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ECONOMIC AND LEGAL
ISSUES**



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Social Marketing in Public Administration

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The relevance of the study is determined by contemporary transformational processes in society, globalization, digitalization, increased social activity of citizens, and the need to improve the effectiveness of communication between the state and the population. The purpose of the study is to define the essence of social marketing, its methods and technologies, as well as ways of integrating it into the public administration system to strengthen social trust and ensure sustainable development. The research methodology combines systematic and structural-functional analysis, content analysis of scientific sources and regulatory documents, comparative analysis of international and national experience, secondary analysis of sociological and statistical data for 2015–2024, as well as expert assessment. The results of the study show that the use of social marketing in public administration contributes to an increase in the level of public trust in state institutions (from 18.4% in 2015 to 55.1% in 2024), increases public participation in social and volunteer initiatives (from 12.1% to 37.2%), and creates an impression of government openness (from 14.7% to 45.8%). The comprehensive use of strategic communication platforms, digital technologies, educational campaigns, and mechanisms for engaging citizens stimulates active participation in social processes, shapes socially responsible behavior, and increases social cohesion. The study also showed that social marketing is effective for implementing sustainable development strategies, particularly in the areas of energy conservation, environmental awareness, and social inclusion, and contributes to the consolidation of society in crises, such as war or economic challenges. Thus, social marketing in public administration is not only a communication tool, but also a mechanism for transforming social values and behavioral patterns of citizens, strengthening partnerships between government and society, and achieving sustainable development goals.

KEYWORDS

social marketing, public administration, social trust, sustainable development, public policy, civic participation, social responsibility, public communications, inclusion.



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СОЦІАЛЬНИЙ РОЗВИТОК: економіко-правові проблеми

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Соціальний маркетинг у публічному управлінні

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СТАТТЯ

АНОТАЦІЯ

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Актуальність дослідження зумовлена сучасними трансформаційними процесами в суспільстві, глобалізацією, цифровізацією, зростанням соціальної активності громадян та необхідністю підвищення ефективності комунікацій держави з населенням. Метою дослідження є визначення сутності соціального маркетингу, його методів і технологій, а також шляхів інтеграції у систему публічного управління для зміцнення соціальної довіри та забезпечення сталого розвитку. Методологія дослідження поєднує системний і структурно-функціональний аналіз, контент-аналіз наукових джерел і нормативних документів, порівняльний аналіз міжнародного та національного досвіду, вторинний аналіз соціологічних і статистичних даних 2015–2024 рр., а також експертне оцінювання. Результати дослідження показують, що застосування соціального маркетингу у публічному управлінні сприяє підвищенню рівня довіри громадян до державних інституцій (з 18,4% у 2015 р. до 55,1% у 2024 р.), зростанню участі населення у соціальних і волонтерських ініціативах (з 12,1% до 37,2%) та формуванню враження відкритості влади (з 14,7% до 45,8%). Комплексне використання стратегічних комунікаційних платформ, цифрових технологій, освітніх кампаній та механізмів залучення громадян стимулює активну участь населення у суспільних процесах, формує соціально відповідальну поведінку та підвищує соціальну згуртованість. Дослідження також засвідчило, що соціальний маркетинг ефективний для реалізації стратегій сталого розвитку, зокрема у сфері енергозбереження, екологічної свідомості та соціальної інклюзії, та сприяє консолідації суспільства в умовах кризових ситуацій, таких як війна або економічні виклики. Отже, соціальний маркетинг у державному управлінні є не лише інструментом комунікації, а й механізмом трансформації соціальних цінностей і поведінкових моделей громадян, зміцнення партнерства між владою та суспільством і досягнення цілей сталого розвитку.

КЛЮЧОВІ СЛОВА

соціальний маркетинг, публічне управління, соціальна довіра, сталий розвиток, державна політика, громадська участь, соціальна відповідальність, публічні комунікації, інклюзія.

1. Introduction

Modern transformation processes in society, caused by globalization, digitalization and the growth of social activity of citizens, require qualitatively new approaches to the organization of the public administration system. In these conditions, the use of innovative tools that ensure effective communication between authorities and the public, increase the level of public trust in state institutions and contribute to the formation of socially responsible behavior is of particular relevance. One of these tools is social marketing, which combines the principles of marketing management with humanistic values and a focus on the public good.

Social marketing in public administration is considered a mechanism for influencing social processes through communication, education, motivation and involvement of citizens in the implementation of state policy. Its application allows state institutions not only to implement social programs more effectively, but also to build partnerships with citizens based on transparency, participation and trust. This approach is in line with the concept of good governance, which implies openness, accountability and orientation to the needs of society.

In the context of military challenges, economic crises and information threats, the issue of improving the interaction of the authorities with the public is of particular importance. Social marketing can become an effective tool for forming a positive image of the state, consolidating society, mobilizing public resources and supporting reforms.

2. Literature Review

The concept of social marketing arose at the intersection of marketing theory and social sciences as a response to society's need to influence social behavior through tools of communication, motivation and citizen engagement. The foundations of the concept were laid by F. Kotler and J. Saltman, who in 1971 defined social marketing as the process of creating, communicating and implementing ideas aimed at changing people's behavior for the public good [11]. Subsequently, the concept was developed in the works of such researchers as A. Andreasen [2], who notes that social marketing has great potential for the public and public sectors, but its implementation in the field of public administration requires a clearer conceptualization, professional infrastructure and a long-term strategic approach. Silva E. and Las Casas A. [23], believe that social marketing can act as a powerful tool of public administration aimed at changing consumer behavior (in particular, fan aggression) through partnerships between authorities, sports clubs and the community to increase social well-being and reduce the level of violence, which have expanded its understanding in the context of public policy, healthcare, education, ecology and public safety.

In scientific research in recent decades, social marketing is increasingly considered not only as a tool for influencing behavior, but as a philosophy for managing social change [8], in particular, a special approach to the formation of voluntary and socially desirable consumer behavior [14]. Its key difference from commercial marketing is the focus on changing the behavior of the target audience for the sake of public benefit, and the return here is measured not financially, but through social benefits [13].

In the Ukrainian scientific literature, the issues of social marketing in public administration are studied in the works of such scientists as N. Mazii [15], Z. Buryk and V. Chernyakhivska [6], K. Romanenko and S. Isaeva [22], who consider it as an innovative tool of the state's communication policy. In particular, it is emphasized that social marketing can ensure the implementation of the principles of openness of power, the formation of social capital and an increase in the level of public participation in decision-making.

Thus, in modern research, social marketing is considered an innovative management technology that can ensure not only the effective delivery of state initiatives to citizens, but also the active involvement of the population in the joint solution of social problems. This determines its significant importance for the development of a modern system of public administration in Ukraine, focused on democratic principles, openness and social responsibility.

3. Problem Statement

The purpose of the study is to reveal the essence of social marketing as an innovative tool of public administration, to determine its role in the formation of socially oriented state policy and to improve the mechanisms of interaction between the authorities and the public.

4. Methods and Materials

In the process of the study, an interdisciplinary approach was used, which combines the methodological principles of public administration, social marketing, communications and sociology, which made it possible to comprehensively reveal the role of social marketing in the formation of socially oriented state policy. Systemic and structural-functional analysis is used to identify the relationships between institutional, communicative and behavioral aspects of social marketing. A content analysis of scientific sources, regulations and state strategies has been carried out in order to identify trends and practices of its implementation in the field of public administration. The comparative method made it possible to summarize the experience of the EU countries and Ukraine on the use of social marketing to increase social trust and citizens' participation in managerial decision-making. The empirical base was formed on the basis of a secondary analysis of sociological and statistical data for 2015–2024, which made it possible to trace the dynamics of public trust and public activity. To specify the factors of effectiveness of social marketing, expert assessment was used, and to generalize the results, methods of induction, deduction, modeling and graphic interpretation. The results obtained confirm that social marketing is an important tool for building trust, partnership between government and society, and achieving sustainable development goals.

5. Results and Discussion

The analysis of scientific publications proves that social marketing is an effective tool for improving the efficiency of public administration, focused on satisfying public needs and forming socially responsible behavior. Its key role is to reorient managerial practices from a directive model to a communicative-partnership one, where the citizen is not an object of influence, but a co-creator of policy. Social marketing ensures the legitimacy of managerial decisions, strengthens the population's trust in state institutions and contributes to the formation of a positive image of public authorities.

Among the modern theoretical approaches to understanding the role of social marketing in public administration, three main ones can be distinguished: communication, behavioral and institutional-managerial (Fig. 1).

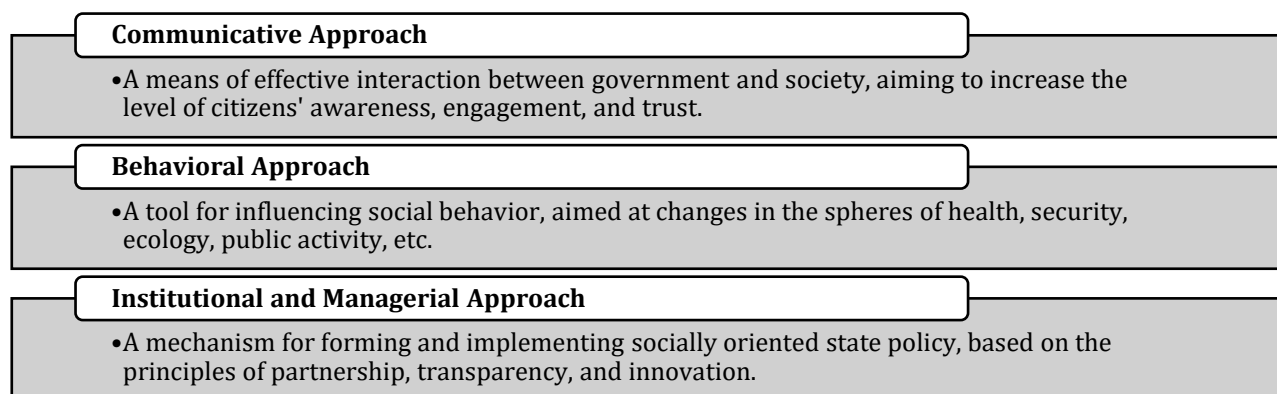


Figure 1. Scientific and theoretical interpretation of the essence of social marketing in public administration

Source: Summarized by the authors based on [4; 5; 11; 12; 16; 17; 20; 25].

