впливає на підходи до управління персоналом. Проаналізовано ключові фактори, що визначають успішність впровадження цифрових технологій у сфері управління кадрами, зокрема, розвиток навичок цифрової грамотності серед працівників, використання новітніх HR-інструментів для автоматизації процесів, а також інтеграція цифрових платформ для ефективної комунікації та взаємодії в колективі. Визначено потенціал цифрових рішень для покращення процесів рекрутингу, навчання, оцінки ефективності та підтримки здорового клімату в організації. Розкрито ризики, що виникають внаслідок недостатньої підготовленості працівників до цифрових змін та необхідність постійного моніторингу результатів впровадження технологій для забезпечення їх ефективності. На основі аналізу запропоновано рекомендації для організацій, які прагнуть оптимізувати стратегію роботи з персоналом в умовах цифровізації.

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Statement of the problem

In the modern realities of enterprises, the human factor is becoming increasingly important, along with technology and information, determining the level of their efficiency and competitiveness. Personnel development is an important component of the human resource management system. Despite the relative novelty of this concept, it is actively used in practice. Since employees' knowledge may lose relevance over time, it is necessary to ensure that it is constantly updated and improved in line with changes in the professional field. This makes it important to effectively manage personnel development both at the strategic level and as part of the day-to-day operations of enterprises.

Analysis of recent research and publications

The issue of staffing remains a key one in scientific research, as the quality of personnel directly affects the performance of enterprises and their competitiveness. A significant contribution to the study of the implementation of personnel development strategies in the context of digitalization has been made by such scholars as: Baluieva O. V., Snopenko G. V., Bey G. V., Sereda G. V. and Borysiak O., who consider innovative technologies in personnel management, in particular, automation of personnel processes. However, despite the in-depth analysis of the main aspects of HR management, the problem of managing quality processes in the field of HR management remains insufficiently addressed.

Formulation of the objectives of the article

The purpose of the article is to study the theoretical foundations of personnel development in the context of digital transformations and to develop recommendations for the practical implementation of this strategy.

Summary of the main research material

Human capital is the basis for the success of any organization. Its competitiveness depends on the level of qualification, initiative and responsibility of employees. Effective human resources management involves the continuous development of professional competencies, ensuring the flexibility of work organization, expanding opportunities for delegation of authority and forming partnerships between employees [5].

With the development of the economy, human resources management has become a strategic function requiring in-depth knowledge and experience. The main goal of the human resources management strategy is to form a cohesive, highly professional team capable of effectively implementing the overall goals of the organization and ensuring its long-term development [9].

The HR strategy has several key features: it has a long-term perspective, is closely linked to the overall strategy of the enterprise, and takes into account both internal and external factors of influence.

To effectively implement such a strategy, various tools are used, including personnel planning, development of personnel development programs, organization of training and career development, addressing social issues, and motivation and reward systems. The HR development strategy is directly linked to both the HR management strategy and the overall management strategy of the organization.

An important basis is the overall strategy of the enterprise, which should be the basis for both the HR management strategy and the employee development strategy. The concept of personnel development covers a set of methods, tools and organizational structures aimed at improving the skills of employees, preparing them for new responsibilities, career advancement, formation of a personnel reserve and overall development of the enterprise [6].

Effective management of personnel development is possible only if it is integrated into the overall personnel management system and closely linked to its other functions. At the same time, the goals of employee development should be consistent with the strategic goals of the enterprise.

Thus, the main goal of human resources development is to provide the company with qualified employees who meet the requirements of its strategy and contribute to the achievement of its goals.

The HR development strategy covers a set of organizational measures aimed at ensuring effective human resource management. It includes personnel assessments to ensure industrial adaptation, performance appraisals, career planning, and stimulation of employees' professional development. Those responsible for making management decisions implement these measures to achieve the organization's strategic goals. The elements of the enterprise personnel development process are shown in Fig. 1.

The elements of the personnel development system may differ depending on the specifics of the enterprise. The structure of HR development management is largely determined by the size of the organization. For example, small businesses often do not need to create a talent pool, and the process of onboarding new employees is simpler and does not require special measures. In addition, the specifics of an enterprise's activities also affect the formation of a human resources development system. In particular, service businesses usually have a greater need for ongoing staff training. In such cases, customers evaluate not only the final result, but also the process of providing services, which must meet modern standards and be competitive [3].

Personnel development covers three main areas: personal, social and professional, the benefits of which are shown in Fig. 2. 2. The formation of a staff development strategy becomes necessary under the influence of the following factors:

− reorganization, merger or acquisition of an enterprise;

− change in the strategic course of the organization, which requires new skills and qualities from employees

− the desire to strengthen market positions;

− identification of problems in the personnel management system;

− rapid obsolescence of knowledge, which requires regular updating of competencies;

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− employees' desire for self-development and unleashing their professional potential.

The following conditions must be met for the successful implementation of the HR development strategy:

− the need for staff development both in the current moment and in the long term;

− an effective system of motivation for development, which involves determining the competencies and abilities of employees;

− personal interest of employees in professional and personal growth[4].

The development and implementation of a personnel development strategy in accordance with certain stages helps to ensure that employees meet the requirements of the organization's overall development strategy.

The development and implementation of digital technologies affects not only all spheres of human activity, but also the organization and methods of doing business, in particular through online services, electronic payments, e-commerce, crowdfunding and other innovative technologies [1].

Digital transformation is also leading to the emergence of new professions and requires new knowledge and competencies that employees must have in the digital economy. The main goal of this transformation is to improve existing industries and create new ones, as well as to increase the efficiency of various processes and spheres of life through modern technologies. Digitalization makes it possible to speed up decision-making, expand the variety of processes to meet customer needs, and reduce the number of employees involved.

In the context of digitalization, HR technologies are key to the implementation of organizational policies. They greatly simplify and speed up the collection and transfer of information, improve communication with employees, and reduce administrative burdens, allowing HR departments to focus on more important functions. Studies show that organizations that effectively use digital tools for HR management have significant advantages over those that do not [3].

In today's environment, human resource management issues are gaining strategic importance for organizations. High competition puts personnel in the center of attention as the main subject and object of management. Digital transformations in the economy create new opportunities for modernizing HR technologies, which can significantly increase the efficiency of the enterprise. Well-known digital technologies that have an impact on the HR sphere include artificial intelligence, virtual reality, big data, blockchain, external and online storage.

The introduction of these technologies into the HR management process can significantly improve the efficiency of this process, which in turn helps to increase labor productivity and strengthen the human resources potential of the organization. The use of artificial intelligence systems allows analyzing the skills, behavior, and activities of the most effective employees, and based on the data obtained, developing individual educational trajectories for staff.

The use of virtual and augmented reality in the learning process can significantly improve the quality of education, making it more interactive and interesting.

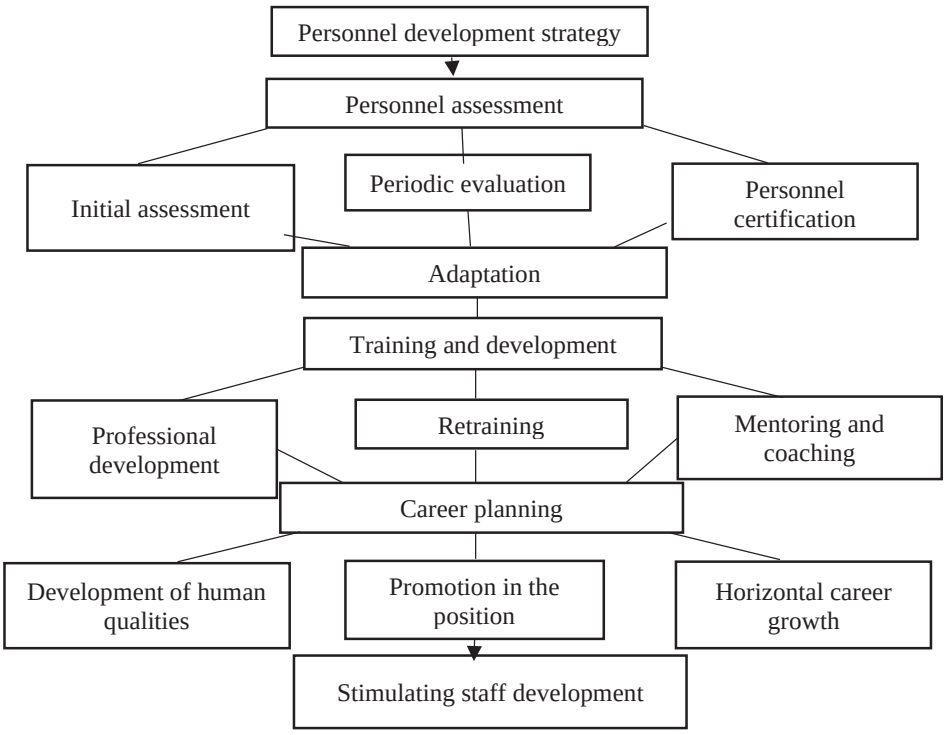

Fig. 1 – Scheme of the enterprise personnel development process
[developed by the authors]

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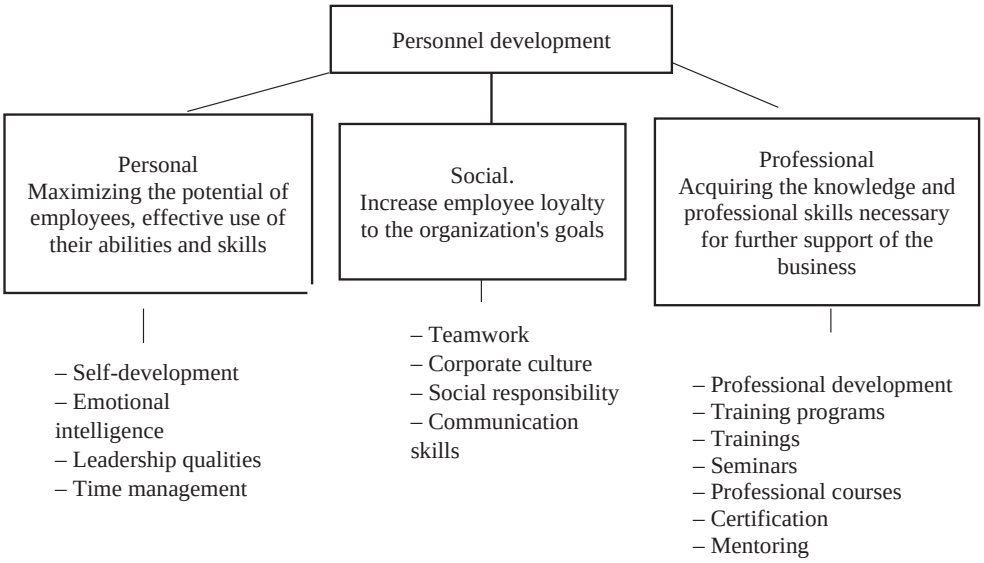

Fig. 2 – Benefits of identifying key areas of staff development.
[developed by the authors]

Modern digital technologies open up new opportunities for HR management, allowing you to simulate real-life situations in a virtual space. This ensures that employees are fully immersed in a learning environment where they can effectively practice their skills. Thanks to common technologies, information can be uploaded to the virtual space, giving every employee access to training materials. For example, online platforms can contain course catalogs and track staff performance [2].

The integration of blockchain technologies also has significant potential. They can be used to create services for storing resumes, certificates, diplomas, and professional achievements. This will significantly reduce the time required for HR professionals to search for candidates and verify the accuracy of their data.

The introduction of digital technologies in human resource management has a number of advantages. Automation and optimization of workflows reduce the workload of the HR department by providing specialists with effective tools for working with staff. In addition, HR management costs are reduced as many routine tasks can be automated using artificial intelligence. This is especially true for large companies, where digitalization allows reducing the number of HR employees and saving significant financial resources [5].

Digital systems also help minimize the impact of the human factor. Programs and applications work according to clearly defined algorithms, which reduces the likelihood of errors. They do not succumb to fatigue and do not depend on subjective factors, as can be the case with people.