From the point of view of public administration, social marketing is integrated into management processes through social communications, educational campaigns, electronic services, mechanisms of public participation, as well as through the formation of the image of state institutions. Its application

contributes to the transition from an administrative model of management to a participatory one, in the center of which are the needs of the citizen.

To ensure the effective integration of social marketing into the practice of public administration, it is necessary not only to understand its conceptual essence but also to understand the specific mechanisms of its implementation. The transition to a participatory model of governance requires the institutionalization of socially oriented tools that ensure interaction between the government and citizens based on partnership, transparency and trust. In this context, the development and implementation of mechanisms that combine marketing approaches with administrative, information, communication and educational tools of public administration is of key importance. They determine the practical implementation of the principles of social marketing in the activities of public institutions.

The main mechanisms for the introduction of social marketing in the field of public administration include: communication and information campaigns, network partnerships, digitalization of marketing, and monitoring of social effects (Fig. 2).

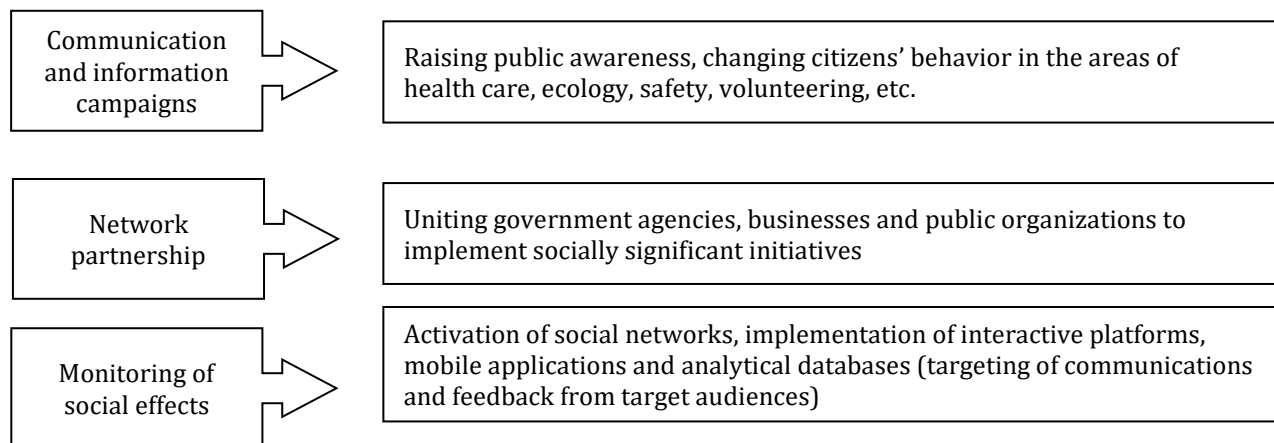


Figure 2. Main mechanisms for the implementation of social marketing in the field of public administration

Source: Summarized by the authors based on [2; 16; 26].

To illustrate the effectiveness of social marketing in public administration and confirm its impact on public activity and trust in state institutions, it is advisable to refer to statistical data. Let us consider the dynamics of indicators of trust in the authorities and citizens' participation in social initiatives for the period 2015–2024, which clearly demonstrates a positive trend and confirms that the introduction of social marketing contributes to the strengthening of partnerships between the government and the population (Fig. 3). These data allow evaluating the specific results of the application of communication, educational and interactive tools in public administration processes.

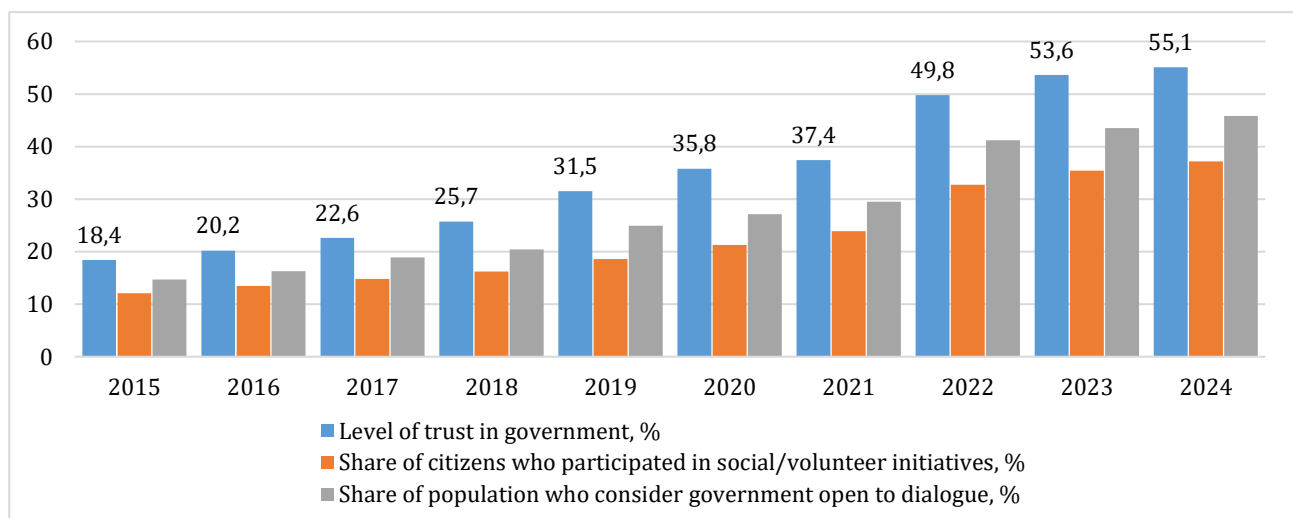


Figure 3. Dynamics of indicators of trust in the authorities and participation of citizens of Ukraine in social initiatives for the period 2015–2024

Source: Summarized by the authors based on [18; 21; 24].

Data analysis shows that for the period 2015–2024. There is a clear upward trend in the main indicators related to social marketing in public administration. The level of trust in the authorities increased from 18.4% to 55.1%, which demonstrates an increase in the legitimacy of state institutions as a result of communication and education campaigns. At the same time, the activity of citizens in social and volunteer initiatives is growing (from 12.1% to 37.2%), as well as the share of the population that considers the authorities open to dialogue (from 14.7% to 45.8%). This confirms the growing role of social marketing as a tool for the formation of participatory management and strengthening mutual trust between the government and society. In 2015–2024. There is a steady increase in citizens' trust in public authorities and their involvement in social initiatives. This indicates a gradual increase in the efficiency of state communications and the strengthening of interaction between the authorities and the public. The most noticeable increase is in 2022–2024. It is explained by the intensification of social campaigns aimed at supporting national unity, the volunteer movement and mutual assistance under martial law.

Social marketing contributes to the strengthening of social capital, the growth of public activity, the increase of trust in the authorities and the legitimacy of their decisions. Its effect is measured not by economic indicators, but by the level of social cohesion, readiness for collective action and stability of socio-management systems. Thus, social marketing in the public sector is turning from a communication tool into an adaptive management mechanism that allows the state to flexibly respond to social challenges, form new values and support sustainable changes in society.

Social marketing is an effective mechanism for the implementation of socially oriented state policy, because its strategic goal is not only to inform or persuade, but to transform social values and behavioral models to achieve the common good. Its key feature is that it aims to change people's social behavior through a system of motivation, communication and participation, forming a responsible and trusting relationship between the state and citizens.

From the standpoint of sustainable development, social marketing plays the role of a platform for social dialogue and behavioral change. It helps the state promote policies of rational consumption, environmental consciousness and social inclusion through clear, emotionally appealing messages. European initiative "Green Deal Communication" [9] uses social marketing to increase the environmental responsibility of citizens, promotes energy saving, waste sorting and the use of renewable resources. Through a combination of educational campaigns, interactive platforms and youth engagement, the initiative contributes to the formation of a culture of sustainable development as an element of everyday behavior. In Ukraine, the campaign "Clean City Starts with You", implemented at the level of local self-government, demonstrates how social marketing contributes to the development of environmental culture and civic responsibility, combining media communication with real practices of separate garbage collection and public actions [3; 7]. In the field of increasing social trust, social marketing strengthens the communication bridge between the authorities and citizens. Thanks to the principles of transparency, bilateral dialogue and the involvement of communities in joint actions, it becomes a means of building social capital. In particular, the Ukrainian campaign "Let's Unite for Victory", aimed at maintaining the unity of society under martial law [25]. It is based on positive narratives, stories of solidarity and mutual assistance that increase trust in state institutions and strengthen civic identity. The international initiative "Trust in Government" (OECD) demonstrates how social marketing helps governments form open communication strategies, increase transparency and create a positive image of the public service [19].

Thus, social marketing in public administration is a tool for humanizing politics that combines social goals with innovative communication technologies. It contributes not only to the implementation of state programs, but also to the formation of a new paradigm of interaction between the government and society, based on trust, partnership and responsibility.

Social marketing in the system of state and local government is a strategic tool for the formation of a socially oriented policy aimed at increasing social trust, participation of the population in social processes and ensuring sustainable development. Its peculiarity lies in its ability to transform social values, motivations and behavioral patterns of citizens, ensuring effective interaction between the authorities and society. In practice, social marketing is implemented through a set of tools, methods and technologies that allow state authorities and local governments to inform, attract, motivate and analyze the behavior of the population (Table 1).

Table 1. Main tools, methods and technologies of social marketing in the field of public administration

Category	Tool/Method	Description and example of application
Communication campaigns	Media and digital platforms	Bulk and targeted messages to inform about programs; Example: Facebook Energy Efficiency Campaigns
Branding of social initiatives	Logos, slogans	Formation of a recognizable image of programs; Example: "The community is active"
Citizen engagement	Surveys, participation platforms, incentives	Public consultations, electronic petitions, bonuses for active participants; Example: participatory budget
Educational and outreach activities	Trainings, webinars, and gamification	Raising awareness and developing competencies; Example: Energy efficiency workshops
Analytical and behavioral tools	Sociological research, beliefs	Study of citizens' behavior and its delicate influence on it; Example: Automatically connect to power saving apps
Digital technologies	Mobile applications, web portals, VR/AR	Operational communication and visualization of projects; Example: interactive portals of participatory budgets

Source: Compiled by the authors.

The integrated application of social marketing tools, methods and technologies allows state bodies and local governments not only to effectively communicate with citizens, but also to stimulate active participation in social and environmental initiatives, increase the level of social trust and ensure the implementation of the principles of sustainable development (Table 2).

Table 2. Ways to integrate social marketing into public administration

Direction	Characteristics of the direction
Strategic communication platforms	Unified government strategies through offline and online channels; Example: social networks and web portals to inform about energy efficiency programs
Performance monitoring and evaluation	Sociological research, surveys, analysis of social networks for campaign correction; Example: focus groups for local initiatives
Citizen engagement and motivation	Electronic petitions, participation budget, volunteer initiatives; Example: Encouraging active participants
Integration into sustainable development policies	Formation of environmental and social awareness (in particular, energy saving campaigns, support for local initiatives)
Digital and innovative technologies	Mobile applications, interactive portals, VR/AR; Example: Project visualization and personalized messages

Source: Compiled by the authors.

The integration of social marketing into public administration ensures systematic, transparent and effective interaction between the authorities and citizens. The use of strategic communications, digital technologies, public engagement mechanisms and performance monitoring allows the state not only to inform citizens, but also to stimulate their active participation, form social norms and behavioral models that contribute to sustainable development. Social marketing is becoming an integral part of modern state communication policy, strengthening social trust, legitimacy of decisions and social capital of society.

6. Conclusions

Social marketing in public administration is a strategic tool for increasing the effectiveness of public policy focused on the public good, citizens' trust and strengthening social capital. Its application combines humanistic values with innovative communication approaches, which is in line with the principles of openness, participation and accountability of the authorities.

The results of the study prove that the integration of social marketing contributes to the growth of social trust, civic activity and legitimacy of institutions. Increasing the level of trust in the authorities and citizens' participation in social initiatives confirms the effectiveness of communication and educational campaigns as tools for forming partnerships between the state and society.

The most effective mechanisms are recognized as strategic communication platforms, digital technologies and network partnerships that ensure the adaptability of management and increase its social orientation. Social marketing is being transformed from an information tool into a means of social change that forms responsible behavior, cohesion and sustainability of society.

Thus, the development of social marketing is a key direction of modernization of public administration in Ukraine, which ensures effective communication between the authorities and citizens, supports the values of trust and partnership, and contributes to the achievement of sustainable development goals.

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SOCIAL DEVELOPMENT: Economic and Legal Issues

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Cooperation Between Higher Education Institutions, Business and Government as a Form of Economic Interaction of Key Stakeholders in Creating an Innovative Economy

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ABSTRACT

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The article examines the processes and strategic consequences of cooperative interaction between higher education institutions, the business environment and government institutions within the economy of Ukraine. The purpose of the study is to form strategic directions of innovation cooperation to identify ways to strengthen the national innovation system and increase the country's competitiveness. The methodological basis of the study is formed by the integration of systemic, institutional and comparative approaches, which allowed for a comprehensive study of the relationships between education, science and innovation. The methods of structural-logical analysis, content analysis of regulatory legal acts of Ukraine and generalization were applied to formulate conceptual provisions on the strategic interaction of stakeholders. The obtained scientific results showed that the concept of the "knowledge triangle" defines the synergistic interaction of higher education institutions as generators of knowledge, business as a mechanism of commercialization and government as an institutional coordinator, forming the basis of the national innovation ecosystem. Key models of cooperation are identified – triple helix, academic-industrial partnerships, innovation clusters, technology parks and regional hubs, which ensure technology transfer and the development of high-tech entrepreneurship. Strategic development directions, innovative decentralization, transformation of universities into entrepreneurial ones, expansion of public-private partnerships and digital platforms for joint research are substantiated. The practical value of the study lies in the possibility of using the proposed models and algorithms to develop regional innovation strategies, improve the regulatory framework and create effective mechanisms for commercializing scientific results. The results can be implemented by government bodies, higher education institutions and business structures to strengthen regional ecosystems and increase the economic efficiency of cooperation. Prospects for further research are associated with an empirical assessment of the effectiveness of the implementation of Smart Specialization in individual regions of Ukraine and monitoring the impact of entrepreneurial universities on the growth of the number of spin-offs.

KEYWORDS

innovation ecosystem, cooperation, smart specialization, entrepreneurial universities, innovative decentralization, technology transfer, public-private partnership, economic interaction.



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СОЦІАЛЬНИЙ РОЗВИТОК: економіко-правові проблеми

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Кооперація закладів вищої освіти, бізнесу та влади як форма економічної взаємодії ключових стейкхолдерів у створенні інноваційної економіки

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СТАТТЯ

АНОТАЦІЯ

Дослідницька

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Стаття досліджує процеси і стратегічні наслідки кооперативної взаємодії між закладами вищої освіти, бізнес-середовищем та владними інституціями в межах економіки України. Мета дослідження полягає формуванні стратегічних напрямів інноваційної кооперації з метою виявлення шляхів посилення національної інноваційної системи та підвищення конкурентоспроможності країни. Методологічна база дослідження сформована інтеграцією системного, інституційного та компаративного підходів, що дозволило комплексно вивчити взаємозв'язки між освітою, наукою та інноваціями. Застосовано методи структурно-логічного аналізу, контент-аналізу нормативно-правових актів України та узагальнення для формулювання концептуальних положень щодо стратегічної взаємодії стейкхолдерів. Отримані наукові результати показали, що концепція «трикутника знань» визначає синергетичну взаємодію ЗВО як генераторів знань, бізнесу як механізму комерціалізації та влади як інституційного координатора, формуючи основу національної інноваційної екосистеми. Виокремлено ключові моделі кооперації – потрійну спіраль, академічно-індустріальні партнерства, інноваційні кластери, технопарки та регіональні хаби, які забезпечують трансфер технологій і розвиток високотехнологічного підприємництва. Обґрунтовано стратегічні напрями розвитку, інноваційну децентралізацію, трансформацію університетів у підприємницькі, розширення державно-приватного партнерства та цифрові платформи спільних досліджень. Практична цінність дослідження полягає в можливості використання запропонованих моделей і алгоритмів для розробки регіональних інноваційних стратегій, удосконалення нормативно-правової бази та створення ефективних механізмів комерціалізації наукових результатів. Результати можуть бути імплементовані органами влади, ЗВО та бізнес-структурами для посилення регіональних екосистем і підвищення економічної ефективності кооперації. Перспективи подальших досліджень пов'язані з емпіричною оцінкою ефективності впровадження Smart Specialisation в окремих регіонах України та моніторингом впливу підприємницьких університетів на зростання кількості спін-офів.

КЛЮЧОВІ СЛОВА

інноваційна екосистема, кооперація, смарт-спеціалізація, підприємницькі університети, інноваційна децентралізація, трансфер технологій, державно-приватне партнерство, економічна взаємодія.

1. Introduction

The development of Ukraine's innovative economy in the context of war and post-war transformations is of decisive strategic importance, since it is innovation activity that is able to ensure the structural reconfiguration of the national economy, increase its resistance to exogenous shocks and form the basis for long-term economic progress during the reconstruction period. Transformational phenomena determined by the large-scale destruction of infrastructure facilities, modification of global production networks, accelerated digital transformation and growing demand for high-tech solutions necessitate the construction of a new paradigm of economic development based on intellectual resources, knowledge capital and the capacity of society to generate and commercially implement innovations. Under such circumstances, the modernization of the institutional architecture, which regulates the relationships of key actors in the innovation process, becomes especially relevant because the effectiveness of this interaction directly correlates with the pace of state recovery and its incorporation into global technological spaces.

The need to intensify cooperation between higher education institutions, the private sector and government agencies is a prerequisite for the formation of an effective innovation ecosystem, since these three categories of subjects provide a full-fledged cycle of knowledge transformation – from its production to implementation in production processes and scaling at the national and international levels.