Another important advantage is time savings. Software performs significant amounts of work much faster than humans. This frees up employees' time to perform more complex and creative tasks, while increasing the requirements for their qualifications. Thus, the introduction of digital technologies in the field of human resources management contributes to increasing work efficiency, reducing costs and optimizing business processes, which are key factors in the successful development of the company.

The digitalization of HR processes offers significant benefits, but at the same time comes with certain disadvantages and risks. One of the key disadvantages is the relatively high cost of implementing digital technologies. Not all organizations have sufficient budget to modernize and automate HR processes. However, these costs should be considered as a long-term investment that can not only pay off in the long run, but also bring additional business profit [2, 3].

Another significant risk is the reduction of jobs requiring medium and low qualifications as a result of full automation of labor processes. In addition, the high cost of errors also remains an urgent problem. Even the most advanced technologies are not immune to failures, and an error in algorithms can cause both financial losses and loss of important information.

The digitalization of HR processes also increases cybersecurity threats. Information presented in the virtual space can be subject to cyberattacks. Therefore, ensuring reliable data protection should be a priority when implementing digital solutions. However, it is worth noting that organizations do not have to develop the necessary HR services and programs on their own. The market offers a wide range of ready-made digital products for HR, the number of which is constantly growing [4; 10].

In general, the introduction of digital technologies in the field of human resources management has significant potential. Digital transformation is one of the key factors that will affect the HR sector in the coming years. The use of digital tools helps to increase the efficiency of work with personnel, automate and modernize work processes, as well as optimize time and financial resources in solving HR tasks.

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Conclusions

In today's realities, human resource management and the development of strategies for its development are becoming increasingly important. Digital technologies play a key role in this context. On the one hand, process automation is becoming a necessity to ensure security and stimulate economic development. On the other hand, it creates new challenges and problems. In addition, there is a growing focus on ethical aspects of management, which forces business leaders to focus not only on short-term economic performance, but also on environmental responsibility, staff development, strengthening corporate culture, and implementing innovative business approaches.

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PROJECT MANAGEMENT AND FINANCIAL AND ECONOMIC SECURITY IN THE CONDITIONS OF GLOBALIZATION

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ASSESSMENT OF THE POTENTIAL OF PUBLIC-PRIVATE PARTNERSHIP IN UKRAINE

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Key words:
public-private partnership (PPP), projects, problems, investments, legislation.

The article is devoted to analyzing public-private partnership (PPP) in Ukraine, which is an important tool for attracting investments and modernizing infrastructure, which requires urgent updating. In the context of economic challenges and limited budget resources, cooperation between the state and the private sector opens new opportunities for effective management of public services. The introduction of PPP reduces the financial burden on the state budget and provides access to the latest technologies and management practices. Emphasizes the importance of transparency in the field of PPP and the need to increase professional training. It also considers successful examples of project implementation in different sectors of the economy, such as health care, energy, and infrastructure. The historical development of public-private partnerships in the country has been investigated and legal achievements and current problems are covered. However, despite the positive results, there are also challenges such as legal ambiguity, corruption, and insufficient financial resources from the state that impede the successful implementation of PPP projects. Emphasis on these challenges can help you create the basis for understanding the need for comprehensive reforms. This article discusses the main aspects of public-private partnership in Ukraine, its advantages and disadvantages, as well as development prospects in the context of modern economic realities. Some examples testify to the potential of public-private partnerships in Ukraine to solve socio-economic problems and improve the quality of life of the population through effective cooperation between the state and the private sector.

The article mentions several projects related to the Public Private Partnership (PPP) in Ukraine in different sectors. One of the prominent examples is the project of reconTstruction of the M-05 Kiev-Odesa road. This project has encountered significant problems, including corruption scandals in trading processes and funding delays, which led to an increase in costs and a decrease in the quality of the final product.

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Another important area that has been emphasized is the healthcare partnership, where cooperation with private hospitals has shown the potential to improve the quality of patient care. These partnerships are recognized for their ability to provide quality services, despite the still unused potential of private companies in this sector.
In addition, projects covering renewable energy, in particular in the solar and wind energy sectors, are noted as significant steps towards improving energy security in Ukraine. Attracting private investors plays a crucial role in accelerating new technologies and reducing costs.
Moreover, the modernization of water supply infrastructure in Lviv is referred to as another project planned for 2018, but faced delays, mainly due to insufficient financial guarantees from the state, preventing private investors from making capital without clear indicators.
In general, these examples illustrate the diverse nature of PPP projects in Ukraine, demonstrating both the potential advantages and the different problems they face.

ОЦІНКА ПОТЕНЦІАЛУ ДЕРЖАВНО-ПРИВАТНОГО ПАРТНЕРСТВА В УКРАЇНІ

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Ключові слова: державне-приватне партнерство (ДПП), проєкти, проблеми, інвестиції, законодавство.

Стаття присвячена аналізу державного-приватного партнерства (ДПП) в Україні як важливого інструменту залучення інвестицій і модернізації інфраструктури, що потребує нагального оновлення. В умовах економічних викликів і обмежених бюджетних ресурсів співпраця між державою та приватним сектором відкриває нові можливості для ефективного управління суспільними послугами. Запровадження ДПП знижує фінансове навантаження на державний бюджет і забезпечує доступ до новітніх технологій та управлінських практик. Наголошується на важливості прозорості у сфері ДПП та необхідності підвищення рівня професійної підготовки. Також розглядаються успішні приклади реалізації проєктів у різних секторах економіки, таких як охорона здоров'я, енергетика та інфраструктура. Проаналізовано історичний розвиток державного-приватного партнерства в Україні, окреслено законодавчі досягнення та наявні проблеми. Водночас, незважаючи на позитивні результати, існують і проблеми, такі як правова невизначеність, корупція та недостатні фінансові ресурси з боку держави, що заважають успішній реалізації проєктів ДПП. Акцент на цих викликах дозволяє усвідомити необхідність комплексних реформ. У статті розглянуто основні аспекти державного-приватного партнерства в Україні, його переваги й недоліки, а також перспективи розвитку в контексті сучасних економічних реалій. Деякі приклади свідчать про потенціал ДПП в Україні у вирішенні соціально-економічних проблем та підвищенні якості життя населення шляхом ефективної співпраці між державою та приватним сектором.