2. Literature Review

A systematic review of the scientific discourse demonstrates that the issue of cooperation between university institutions, the private sector and public bodies occupies a central place in the study of innovation dynamics. In the scientific works of Podolchak N. et al. [9], Ponomarenko V. et al. [10], it is emphasized that the interaction of the subjects of the innovation ecosystem determines the production of new knowledge, technological progress and strengthening of the economic capacity of territorial entities. Scientists state that universities are increasingly acquiring the status of centers for generating innovations, while the business environment functions as a leading tool for commercialization and practical implementation of scientific achievements, and management structures form an institutional environment for strategic coordination.

Research by Bebko S. [2], Lazarenko Y. [11], Makedon V. et al. [15] focus on the triple helix model, which conceptualizes innovative development through the prism of the interaction of three institutional actors – universities, the industrial sector and the state. Alternative scientific research Orzhel O. and Chankotadze Y. [17], Skyba Y. [21], investigate the functional role of regional innovative cluster formations and research centers formed around higher education institutes and technological corporations. Scientists, such as Krupka M. et al. [12], Yashchyshyna I. [23] emphasize the importance of the concept of reasonable specialization and its impact on the formation of competitive advantages of territories, as well as highlight the key role of entrepreneurial universities in the transformation of the higher education system. In general, a critical analysis of the scientific literature confirms the thesis that the synergistic interaction of educational, scientific, and business spheres is a critical factor in Ukraine's innovative progress in the context of global competition.

3. Problem Statement

The purpose of the article is to substantiate the normative, organizational and institutional foundations for ensuring cooperation in the format of "HEI-business-power" for Ukraine.

4. Methods and Materials

The methodological basis of the study is designed based on the integrated application of systemic, institutional, and comparative approaches, which enables the examination of the multifaceted relationship between higher education institutions, the private sector, and government agencies in the context of building a national innovation ecosystem. The methods of structural and logical analysis for

the identification of intra-system and intersectoral relationships in the three-tier model “education – science – innovation”, as well as the method of generalization to formulate conceptual provisions for strategic cooperation, have been implemented. The involvement of content analysis of legislative and regulatory acts made it possible to establish regulatory characteristics of the functioning of the innovation system; at the same time, a comparative analysis of international partnership models contributed to the identification of relevant practices suitable for implementation in the Ukrainian context.

5. Results and Discussion

The concept of the “knowledge triangle”, which integrates education, science and innovation into a single dynamic system for creating and disseminating new knowledge, is defined by us as a fundamental reference point for countries seeking to gain a sustainable position in the global economy. It is in Ukrainian realities that it acquires special significance, as it determines the logic of interaction between key stakeholders capable of ensuring national competitiveness through the systemic transformation of knowledge production modes, their practical application and dissemination in the context of continuous technological changes. The above concept assumes that each of the three elements – education, science and innovation, cannot function autonomously, but can be in a constant mutual exchange of resources, results and competencies, at the same time forming a synergistic model in which the development of one segment determines the intensity of development of the rest. Moreover, this dependence is especially noticeable in national innovation systems, where the uneven development of at least one component leads to chain dysfunctions in the entire system.

Within the framework of this concept, higher education institutions form the intellectual core of society, because they create new knowledge, produce scientific results, provide training of specialists with research and innovation competencies, and fulfill an important social mission – support for the cultural, technological and economic development of the country. This part is provided through the modernization of educational programs, the integration of the latest scientific results into the educational process and active participation in the formation of regional innovation ecosystems. Business in this triangle plays a critical role as a “mechanism for the materialization of knowledge”, since it is enterprises/companies that have the opportunity and technological base to transform scientific developments into products, services and technologies that form the innovative potential of the national economy. The entrepreneurial sector is a source of demand for applied scientific results and competencies, only it forms technological challenges with which HEIs and scientific institutions must cooperate and adapt their research areas [6]. Business provides commercialization processes that determine the viability of innovations, because without an effective mechanism of market implementation, even the most promising scientific discoveries remain unrealized, which is especially important for Ukraine, where the indicators of commercialization of research are still low compared to the world's leading innovative economies within the framework of economic interaction.

Accordingly, the state plays the role of an institutional coordinator capable of harmonizing the interests of universities, business and society through the development of policies, regulations, support programs and financial instruments that stimulate cooperation, development of R&D infrastructure, modernization of the educational sector and integration of Ukrainian innovative institutions into the global scientific space. The Law of Ukraine “On Innovation Activity” is a basic document that prescribes the legal foundations of the innovation system of the state, defines the concept of innovation, innovative product, innovation project, its life cycle, mechanisms of state support and economic stimulation, and also creates a regulatory basis for organizing interaction between subjects of innovation activity, among which higher education institutions and scientific institutions occupy an important place [7]. The Law not only enshrines the principles of state policy in the field of innovation, but also promotes the integration of science and production, as it establishes legal mechanisms for financing innovation projects, provides an opportunity to create special innovation structures and defines forms of state support, including tax incentives, investment grants, subsidies and targeted lending [14]. The law also forms legal conditions for the development of partnerships between business, higher education institutions and public authorities, as it provides for joint financing of projects, pooling of material and intellectual resources, integration of educational programs and research infrastructure. In addition, the processes of stimulating the commercialization of scientific research results, as well as the development

of knowledge-intensive entrepreneurship, which is an important element of the national innovative economy, are provided.

The Law of Ukraine "On Scientific and Scientific-Technical Activities" complements innovation legislation, as it regulates the status of science in Ukraine, determines the principles of organization of scientific activity, establishes the rights and obligations of scientists, sets the rules for the functioning of scientific institutions, and also forms an institutional mechanism of state policy in the field of science and technology. Within the framework of the law, the role of higher education institutions is defined as leading subjects of scientific activity, capable of ensuring the generation of new knowledge, the development of scientific schools, the training of researchers and scientific and pedagogical personnel, as well as creating conditions for the integration of science with production through joint research and projects [8]. The Law enshrines the principle of autonomy of scientific entities, defines the system of financing science (basic, competitive, grant), establishes mechanisms for the integration of Ukrainian science into the European Research Area and sets the legal framework for the creation of innovative structures based on universities, which contributes to the development of the technology transfer system, commercialization of research results and the formation of partnerships with business.

Another basis of regulatory and legal support is the Law of Ukraine "On Higher Education", which contains provisions on the legal, organizational and financial principles of the functioning of universities, establishes the principles of autonomy, academic freedom, institutional responsibility and guarantees of the quality of education, and also determines the place of universities in the national innovation system. The Law forms the basis for the creation of scientific collaborations based on higher education institutions, regulates the issues of joint use of property, joint research, conclusion of partnership agreements with enterprises, and also defines the mechanisms of dual education that contribute to the integration of business into personnel training and modernization of educational programs. This law also outlines the rights of higher education institutions to create startups, economic structures and innovative enterprises, which determines the principles for them to participate in the commercialization of research results and be active participants in economic activity in innovation sectors [18].

The Strategy for Innovative Development of Ukraine complements these provisions, as it details the mechanisms for the functioning of the innovation system, defines the institutional architecture of innovation support, from incentives for scientific research to the development of startup infrastructure, and forms a list of policy instruments that will be aimed at the development of innovation activities, including financial incentives, regulatory support for innovation clusters, public administration reform in the field of science and technology, as well as development of the legal system of intellectual property protection. The strategy provides for strengthening the role of universities as centers of innovative development, creating a network of regional innovation platforms, supporting academic and industrial partnerships, and developing joint research projects based on business needs (Fig. 1).

The mechanisms and models of cooperation of these participants form a complex multi-level system of interaction, which is based on the permanent exchange of knowledge, resources and management decisions. For these reasons, academic-industrial partnerships are an element of this system, as they provide not only technology transfer, but also the formation of an environment for innovative creativity, commercialization of research and development of high-tech entrepreneurship. Joint research projects developed in the format of a partnership between universities and enterprises can combine academic potential with applied production needs, and cooperation often takes place in areas where the country feels the greatest need for innovation: materials science, mechanical engineering, biotechnology, IT sector, energy and agro-industrial complex, etc. University scientists offer methodological depth, access to laboratory facilities and basic research, while business provides opportunities for practical validation, prototype testing, scaling of technological solutions, and market entry, which turns such projects into an effective mechanism for accelerated innovation dynamics [2].

Such partnerships become quite effective in the format of innovation laboratories and R&D centers, which are created at higher education institutions with the participation of industrial partners and act as platforms for experimental research, development of high-tech products and applied testing necessary for the transformation of scientific hypotheses into commercial innovation. In Ukrainian realities, such centers are not only platforms for scientific developments, but also centers for the formation of a culture of innovative thinking and entrepreneurial competencies among students and

young scientists, which makes it possible to build a natural chain “education, → research, → startup → production” [1].

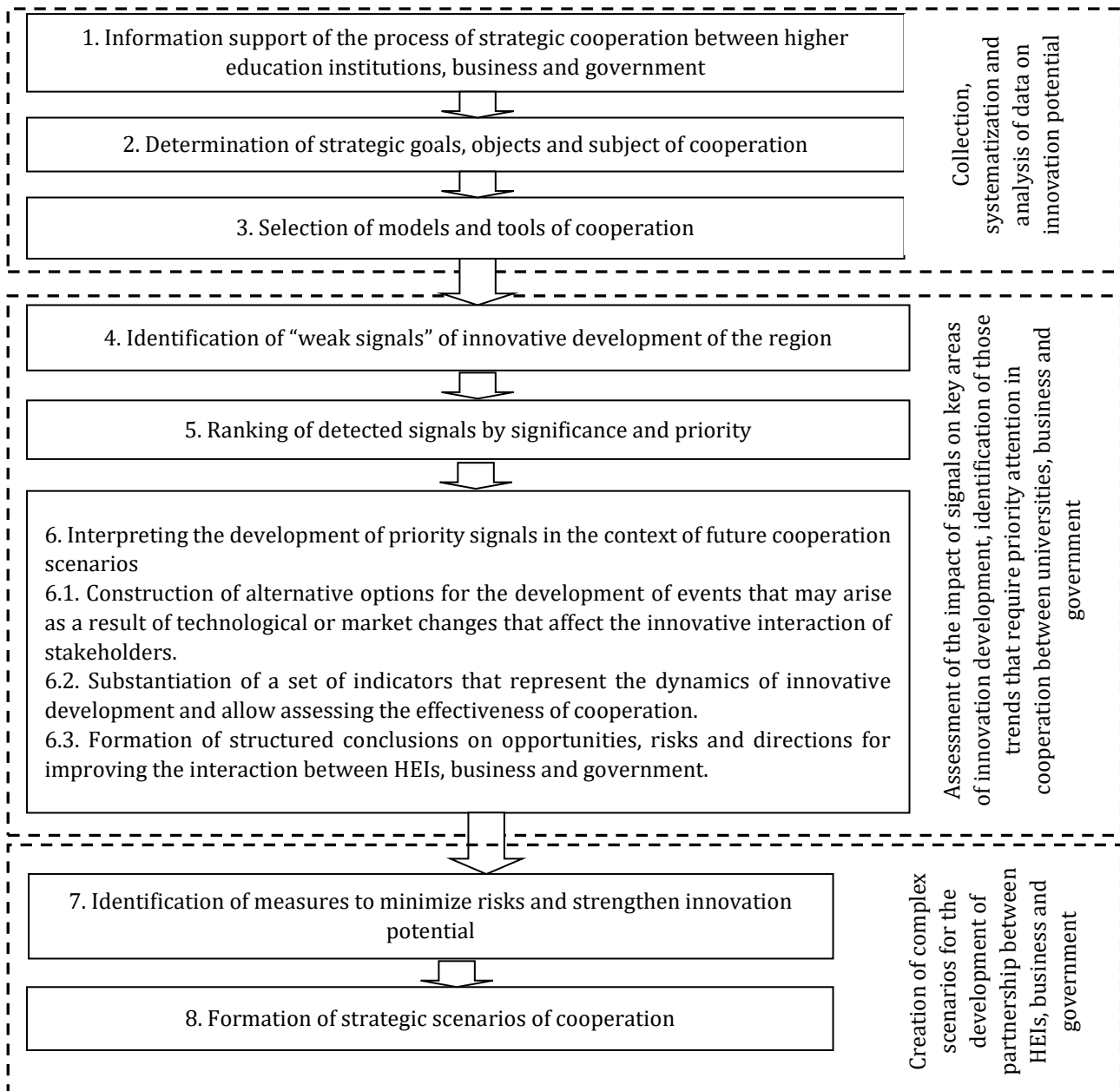


Figure 1. Level Processes of Strategic Cooperation of Higher Education Institutions, Business and Government in the Context of the Formation of an Innovation Ecosystem

Source: Developed by the authors.

Quite indicative for Ukraine are the examples of duets “university → industrial enterprise”, where the practice of cooperation is based on the long-term interests of both parties. Thus, the partnership between the higher education institution “KPI. Igor Sikorsky” and aviation and defense enterprises is aimed at joint research in the fields of aerospace technology, unmanned systems, composite materials and digital technologies, which allows combining academic basic research with applied engineering developments and the creation of serial technological solutions. Lviv Polytechnic actively cooperates with IT companies and industrial enterprises in the fields of automation, robotics and electronics, creating joint educational programs where students work on real production tasks. Kharkiv National University of Radio Electronics already has partnerships with companies in the telecommunications sector, combining training, research and practical developments in the field of communication technologies, artificial intelligence and cybersecurity [9].

In addition to academic-industrial partnerships, another plane of cooperation is being built – regional innovation ecosystems. They are formed through a set of tools to support innovation activities, coordinated by both state institutions and local communities. Industrial parks and technology parks are able to take on the role of ensuring the development of these ecosystems, as they create infrastructural conditions for the location of high-tech enterprises, conducting experimental research, organizing production lines and attracting investments to the region. An industrial park does not function only as an area with certain technical capabilities, instead it turns into an environment where enterprises interact with universities, research centers, investors and authorities, which provides a multiplier effect on the development of the local economy. Techno parks, in turn, have a greater innovation orientation, because they concentrate scientific laboratories, startup incubators, technology transfer centers and business offices, which allows you to carry out a full cycle of innovations – from an idea to a commercial product.

Techno hubs, in particular in the fields of digital technologies, biomedicine, aggrotech or robotics, form local networks of innovative actors, where universities, enterprises and local administrations work to solve common regional problems, including increasing the technological capacity of enterprises, developing human resources and creating new jobs in high-tech industries. An example is the initiative to develop innovation spaces in Lviv, Kyiv, Kharkiv, or Dnipro, where techno hubs act as centers of urban innovation policy and platforms for cooperation between startups, universities, and real business [19, p. 127–128].

The coordinating function in regional innovation ecosystems is performed by local governments, as they create regulatory, infrastructure and financial conditions for the development of entrepreneurship, attracting investments, implementing innovative solutions in the field of urban governance, as well as initiating cooperation programs with universities related to the development of Smart City, digitalization of utilities, energy efficiency, environmental monitoring and mobility. Local communities become active customers of innovations, contributing to the creation of local markets for high-tech products and creating a favorable environment for cooperation between the academic sector and business, as well as ensuring the long-term sustainability of innovation ecosystems, since support from the authorities reduces risks for investors and stimulates the development of enterprises [3, p. 15].

Clusters that unite enterprises, higher education institutions and research institutions on an industry or technological basis also play a system-forming role, as they optimize information exchange processes, accelerate knowledge transfer, and jointly solve the problems of technological gaps. In Ukraine, IT clusters are developing quite dynamically, which form an environment of high cooperation between higher education institutions, development companies and local authorities, which stimulates the creation of innovative infrastructure, the implementation of educational programs with a practical component, and the launch of startups (Table 1) [20]

Table 1. Models of Innovative Interaction of Higher Education Institutions, Business Environment and Government

Triple Helix	Constant exchange of knowledge, resources and personnel	Strategic planning and grant funding	Ordering applied research, co-financing	Knowledge generation, training, technology transfer
Academic-industrial partnerships	Long-term contracts for joint research and development	Tax Benefits and Government Support Programs	Investing in R&D, providing production sites	Scientific leadership, laboratory facilities, student engagement
Innovation clusters	Territorial concentration of actors of the same or related industries	Formation of the regulatory framework of the cluster, infrastructure subsidies	Joint investment in shared infrastructure	Scientific and methodological center, training of specialists for the needs of the cluster
Technoparks and science parks	Physical infrastructure at or near the HEI	Preferential tax regime for residents, co-financing of construction	Lease of premises, creation of subsidiaries	Park management, startup incubation, technology transfer
Regional Innovation Hubs	Multifunctional platforms for startups, laboratories and business incubators	Municipal Funding and Regulatory Easing	Mentoring, venture investment, pilot projects	Coordination of educational and scientific activities, interdisciplinary laboratories

Source: Systematized by the authors according to the data given in [4; 16].

The formation of perspective and strategic directions for the development of the subject economy may involve a deeper restructuring of the logic of interaction between key stakeholders of the innovation economy. Because it is their concerted actions that create the prerequisites for the development of high-tech sectors, attracting investments, increasing labor productivity, strengthening scientific potential and forming the state's competitive position in global markets, scaling innovations and creating stable mechanisms of economic growth (Fig. 2).