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The purpose of the article is to study the peculiarities and mechanisms of PPP implementation in Ukraine, to consider the historical aspect, to analyze its impact on the country's economic development, and to assess the benefits and challenges faced by public and private partners. The article also aims to identify the key areas of PPP application, review examples of project implementation, and offer recommendations for improving cooperation between the state and business. The article highlights the importance of PPPs for attracting investment and modernizing infrastructure in Ukraine.

Analysis of recent research and publications

The study of public-private partnership is relevant, since it is precisely such relationships that ensure effective activity. Berezhnytska U. in the article "Small and Medium-Sized Entrepreneurship – an Institute for the Development of the National Economy" identified the problems, role and importance of small business for the national economy and the expediency of its development [1].

In the article Svirko S. V., Vlasiuk T. O., Shevchuk O. A., & Suprunova I. V. "Public-private partnership as a tool for innovative development of urbanized territories" the issue of public-private partnership in Ukraine is revealed and attention is focused on urban economy. A model for the development of public-private partnership in urbanized territories has been proposed and the mechanism of its implementation in the field of innovative development of urbanized territories has been improved [2].

Information on public-private partnerships in Ukraine can be found in a number of publications, including Malin O.L. 'Analysis of PPP Development in Ukraine and the World' [3], Ministry of Economy of Ukraine 'State of PPP Implementation in Ukraine' [4], as well as in numerous articles and research papers, several relevant laws of Ukraine are presented on legal support.In the monograph Nebrat V.V., Suprun N.A. a historical and institutional analysis of entrepreneurship in Ukraine is performed, the problems of small business are investigated and proposals are made for its activation and the need for public-private partnership [5].

However, the factors influencing the development of public-private partnership have not been studied. Therefore, the topic is relevant and timely.

Problem statement

Public-private partnerships (PPPs) in Ukraine are an important tool for attracting investment and modernizing infrastructure, but their development faces numerous challenges that need to be addressed urgently. Despite the adoption of legislation regulating relations between the state and the private sector, there are a number of obstacles that impede the effective implementation of PPP projects. The main problems include insufficient consistency of the regulatory framework, overlapping functions of various government agencies, and the lack of clear mechanisms to support private investors.

Summary of the main material

Public-private partnerships in Ukraine have developed under the influence of several factors. Its historical origins can be found in the early 2000s. This period saw the first attempts at cooperation between the state and private enterprises.

Firstly, in 2004, the Ministry of Economy developed the concept of public-private partnerships. It helped to create a legal environment for the development of this type of cooperation. The concept was an important step in attracting investment in socially important areas.

Secondly, in 2006-2010, Ukraine implemented its first PPP projects. These were mainly in the area of infrastructure. Thus, the construction of roads and bridges received a new face. Private companies began to be actively involved in the implementation of state projects.

However, the dynamic development of PPPs during this period was hampered by imperfect legislation. There were

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difficulties with tenders and a lack of clear implementation mechanisms. Many investors were hesitant to enter the Ukrainian market due to the uncertainty of the rules of the game.

In the early 2010s, the situation began to change. The Ukrainian government realized the importance of PPPs for economic and social infrastructure development. In 2010, the Law of Ukraine 'On Public-Private Partnership' was adopted. This was an important step towards formalizing cooperation between the state and business. The law defined the basic principles and mechanisms of PPPs, which helped to attract new investments. It established that partnerships can take various forms - concessions, joint venture agreements, construction financing, etc.

The next legal document is the Budget Code of Ukraine, which establishes the basic principles of financing PPP projects, including the sources of revenue and the procedure for using funds, which is important for risk management and guarantees of public funding.

As well, many projects are regulated locally through local government acts, which often make the regulatory framework more regionally specific.

However, the existence of a law alone does not solve all problems. In practice, difficulties arise due to the lack of development of specific by-laws. This makes it difficult to implement the plans.

In addition, the existence of numerous rules and regulations can lead to delays in project implementation. Often, ambiguities in legislation lead to litigation between the state and private partners.

Transparency is an important aspect of PPPs in Ukraine. Many investors raise questions about the fairness of the processes. Regular corruption scandals have become an obstacle to attracting new participants.

At the current stage, PPPs in Ukraine cover a variety of areas. From road and school construction to energy and healthcare development. Among the successful projects is cooperation in the healthcare sector. Partnerships with private hospitals have shown that together we can create high-quality conditions for patients.

The current state of PPPs in Ukraine requires focusing on a number of key points. First, it is important to raise awareness of PPP opportunities among businesses. Often, companies are not aware of the benefits they can gain. Second, government agencies need to improve communication with the private sector. Regular dialogue will help to resolve problems that arise in the course of implementing plans.

It is also important to educate PPP professionals. Training will contribute to a better understanding of the mechanisms and specifics of cooperation. Successful examples from other countries demonstrate that education is a key element in establishing effective public-private partnerships.

PPPs in Ukraine have great potential. The right steps in improving the efficiency of the system and legislation can stimulate economic development. Interaction between the government and business will create new opportunities for infrastructure development and improve the quality of life.

Taking into account the successful experience of foreign countries, it is important for Ukraine to continue to improve its regulations in this area. It is necessary to take into account best practices and create a system that guarantees legal purity and transparency.

Public-private partnerships in Ukraine face various challenges and constraints that hinder their development. These barriers prevent successful outcomes in PPP projects. Understanding these issues is important for formulating an effective strategy for implementing public-business partnerships.

One of the main problems is the lack of legal certainty. PPP legislation is frequently changed, which leads to uncertainty among investors. The absence of clear and consistent rules creates risks in the implementation of intentions. For example, in 2019, a legislative reform was introduced to improve the PPP environment. However, qualified investors continue to face uncertainty about the application of the new rules.

Corruption is another major barrier to PPP development. Corruption is caused by both imperfect legislation and the strong influence of political interests. In public procurement, corruption schemes lead to a decrease in transparency. This discourages investors who seek significantly higher standards of business conduct. Such problems impede fair tenders, making it difficult to attract private capital.

Insufficient professional training in the field of PPPs is also a factor. Many civil servants lack the necessary knowledge of PPP mechanisms. This leads to ineffective negotiations with private partners. Project teams consisting of qualified specialists are absent in many regions.