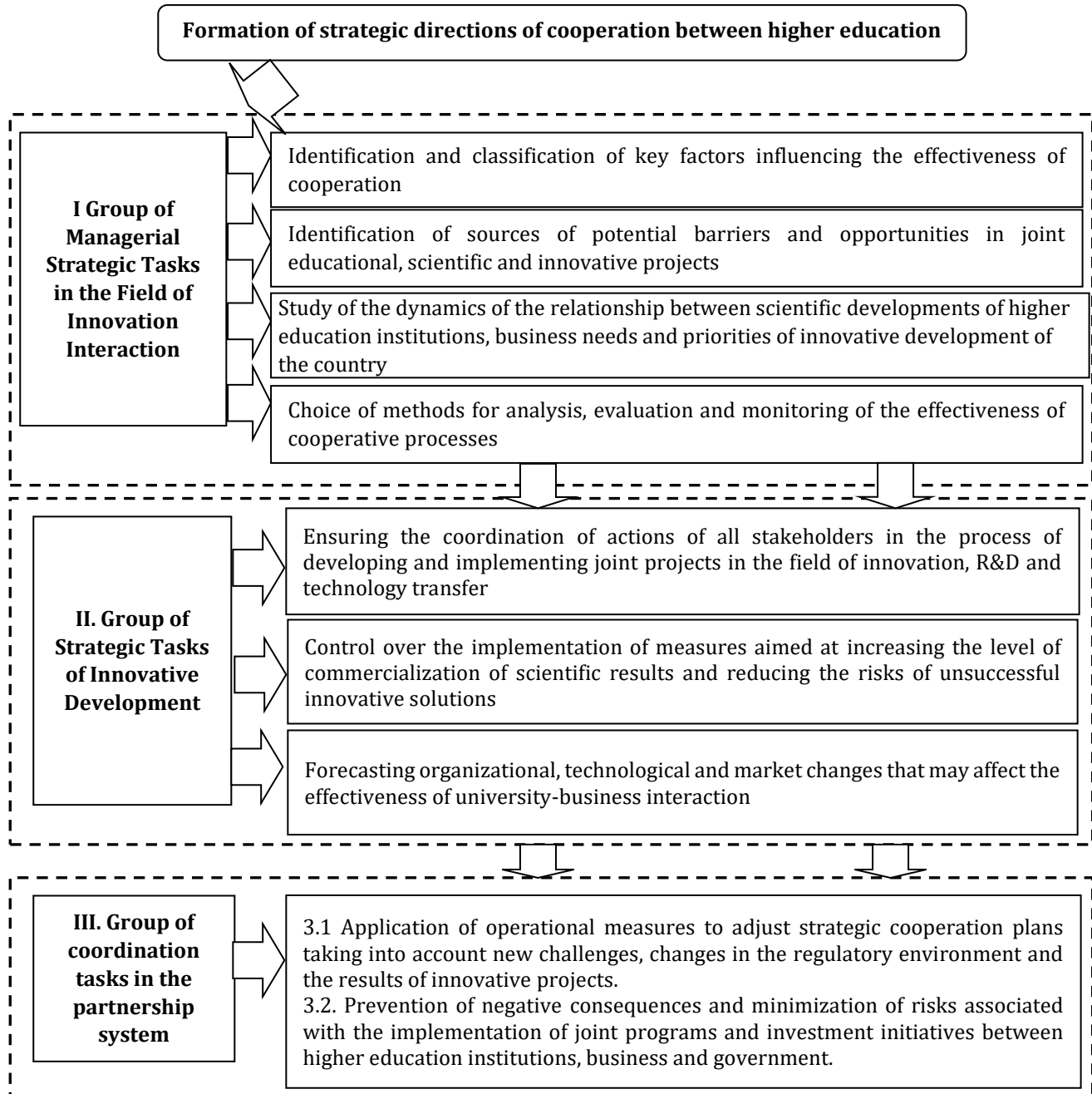


Figure 2. Structural model of formation of strategic tasks of interaction between HEIs, business structures and public authorities

Source: Developed by the authors.

In this vein, the implementation of the Smart Specialization (S3) concept, which enables the regions of Ukraine to identify their own technological and economic niches, is gaining weight. Within their framework, they can achieve the greatest innovative efficiency, which reorients fragmented innovation initiatives to systematically organized strategic platforms that are aimed at solving specific regional problems and using local advantages. Smart Specialization involves the involvement of a wide range of stakeholders: representatives of business, universities, technology parks, incubators, professional communities and government agencies, in the process of entrepreneurial discovery, within

which participants collectively identify technological areas that can ensure the growth of the region. In Ukrainian conditions, S3 is already proving itself as a tool that is really able to direct regional policy to those industry dominants where there is a real potential for a high-tech breakthrough: from agrobiotechnology in the central regions to aerospace and engineering technologies in the east, from IT and medical innovations in the west to logistics and innovation clusters in the southern regions [5, p. 10; 11].

Innovation decentralization as a strategic direction complements Smart Specialization, as it strengthens the capacity of local communities to independently form innovative strategies, manage resources and implement development policies in accordance with identified competitive niches, which creates a new level of autonomy for regions in terms of stimulating the innovation environment. Decentralization contributes to the emergence of local institutions – from public development funds to local technology parks, which will be able to promptly respond to the needs of enterprises and universities, create programs to support startups, and develop technological infrastructure. The expansion of the powers of local self-government bodies in innovation policy allows developing those areas that are most relevant to the local labor market and the economic structure of the community, creating conditions for greater involvement of universities in regional planning and implementation of innovation initiatives [12].

Against this background, the transformation of HEIs into “entrepreneurial universities” is of key importance, since it is the entrepreneurial university that becomes an institution capable of integrating academic, research and entrepreneurial functions into a single system that produces new technologies, promotes the commercialization of knowledge, forms startups, supports innovative entrepreneurship and creates human resources for strategically important sectors of the economy. An entrepreneurial university is not only a structure that creates startups or has a business incubator, but is an institution of a new type, based on the ability to create innovations through interaction with business and the state, as well as the ability to transform educational programs in such a way that they correspond to the dynamics of technological markets and global trends in the field of digitalization [22].

The creation of university hubs that bring together laboratories, research centers, business incubators, technology transfer centers and educational platforms allows for a continuous cycle of innovation activities, in which ideas arising from the educational or scientific process can be quickly transformed into prototypes, research projects or startups, and then scaled with the participation of business partners. These types of hubs play the role of multifunctional innovation centers in which students, teachers, entrepreneurs, investors and government officials interact in a common space, which contributes to the formation of a culture of interdisciplinarity, the development of technological entrepreneurship and the creation of an environment in which innovations become not an accidental product of individual efforts, but a natural result of systematic cooperation. University hubs also allow for the creation of network innovation platforms between different regions of Ukraine, deepening the integration of educational and scientific institutions into joint innovation projects, which strengthens the nationwide innovation system.

Cooperation incentives are a condition for supporting these processes, as they create economic incentives for enterprises and universities to be more actively involved in innovation activities, invest in high-tech projects, develop R&D infrastructure and participate in joint research (Table 2).

Public-private partnership (PPP) mechanisms are the next element of stimulating cooperation, as they allow combining the resources of the state, universities and business to implement large innovative projects, create infrastructure and implement technological solutions that require significant investments. PPPs can be used to create laboratory complexes, technology parks, centers for the collective use of scientific equipment, innovative campuses and research factories that provide universities and enterprises with access to infrastructure that they could not build on their own. Within the framework of PPP, joint educational and scientific programs can be implemented that train specialists for specific sectors of the economy, as well as dual education projects that help students acquire practical skills directly at enterprises [3, p. 15].

State grants and competitions for joint projects complement these tools, as they allow you to support exactly those areas in which the synergy between science, education and business can provide the maximum socio-economic effect. Grant support is aimed at stimulating interdisciplinary research, developing R&D teams, supporting startups, modernizing scientific laboratories, introducing technologies into production and creating innovative products that increase the competitiveness of

Ukrainian companies. In addition, competitions for joint projects allow universities to expand cooperation with enterprises and regional authorities, creating conditions for the formation of long-term partnerships.

Table 2. Prospects and Strategic Directions for the Development of Cooperation Between HEIs, Business Entities and Government Institutions

Strategic direction	Key Implementation Tool	Main stakeholders-initiators	Projected economic effect	Priority time horizon
Smart Specialisation (S3)	Entrepreneurial opening of priority niches in the region	Regional councils, higher education institutions, business associations	Concentration of resources on 3–5 strong sectors of the region	2025–2030
Transformation into entrepreneurial universities	Creation of technology transfer centers and startup studios	Ministry of Education and Science, Rectorate of Higher Education Institutions, Venture Funds	Growth in the number of university spin-offs by 150–200% by 2030	2025–2028
Innovative decentralization	Transfer of powers of local self-government bodies regarding innovation funds and benefits	Amalgamated territorial communities, regional state administrations	Increase in regional GDP at the expense of high-tech sectors by 8–12%	2026–2032
Development of public-private partnerships in large infrastructure	PPP for the construction of research campuses and laboratory complexes	Cabinet of Ministers, EBRD/EIB, large corporations	Creation of 15–20 new large R&D facilities by 2035	2027–2035
Digital platforms for collaborative research and transfer	Unified national application platform for joint projects and IP marketplace	Ministry of Digital Transformation, Ministry of Education and Science, IT companies	Reduction of time from idea to prototype by 40–60%, increase in patenting by 100%	2025–2029

Source: Developed by the authors.

Together, these areas determine the strategic path of development of the Ukrainian innovation ecosystem, in which universities, business and government form an integrated system capable of generating, scaling and commercializing innovations, ensuring the development of high-tech industries and strengthening Ukraine's competitive position in the context of global economic competition.

6. Conclusions

The analysis shows that the effectiveness of the national innovation system is determined by the level of coordination of interaction between higher education institutions, the private sector and state structures. It has been established that the three-tier model “education – science – innovation” forms the foundation for sustainable economic progress, the formation of technological independence and the strengthening of the state's competitive position at the global level. The analysis of the legislative framework of Ukraine demonstrates the existence of a legal basis for the implementation of knowledge and technologies in production processes, at the same time the need to strengthen institutional coordination between stakeholders through the improvement of financial mechanisms, creation of incentives for the commercialization of scientific results and the development of innovation infrastructure has been identified.

The results of the study confirm that academic and industrial alliances, innovative cluster formations, technology parks, regional centers and other configurations of cooperation function as defining structural elements that contribute to technology transfer, the formation of high-tech entrepreneurship, the activation of innovative activities of the business environment and the growth of human capital. It has been established that universities acquire the status of central institutions of the innovation ecosystem, implementing the functions of knowledge production, training qualified personnel, initiating startup projects and providing scientific and technological support to sectors of the economy that need technological updating. It is argued that the synergy of resources of higher education institutions, entrepreneurial structures and government institutions makes it possible to form new value chains, intensify the commercialization of scientific developments and increase the productivity of economic processes.

It has been determined that the strategic vectors of cooperation development – the concept of smart specialization, innovative decentralization, transformation of universities into entrepreneurial structures, development of public-private partnership and introduction of digital platforms for collective research – form an updated architectonic model of innovative development of Ukraine, aimed at concentrating resources, diversifying technological specializations and increasing the effectiveness of regional innovation ecosystems. It is substantiated that the implementation of these areas provides not only stimulation of research activity, but also the creation of stable mechanisms of commercialization, mobilization of investment resources and the formation of technologically capable territories.