It is also important to note the lack of financial resources. The state often fails to provide adequate support for projects. Limited budgets make it difficult to implement large infrastructure programs. Private investors are not ready to invest without guarantees of return on investment.

The example of the M-05 Kyiv-Odesa road reconstruction project illustrates how these problems are linked to low efficiency. The original intention was to build new, safer roads. However, due to corruption scandals in tenders and delays in funding, the project was delayed for several years. This led to higher costs and lower quality of the final product. Uncertainty in legislation, corruption, and a lack of trained personnel are just some of the challenges investors face.

Under these conditions, businesses are only interested in short-term and most profitable ideas, the implementation of which is also part of the country's international obligations. An example of such projects is the facilities built for Euro 2012. In the preparation for and hosting of Euro 2012, no potential PPP projects were specially prepared and put out to tender in certain regions. Accordingly, no official PPP agreements were concluded in the context of the preparation and holding of Euro 2012. In their reports on PPP development, public authorities mostly present contracts that can only be conditionally classified as PPPs [6].

One of the projects that has faced difficulties is the construction of a renovated terminal at Boryspil Airport. The partnership with the private sector promised to improve the quality of service and increase passenger traffic. However, imperfect contracts and delays in implementation have raised serious questions about the project's success.

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Investors often point to confusion in tender procedures. In Ukraine, there are many regulations governing tenders. The accumulation of these regulations only complicates the process. Private companies are concerned about delays during auctions. There are often situations when tenders are canceled due to violations.

Another important project is the modernization of the water supply infrastructure in Lviv. The project was scheduled for 2018, but its implementation was delayed. The main problem was the lack of funding guarantees from the state. A private investor could not decide to invest capital without clear indicators.

In Ukraine, PPP projects are not always evaluated according to performance criteria. Many initiatives do not receive adequate analytical support, which leads to uncertainty about the results. This makes it difficult to assess their long-term viability.

In addition, the lack of transparency in tenders and subsequent project implementation also affects efficiency. Investors often feel the need to protect their interests. This situation complicates partnerships as businesses try to avoid potential risks.

There are also problems with the long-term strategy for PPP development. The lack of clear goals and strategy hinders investment attraction. Without addressing this gap, government policy will not have significant results.

Dialogues between government agencies and the private sector are necessary to identify common interests. This will allow for proper coordination of efforts within the plans. Changing the approach to project management is also an important element. Adopting new business practices can lead to more efficient implementation of PPP plans.

Problems with coordination between different government agencies do not contribute to the successful completion of projects. Interaction between ministries and local administrations is often insufficient. This leads to conflicts of interest. Investors do not receive clear guidelines, which further complicates obtaining permits and approvals.

Solving the problems of PPPs in Ukraine will require a comprehensive approach. It is necessary not only to improve the legislation but also to establish communication between all participants. It is important to create a mechanism that regulates the activities of project teams and provides them with training.

Undoubtedly, the main goal is to improve the investment climate. Increased transparency and security of projects will lead to increased trust from international partners. Attracting new resources will open up new opportunities for Ukraine.

Assessing the potential of PPPs in different sectors of Ukraine's economy should take into account the specifics and needs of each industry. For example, in the transport infrastructure sector, public-private partnerships can help modernize roads, bridges, and railways. The need for road repairs and construction is extremely urgent today. As of 2023, more than 50% of roads require capital investment. Implementation of PPP projects in this area will not only improve the quality of transport links but also attract the necessary investments for modernization.

In the energy sector, PPPs can ensure the rehabilitation and modernization of energy-generating facilities. Ukraine has significant potential in the renewable energy sector. Attracting private investors to develop solar and wind power plants is an important step towards energy security. Ukraine has already implemented over 1500 projects in this area with a total capacity of over 6 GW. Partnerships with the private sector can significantly accelerate the introduction of new technologies and reduce costs.

The healthcare sector also has great potential for development through PPPs. Attracting private investment will help modernize hospitals, purchase new equipment, and develop innovative medical services. Private companies are already involved in implementing projects in this area, but their potential has not yet been fully exploited. For example, ideas for public-private partnerships in the healthcare sector could include the construction of new hospitals or the development of outpatient services.

The education sector can also find applications for PPPs. Improving the infrastructure of educational institutions, implementing new educational programs, and IT-related projects can be successfully implemented through public-private partnerships. Partnerships with private companies will help improve the level of education and ensure that the technical equipment of educational institutions is updated.

Only the joint work of the state and business can ensure the successful implementation of projects and changes in the lives of Ukrainians.

Public-private partnerships in Ukraine have a huge potential for the development of various sectors of the economy. This mechanism of interaction between the state and the private sector opens up new opportunities for investment and modernization of important infrastructure facilities. The existing PPP system in Ukraine can be characterized by best practices that can serve as a basis for further development and implementation of projects in many areas.

An analysis of the experience of successful implementation of public-private partnership projects by European governments has shown that several conditions are required for positive results from their implementation:

– a stable political situation in the country, as it is very important that the public sector is unchanged and clearly defines what it wants;

– clear and transparent ‘rules of the game’, i.e. the rights and obligations of the state and the private partner, which should be enshrined in legislative acts;

– introduction of the most favored nation regime for the private partner, introduction of tax benefits, exemption from concession payments for the first 5 years of the public-private partnership project;

– the principle of non-interference of the state in the economic activities of the private partner;

– providing guarantees for the preservation of investments and private property, regardless of which political force is in power;

– preservation of state and municipal ownership of facilities while introducing mechanisms for infrastructure management by private partners;

– openness and transparency of the activities of state and local authorities in identifying private partners;

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– ensuring the provision of high-quality and low-cost services as an indicator of the effectiveness and efficiency of public-private partnerships;

– combining resources of financial and credit institutions under the guarantees of state and local authorities;

– distribution of risks, definition of obligations and responsibilities in the public-private partnership agreement;

– protecting the interests and meeting the needs of the community, controlling the quality of services provided by private partners, discussing and monitoring projects involving NGOs [7].

Based on this experience, Ukraine can improve its PPP practices, but it needs to expand the list of suggestions based on its characteristics.

One of the main suggestions is to improve legislation. A clear and stable legal framework is critical to attracting investors. Selecting legislative initiatives that will simplify procedures and minimize bureaucracy can radically improve the situation. Legislation should be adapted to current market conditions, taking into account the needs of investors.

Education and training of PPP personnel is also an important element. The creation of educational programs that include all stakeholders - civil servants, private sector representatives, and experts - will help to increase the level of knowledge about PPP mechanisms and principles.

More attractive conditions for investors should be created to attract capital. The use of public-private financing mechanisms, the availability of state guarantees, and a reduction in the tax burden on investors are just some of the possible solutions.

To address the problem of corruption, it is necessary to ensure fairness in tender procedures, transparency in determining the winners, and publicity of project information. Establishing independent oversight bodies for PPP programs should be a priority.

It is also important to create platforms for dialogue between government agencies and the private sector. Regular meetings, conferences and discussions on ways to develop PPPs will contribute to better understanding between all participants in the process. This will allow for a prompt response to problems that arise during project implementation.

Involving international partners to exchange experience will be useful. Ukraine can study PPP mechanisms that are successfully used in other countries. For example, Poland's experience in the field of partnership in transport infrastructure can be a valuable lesson for Ukrainian experts and government structures.

The prospects for PPP development in Ukraine are great and can become a driving force for the modernization of the economy, development of infrastructure and improvement of the quality of life, because the existing problems are not insurmountable, and efforts aimed at solving them, together with the active participation of the state, support of investors and a sincere desire to work, can significantly improve the situation and change the future of Ukraine for the better.

Research results

The effectiveness of PPPs depends significantly on the creation of a stable legal framework. The presence of clear and transparent rules defining the rights and obligations of the government and private partners is important for building investor confidence. Recommendations are provided for a reliable regulatory environment that minimizes current fluctuations.

The study highlights the critical problem of insufficient financial resources available to the state, which is an obstacle to the implementation of significant infrastructure projects. Limited budgetary opportunities limit the implementation of major initiatives, which, in turn, discourages private investors from making commitments without guarantees of profit.

In addition, the article identifies corruption as a major problem that undermines the integrity of public procurement and transparency within PPPs. This corruption leads to a lack of trust among potential investors who prefer an ethical business environment.

Another important finding is poor coordination between government agencies involved in PPP initiatives. Such disorganization complicates project completion and creates conflicts of interest, hindering effective cooperation between the public and private sectors.

Conclusions

The significant potential of PPP in Ukraine requires a comprehensive approach to implementation. The development of clear regulatory and legal acts that regulate the processes of public-private partnership, as well as the promotion of relevant education and training, are critically important for the development of this sector. It is noted that without the active participation of the state, it is impossible to ensure the stability of the functioning of PPPs.

Recommendations for improving legislation and practice for the implementation of PPP plans in Ukraine are based on the need to create transparent and stable conditions for investors. This includes simplifying the procedures for registering projects, as well as ensuring access to information about existing projects. The development of clear criteria for selecting investors will reduce the risk of corruption and help increase trust in the PPP system.

In addition, the presence of independent bodies for monitoring PPP projects can help ensure transparency and accountability. Such bodies should be able to assess the effectiveness of programs at all stages of their implementation.

Therefore, effective public-private partnerships can become an important tool for the development of Ukraine's economy if a systematic approach to the implementation and support of such ideas is ensured. This will allow Ukraine to realize its strong potential for economic growth and social development.

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STRUCTURE AND MAIN COMPONENTS OF THE SYSTEM OF FINANCIAL AND ECONOMIC SECURITY OF INDUSTRIAL ENTERPRISES

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Key words:
security, financial and economic security, strategy, enterprise, industrial sector, resources, crisis management, profit, sustainable development, protection of financial systems, financial monitoring, investment security.

The importance of the concept of "financial and economic security" for industrial enterprises is analyzed. A number of unresolved problems of many Ukrainian industrial enterprises that have adapted to new conditions and are implementing innovative financial and security solutions are highlighted. The author characterizes Ukrainian and world scientists who have made a significant contribution to the development of theoretical and practical aspects of financial and economic security of enterprises. A number of elements are identified and characterized, each of which plays an important role in maintaining the financial stability and competitiveness of an industrial enterprise. The main problems in the field of financial and economic security of enterprises are substantiated. The main factors that determined the state of the industrial sector are identified, in particular: the impact of hostilities, economic instability and the need to adapt to wartime conditions. It is characterized that the period of 2022-2024 was a test for industrial enterprises of Ukraine, but at the same time stimulated them to introduce new approaches to ensuring financial and economic security and adaptation to difficult conditions. The author makes assumptions about the industrial sector of Ukraine in 2025, which will continue to adapt to new realities. The European countries that demonstrate a high level of digitalization and integration of financial technologies (FinTech) in ensuring economic security are analyzed. The main trends in European countries are characterized. The main problems of financial and economic security of enterprises are identified and characterized. Suggestions for improving the system of financial and economic security of industrial enterprises in Ukraine are provided. Conclusions on ensuring the stable development of industrial enterprises and increasing their competitiveness are provided.

СТРУКТУРА ТА ОСНОВНІ СКЛАДОВІ ЕЛЕМЕНТИ СИСТЕМИ ФІНАНСОВО-ЕКОНОМІЧНОЇ БЕЗПЕКИ ПРОМИСЛОВИХ ПІДПРИЄМСТВ

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Ключові слова:
безпека, фінансово-економічна безпека, стратегія, підприємство, промисловий сектор, ресурси, антикризове управління, прибуток, стійкий розвиток, захист фінансових систем, фінансовий моніторинг, інвестиційна безпека.