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Theoretical and Methodological Foundations of Cost Management for the Production of Building Materials

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ABSTRACT

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Cost control is of particular importance in modern market conditions, as the effective regulation of expenditure activities directly impacts product cost, the enterprise's financial results, and its capacity for innovative development. Currently, Ukraine virtually lacks a holistic and systematic cost control model that defines corporate policy for rationalizing resource-intensive activities. The research aim is to study the theoretical and methodological foundations of cost management for the production of building materials. The scientific article defines the key organizational conditions for the production of building materials. It outlines the main elements of the production cost control system, which include: cost regulation, strategic cost forecasting, integrated resource planning (ERP), adaptive resource normalization, operational economic analysis, process-oriented costing, deviation control and real-time response, cost optimization, cost auditing, feedback, and corrective management. The analytical elements of the cost management system during the production of building materials are presented as follows: cost forecasting and planning; cost normalization; cost calculation; cost accounting; cost and cost price analysis; and control and regulation of the cost management process. Cost accounting is carried out in accordance with a defined nomenclature of cost items, within which the accumulation and allocation of costs by costing objects are reflected. Particular attention is paid to the precise determination of the actual cost price of products based on classification approaches (by economic content, cost items, place of occurrence, etc.), which is critically important for construction-profile enterprises. The methodological essence of the cost management system lies in forming a comprehensive mechanism for integrating the processes of supply, consumption, control, and regulation of resource flows in accordance with established strategic and tactical objectives. The key characteristics of such a system are purposefulness, flexibility, adaptability, manageability, and the ability to transform under the influence of external and internal factors.

KEYWORDS

costs, cost management, cost accounting, construction, building materials.



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Теоретико-методологічні основи управління витратами на виробництво будівельних матеріалів

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СТАТТЯ

АНОТАЦІЯ

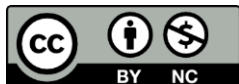
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Контроль витрат набуває особливої ваги в умовах сучасних ринкових відносин, оскільки ефективне регулювання витратної діяльності безпосередньо впливає на собівартість продукції, фінансові результати підприємства та його інноваційний розвиток. На сучасному етапі в Україні практично відсутня цілісна і системна модель контролю витрат, що визначала б політику компаній щодо раціоналізації ресурсозатратної діяльності. Метою дослідження є вивчення теоретико-методологічних основ управління витратами на виробництво будівельних матеріалів. У науковій статті визначено ключові умови організації виробництва будівельних матеріалів. Наведено основні елементи системи контролю виробничих витрат, що включають: регулювання витрат, стратегічне прогнозування витрат, інтегроване планування ресурсів (ERP), адаптивне нормування ресурсів, операційний економічний аналіз, процесно-орієнтоване калькулювання, контроль відхилень і реагування в реальному часі, оптимізація витрат, аудит витрат, зворотний зв'язок та корекційне управління. Наведено аналітичні елементи системи управління витратами в ході виробництва будівельних матеріалів, а саме: прогнозування і планування витрат; нормування витрат; калькулювання собівартості; облік витрат; аналіз витрат і собівартості; контроль і регулювання процесу управління витратами. Облік витрат здійснюється відповідно до визначеної номенклатури калькуляційних статей, у межах якої відображається накопичення та розподіл витрат за об'єктами калькулювання. Особливу увагу приділено точному визначенню фактичної собівартості продукції на основі класифікаційних підходів (за економічним змістом, статтями калькуляції, місцем виникнення тощо), що є критично важливим для підприємств будівельного профілю. Методологічна сутність системи управління витратами полягає у формуванні комплексного механізму інтеграції процесів постачання, споживання, контролю і регулювання ресурсних потоків відповідно до встановлених стратегічних і тактичних завдань. Ключовими характеристиками такої системи виступають цілеспрямованість, гнучкість, адаптивність, керованість, а також здатність до трансформації під впливом зовнішніх та внутрішніх факторів.

КЛЮЧОВІ СЛОВА

витрати, управління витратами, облік витрат, будівництво, будівельні матеріали.

1. Introduction

In the current market environment, cost control acquires paramount importance, as the effective regulation of expenditure activities directly impacts the product's cost price, the enterprise's financial results, and its potential for innovative development. This is particularly relevant for the production of building materials, which is characterized by high resource intensity, a significant proportion of material costs in the cost price structure, and the need for rapid response to price instability in raw materials and energy carriers. Cost control is a dynamic and multi-component management process that integrates a complex of measures aimed at achieving the enterprise's strategic and operational economic goals. This process is not limited merely to cost reduction but encompasses the entire spectrum of control tools that ensure effective cost management in real-time.

The relevance of the study is amplified by the fact that in contemporary Ukraine, amidst the recovery and development of the construction industry, a holistic and systematic model of production cost control is virtually absent, which would ensure the rationalization of resource-intensive activities specifically within this sector. Therefore, there is an urgent need to develop and theoretically substantiate methodological foundations capable of ensuring the integration of strategic forecasting, adaptive normalization, and process-oriented costing.

2. Literature Review

Effective cost management is a critical factor for ensuring the competitiveness and financial stability of enterprises, particularly in the production of building materials, where pricing policy and production resource intensity play a decisive role. The need for rational resource utilization and the continuous search for ways to optimize cost price amidst inflationary pressure and market uncertainty requires an in-depth study of theoretical and methodological developments. The presented literature review reflects the evolution of scientific views on cost management, spanning from integrated accounting systems to modern models oriented towards the product life cycle and production processes.

R. Kaplan and R. Cooper (1998) examine the concept of integrated cost management systems, particularly Activity-Based Costing (ABC) [1]. The authors explain how to account for costs more accurately and improve profitability, providing examples of implementing modern costing systems in enterprises.

The work of L. Koskela (2000) lays the theoretical groundwork by exploring production theory and its application in construction [2]. The identified production principles, notably the concepts of Lean Construction, are key to developing a methodology for managing costs in the manufacturing of building materials. This allows for the optimization of production processes, the minimization of resource and raw material losses, and increased efficiency.

I. Davydov (2001) analyzes the role of cost management in increasing enterprise operational efficiency [3]. The author emphasizes the importance of optimizing cost processes in contemporary conditions, reviewing methods for cost reduction and providing recommendations for improving financial results.

O. Krushelnytska (2008) studies the effective management of an enterprise's material resources [4]. The methods for planning, normalization, and control of material flows are considered. The author focuses attention on minimizing costs associated with supplying resources to production.

The research by M. Hanid (2014) uses the Design Science Research approach to develop conceptual solutions aimed at improving cost management in construction [5]. These solutions can be adapted to create new effective models for controlling production costs related to raw materials, energy, and labor in building materials manufacturing.

The work of A. Ashworth and S. Perera (2015) present the basic knowledge and methodologies for conducting building cost studies [6]. These approaches are fundamental for accurate planning and control of costs for the procurement and use of building materials within the total construction cost structure. Understanding these principles is essential for developing a methodology for managing production costs.

R. Antunes and V. Gonzalez (2015) develop a theoretical foundation for a production model in construction [7]. This framework is important for identifying and systematizing all production processes involved in manufacturing building materials. A structured approach to production modeling directly impacts the accuracy of accounting and the effectiveness of cost management.

A. Kazaz et al. (2016) propose a methodology, oriented towards building materials, for solving time-cost-quality trade-off problems [8]. This approach is critically important for managing materials production costs, as it allows for finding the optimal balance between the product's cost price and the necessary technical characteristics.

The study by N. Bozgulova et al. (2019) focuses on calculation methods applied to cost management in the construction industry [9]. The authors examine specific methodologies that can be implemented directly in the production of building materials, ensuring precise accounting and control of their cost price formation.

K. Mamonov and V. Troian (2019) analyze theoretical and methodological approaches to brand assessment of construction enterprises [10]. Although the work does not directly address production costs, it highlights the importance of intangible assets, which influence the market value of building materials and the overall economic effectiveness of enterprise cost management.

I. Markina et al. (2020) investigate theoretical approaches to enterprise cost management [11]. The authors analyze modern models, principles, and factors influencing the cost mechanism, considering the importance of rational cost management in a competitive environment.

L. Gerasimova (2020) focuses on improving cost management in the construction industry from a methodological perspective [12]. The work suggests specific ways to enhance existing methods, which is crucial for developing effective theoretical and methodological foundations for cost management, helping to improve the economic justification of production management decisions.

S. Uvarova et al. (2023) examine the methodology and practice of cost forecasting for building materials under conditions of uncertainty [13]. The research results are important for including elements of strategic planning and risk management in the methodological foundations of production cost control, ensuring enterprise sustainability in an unstable market.

J. Smetanková et al. (2024) explore the theoretical foundations and impact of technological progress on the Life Cycle Costing (LCC) of buildings [14]. This approach is key to forming management decisions in the materials production sector, shifting the focus from initial costs to the overall economic efficiency of the product throughout its service life.

Despite significant scientific achievements in cost management and its integration into the construction industry, most studies emphasize general models (ABC, LCC) and Lean Construction principles, often overlooking the creation of a holistic and systematic cost control model adapted to the specifics of Ukrainian building materials production. In particular, issues of cost price formation in contemporary conditions and the comprehensive functional provision of control in both preventive and operational modes of influence on production activity remain insufficiently researched, which is critical for correcting deviations from planned parameters. In fact, a clear system for managing the cost optimization process is still absent in Ukraine, complicating the implementation of effective cost policy under increasing inflationary pressure. Thus, the task of developing theoretical and methodological foundations that integrate strategic forecasting, adaptive normalization, and process-oriented costing into a single mechanism for improving enterprise economic efficiency remains relevant.