Проаналізовано важливість поняття «фінансово-економічна безпека» для промислових підприємств. Виокремлено низку невирішених проблем багатьох українських промислових підприємств, які адаптувалися до нових умов і впроваджують інноваційні фінансові та безпекові рішення. Охарактеризовано українських на світових науковців, які зробили значний внесок у розвиток теоретичних та практичних аспектів фінансово-економічної безпеки підприємств. Виокремлено та охарактеризовано низку елементів, кожен з яких виконує важливу роль у збереженні фінансової стійкості та конкурентоспроможності промислового підприємства. Обґрунтовано основні проблеми у сфері фінансово-економічної безпеки підприємств. Визначено основні фактори, які визначали стан промислового сектору, зокрема: вплив воєнних дій, економічну нестабільність та необхідність адаптації до умов воєнного часу. Охарактеризовано, що, період 2022–2024 років став випробуванням для промислових підприємств України, проте водночас стимулював їх до впровадження нових підходів у забезпеченні фінансово-економічної безпеки та адаптації до складних умов.

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Надано припущення щодо промислового сектору України у 2025 році, який продовжить адаптацію до нових реалій. Проаналізовано Європейські країни, які демонструють високий рівень цифровізації та інтеграції фінансових технологій (FinTech) у забезпеченні економічної безпеки. Охарактеризовано основні тенденції Європейських країн. Визначено та охарактеризовано основні проблеми фінансово-економічної безпеки підприємств. Надано пропозиції щодо вдосконалення системи фінансово-економічної безпеки промислових підприємств в Україні. Надано висновки щодо забезпечення стабільного розвитку промислових підприємств та підвищення їх конкурентоспроможності.

Statement of the problem

The financial and economic security of industrial enterprises is an important factor in their sustainable development and competitiveness. In the context of modern challenges, such as military operations, global economic crises, sanctions pressure and technological changes, the issue of financial security is becoming a key task for industrial enterprises [5-6].

While many Ukrainian industrial enterprises have adapted to the new environment and are implementing innovative financial and security solutions, a number of unresolved issues remain:

1. The impact of external economic threats:
− military actions and destruction of industrial infrastructure, which lead to a reduction in production and an increase in costs;
− currency market instability and inflationary risks that complicate financial planning of enterprises;
− limited access to international financial markets and a decrease in Ukraine's investment attractiveness.
2. Insufficient level of financial control and crisis management:
− lack of an integrated approach to financial risk management at most enterprises;
− insufficient use of modern methods of financial monitoring and analytics;
− lack of flexible mechanisms for responding to financial threats and crises.
3. Growth of cyber threats:
− lack of effective cybersecurity measures at enterprises, which leads to the risk of loss of financial information;
− increase in attacks on financial systems of enterprises, which may lead to their destabilization;
− low level of digital literacy of employees in the field of financial security.
4. Limited financing and investment security:
− lack of available credit resources for the development of industrial enterprises;
− uncertainty about future macroeconomic conditions, which hinders long-term financial planning;
− lack of sufficient state support for the industrial sector in the area of financial security.
5. Regulatory and legal issues:
− low efficiency of legislative mechanisms in the field of financial control and economic security;
− lack of incentives for the introduction of modern financial and analytical systems;
− high level of bureaucracy and administrative burden on industrial enterprises.

Based on the above, it should be noted that the current challenges faced by Ukrainian industrial enterprises require a revision of approaches to ensuring financial and economic security. The need to strengthen crisis management, digital transformation of the financial sector, efficient use of resources, and integration into the international financial system are key areas for further research and development of practical solutions.

Analysis of recent research and publications

A significant contribution to the development of theoretical and practical aspects of financial and economic security was made by such Ukrainian scholars as: Heets V. M. [1], who studied macroeconomic stability and financial risks; Hryniova V. M., who dealt with the issues of economic sustainability of enterprises; Dashko I. M. [2; 3; 5], who studies the issues of financial and economic security of industrial enterprises and her scientific works are focused on the development of theoretical and practical aspects of ensuring the financial and economic security of industrial enterprises in order to increase their competitiveness and sustainability in the face of dynamic changes in the external environment, development of strategies to ensure competitive; Cherep A. V. [5; 6; 13] – is a leading Ukrainian scientist in the field of financial and economic security of industrial enterprises, her scientific interests cover a wide range of issues related to economics, entrepreneurship and financial management, in particular, in the monograph "Financial and Economic Security of Industrial Enterprises" she analyzed the current challenges and threats facing industrial enterprises and proposed strategies to ensure their financial stability; Chechetov M. V. [7] – analyzed the management of economic security of enterprises; Shvydanenko H. O. – studied corporate aspects of financial security.

At the international level, a significant contribution was made by: Porter M. (USA), who developed a model of competitive strategies to improve economic security; Kaplan R. & Norton D. (USA) [8] – created the concept of a balanced scorecard (BSC), which is used to analyze economic security; Beck T. (Germany) [10] – studied financial security and banking risks; Stiglitz J. (USA) [9] – analyzed financial crises and risk management mechanisms, but there are unresolved issues from this study that need to be disclosed and suggestions for improvement.

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Formulation of the objectives of the article

The purpose of the study is to develop the theoretical and practical foundations for ensuring the financial and economic security of industrial enterprises, to analyze its main components, to identify modern threats and to formulate strategies for minimizing risks.

Summary of the main research material

In the context of globalization, unstable economic situation and increased competition, the financial and economic security of industrial enterprises is of particular importance. Modern enterprises are forced to adapt to new challenges, such as financial crises, sanctions policy, cyber attacks, inflationary processes, changes in legislative regulation and currency market instability.

In Ukraine, the situation is complicated by factors such as high dependence on foreign markets, instability of the banking sector, limited access to cheap credit, and low digital security of enterprises. The absence of an effective financial monitoring and risk management system can lead to company bankruptcies, loss of investment, and weakening of competitive positions in the international market.

Financial and economic security is the key to sustainable operation of enterprises, efficient use of resources and their adaptation to changes in the external environment. Development of effective financial security strategies is a key task of modern management and economic policy of the state [13].

The system of financial and economic security of an enterprise consists of a number of elements, each of which plays an important role in maintaining financial stability and competitiveness (Table 1):

According to the World Bank and the State Statistics Service of Ukraine, the main problems in the area of financial and economic security are:

− instability of financial flows due to the economic crisis;

− insufficient funding for information security measures;

− lack of a systematic approach to investment risk management;

− high level of corruption in the field of enterprise resource management [12].

In 2022-2024, Ukrainian industrial enterprises faced a number of challenges that significantly affected their financial and economic security. The main factors that determined the state of the industrial sector include the impact of hostilities, economic instability, and the need to adapt to wartime conditions:

1. The impact of hostilities and economic adaptation: Russia's full-scale invasion of Ukraine in 2022 resulted in significant damage to industrial infrastructure, especially in the east and south of the country. Many businesses were forced to suspend operations or relocate production facilities to safer regions. This led to a decline in production and revenues. In 2022, only 56% of industrial enterprises made a profit, while in 2021 this figure was 75.5% [1].

In response to these challenges, businesses began implementing strategies to adapt to wartime conditions. This included reorientation to manufacturing products for defense needs, cost optimization, and the search for new markets. The state, for its part, introduced support programs aimed at restoring and developing the industrial sector in the wartime environment [4].

2. Financial and economic security and risk management: In the context of the crisis, the issue of financial and economic security has become particularly relevant. Companies focused on developing and implementing risk management systems aimed at minimizing financial losses and ensuring business sustainability. Key measures included diversification of suppliers, introduction of modern cybersecurity technologies, and strengthening of internal control [2].

3. The role of cybersecurity: The growing dependence on digital technologies has increased the importance of cybersecurity. The increase in the number of cyberattacks on industrial enterprises required the introduction of modern means of protecting information systems and training personnel in the basics of cyber hygiene. This has become an integral part of ensuring the financial and economic security of enterprises [3].

It should be noted that the period of 2022-2024 was a test for Ukrainian industrial enterprises, but at the same time stimulated them to introduce new approaches to ensuring financial and economic security and adaptation to difficult conditions [7-8].

It is expected that in 2025, Ukraine's industrial sector will continue to adapt to new realities. Priority areas will be the restoration of destroyed enterprises, the introduction of innovative technologies and integration into European markets, while ensuring financial and economic security will remain a key factor in the sustainable development of industrial enterprises in the post-crisis period.

Analyzing European countries, we can say that they demonstrate a high level of digitalization and integration of financial technologies (FinTech) in ensuring economic security, where the main trends are:

− use of artificial intelligence for financial monitoring;

− introduction of cybersecurity standards to protect financial systems;

− active involvement of ESG (environmental, social and corporate governance) tools in the strategies of enterprises.

The main problems of financial and economic security of enterprises include:

1. High level of economic risks:

− instability of the macroeconomic environment and crisis phenomena in the financial sector;

− the impact of global economic shocks on the financial stability of enterprises;

− high volatility of exchange rates, which affects the cost of raw materials and products.

2. Low level of financial control and risk management:

− lack of effective methods of financial risk management;

− insufficient transparency of financial reporting;

− lack of automated systems for monitoring financial flows.

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Table 1 – Main components of the financial and economic security system

No. p/n	Element	Main functions	Possible threats
1	Financial security	Control of financial flows, crisis prevention	Financial fraud, insolvency
2	Information security	Data protection against unauthorized access	Cyberattacks, information leakage
3	Investment security	Risk analysis, investment management	Inefficient investments, fraud
4	Operational security	Cost optimization, efficiency improvement	Low productivity, misuse of resources
5	Legal security	Compliance with legislation, legal support	Litigation risks, regulatory changes
6	Personnel security	Personnel protection, minimization of internal threats	Data leakage, employee fraud

[developed by the author]

3. Information security issues:
− growing threats in the field of cybersecurity;
− financial data leaks due to insufficient security of information systems;
− insufficient funding for cybersecurity measures.
4. Insufficient level of investment security:
− high risks associated with investing in unstable economic conditions;
− limited access to financing and credit resources;
− lack of mechanisms for state support of investments in the industrial sector.
5. Personnel problems:
− outflow of professional staff abroad due to better working conditions;
− lack of an effective system of training specialists in the field of financial security;
− insufficient level of financial literacy of business managers.
6. Imperfect legal regulation:
− lack of effective legislative control in the field of corporate security;
− corruption risks that complicate doing business;
− high tax and administrative burden on enterprises.

Therefore, based on the above problems, the following is recommended to improve the system of financial and economic security of industrial enterprises in Ukraine:

1. Increase the efficiency of financial risk management.
2. Implementation of international risk management standards (ISO 31000, COSO ERM).
3. Development of digital technologies for analyzing and controlling financial flows.
4. Strengthening legal regulation in the field of corporate security.
5. Education and training of personnel to reduce internal threats:
− introduction of modern financial monitoring tools;
− use of big data analytics for risk assessment;
− application of financial risk insurance mechanisms.
6. Strengthening cybersecurity:
− introduction of artificial intelligence systems to detect cyber threats;
− use of blockchain technologies for secure financial transactions;
− training of personnel in the basics of cybersecurity and financial protection.
7. Optimization of investment policy:
− creation of mechanisms for state support of investments in strategic sectors;
− use of the latest methods of investment risk assessment;
− development of partnerships between business and scientific institutions for innovative development.
8. Development of human resources:
− implementation of training programs for specialists in the field of financial security;
− stimulating enterprises to improve staff qualifications;
− support for initiatives to attract Ukrainian specialists working abroad.
9. Improvement of legal regulation:
− harmonization of national legislation with international standards of financial risk management;
− development of new anti-corruption mechanisms in the financial sector;
− improvement of tax policy to stimulate the development of industrial enterprises.
10. Automation of financial processes:
− use of ERP systems for integrated enterprise management;
− development of FinTech solutions for financial analysis;
− introduction of cloud technologies for managing financial flows.

Thus, the current challenges faced by Ukrainian industrial enterprises require a revision of approaches to ensuring financial and economic security. The need to strengthen crisis management, digital transformation of the financial sector, efficient use of resources, and integration into the international financial system are key areas for further research and development of practical solutions.

Conclusions

Financial and economic security is a key element of the sustainability of industrial enterprises. The integration of modern digital technologies, effective financial control and the development of international cooperation will help ensure the stable development of industrial enterprises and increase their competitiveness.

To achieve these goals, companies need to implement financial flow control systems, strengthen information security, and develop risk minimization strategies. The integration of modern analytical tools, the introduction of financial monitoring, and the improvement of corporate governance will help to counteract internal and external threats more effectively.

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NOTES

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