3. Problem Statement

The study aims to examine the theoretical and methodological foundations of cost management for the production of building materials. To achieve this goal, it is necessary to analyze the main theoretical provisions and systematize the analytical elements of the cost management system. This will allow for the formation of a holistic and systematic cost control model for rationalizing the resource-intensive activities of building materials producers.

4. Methods and Materials

The following scientific methods were used in the research: analysis and synthesis to study the cost components in building materials production and to generalize theoretical approaches to their

management; abstraction and generalization to highlight the essential characteristics of the cost management process and formulate theoretical and methodological provisions; comparative analysis to assess the differences in cost management approaches across various enterprises in the building materials industry and identify the most effective practices; a systemic approach to ensure a comprehensive view of the cost management system as an interconnected set of production process elements; structural-logical method to build a logical scheme of cost management and determine the place of each element in the overall system; and the expert evaluation method to identify the key factors influencing cost formation and assess the effectiveness of management decisions.

5. Results and Discussion

The key challenge in cost control lies not so much in the absolute accuracy of determining the product's cost price, but in understanding the mechanisms of its formation, and in ensuring control functions in both preventive and operational modes of influence on the enterprise's production activity, aiming to correct deviations from planned parameters. Domestic cost management practice during Ukraine's independence faced significant difficulties due to insufficient attention to cost price formation, which negatively affected the methodology of planning, accounting, and analysis of production costs. As a result, scientific and technical developments created in previous periods were lost, significantly limiting the competitiveness of national enterprises [15].

Production costs serve simultaneously as both an object and a subject of management in the enterprise economy at the micro-level, being an integral part of management accounting. However, at the current stage in Ukraine, a holistic and systematic cost control model is virtually absent, which would determine corporate policy for rationalizing resource-intensive activities. It should be noted that the lack of a clear system for managing the cost reduction process complicates the implementation of an effective cost policy. Increasing inflationary pressure only exacerbates this problem, as the primary source of company profit is often associated with raising selling prices rather than optimizing production costs.

Modern production operates under multifaceted constraints, determined by the psychological characteristics of employees, the level of scientific and technical innovation implementation, and the quality and quantity of labor resources and the enterprise's material and technical base. To achieve productivity goals, a comprehensive analysis of the economic efficiency of the enterprise's operations is necessary, including the evaluation of each structural unit's activities. Such analysis is implemented through a control system that covers the quality, productivity, and profitability of various types of products [1].

The effectiveness of enterprise management largely depends on the organization and level of control over production costs. Figure 1 illustrates the main elements of the cost control system, including cost regulation, strategic cost forecasting, integrated resource planning, adaptive normalization, cost accounting, process-oriented costing, operational economic analysis, deviation control and real-time response, cost auditing, feedback, and corrective management, where these components interact within a single cost management mechanism [16].

In critical operational conditions for the enterprise and when the industry's existence is threatened, management increasingly realizes the need for rational resource utilization at every stage of the production process, especially in the context of constantly rising prices for materials and energy resources. A significant number of enterprises have the potential to reduce costs to an optimal level, ensuring increased economic efficiency and competitiveness.

Cost control has an integrative nature, combining the methodological aspects of cost management and the overall operational efficiency of the enterprise, focusing on the final financial result – profit [16]. Some scholars support the position that cost control allows not only for a more precise determination of actual cost levels but also for identifying reserves for their reduction. At the same time, the control process must be purposeful, oriented towards operational intervention in management processes, ensuring timely correction of deviations [17].

The contemporary period is characterized by high costs and rising market prices, which, despite negative economic consequences, stimulate the rational allocation of resources and orient enterprises towards profitable production. In this context, the continuous search for ways to optimize costs becomes a necessary element of the enterprises' competitive strategy [16]. Production cost

management at the current stage is defined as a process of systematic control over the deployment of expenditure resources and the active participation of management personnel, ensuring continuous monitoring and adjustment of the product's cost price. The main factors determining increased attention to cost price in management are: rationalization of limited resources, ensuring profitability through savings, supporting integrated indicators of economic efficiency, analyzing planned and actual costs to identify deviations, determining gross profit, making management decisions regarding the optimization of production processes, and expanding the product range.

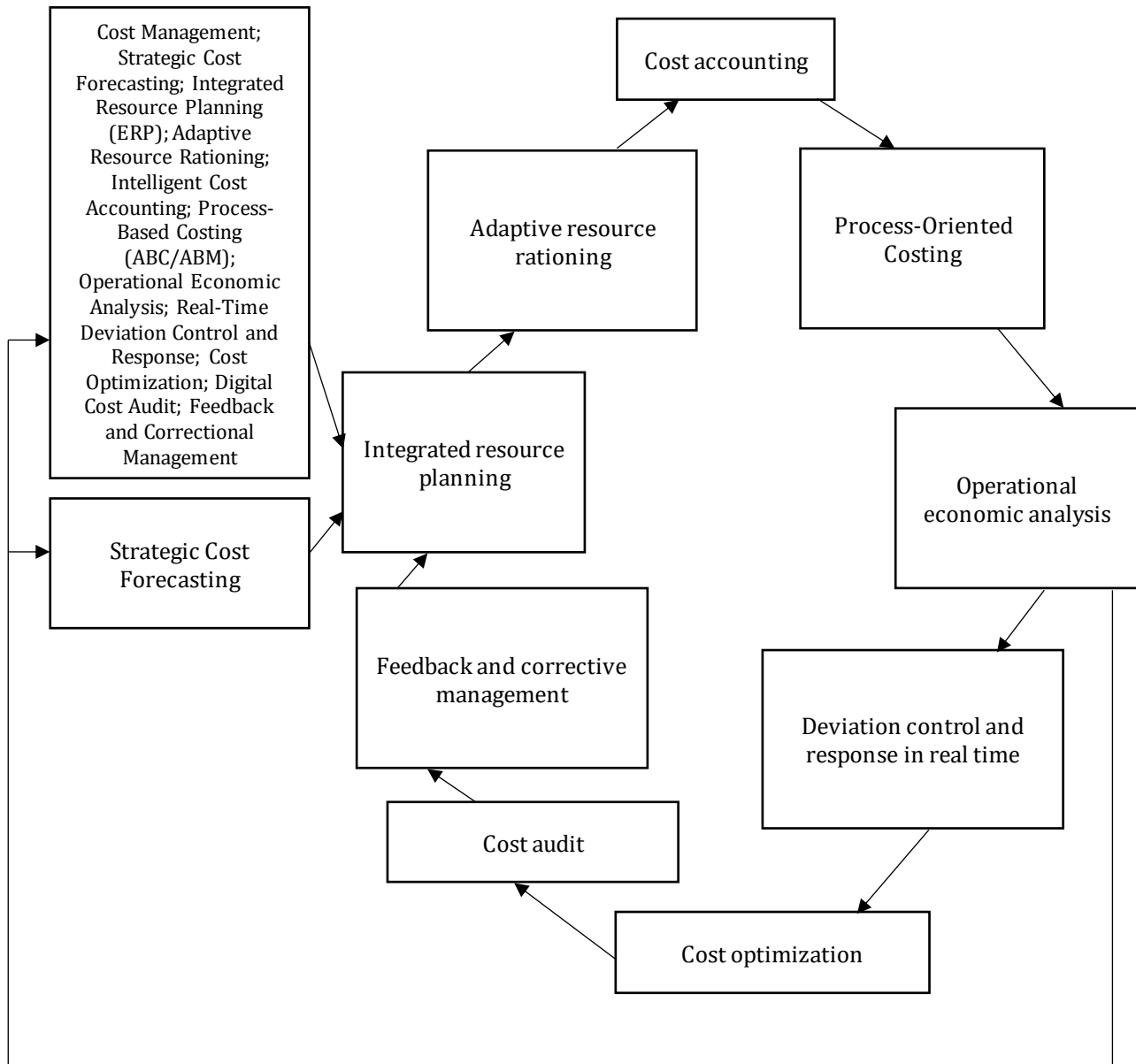


Figure 1. Main Elements of the Production Cost Control System

Source: Author's own development.

The development of a cost control system is based on three fundamental principles: deep and comprehensive analysis of the enterprise's activities, building a system based on cost assessment, and implementing mechanisms for continuous improvement of production processes. This approach ensures a high level of adaptability and functional integrity of the control system compared to other cost formation and management models [3].

It should be emphasized that cost control is not synonymous with direct cost management, and effective management can only influence the cost level by transforming production activities and changing tactical and operational goals. Therefore, the stages of cost management include setting accounting and costing standards, ensuring integration with other enterprise systems, monitoring

actual costs, comparing them with normative indicators, and analyzing deviations for operational adjustment of production processes [17].

Most modern studies emphasize that costs are not only the basis for cost price calculation but also an integrated indicator of economic rationality, technological sophistication, and financial discipline of the enterprise [18]. Given this, the scientific and methodological prerequisite for improving cost management systems is a comprehensive analysis of their structure, functional relationships, and the identification of potential dysfunctions.

According to the position of the leading Ukrainian researcher O. Krushelnytska, cost management is viewed as a multi-component process that includes a complex of organizational and managerial measures aimed at achieving maximum economic efficiency of the enterprise's operations [4, p. 98]. By her definition, the cost management system is a holistic, rationally structured model that functions based on the principles of continuity, goal integration, and the interdependence of organizational elements (Figure 2).

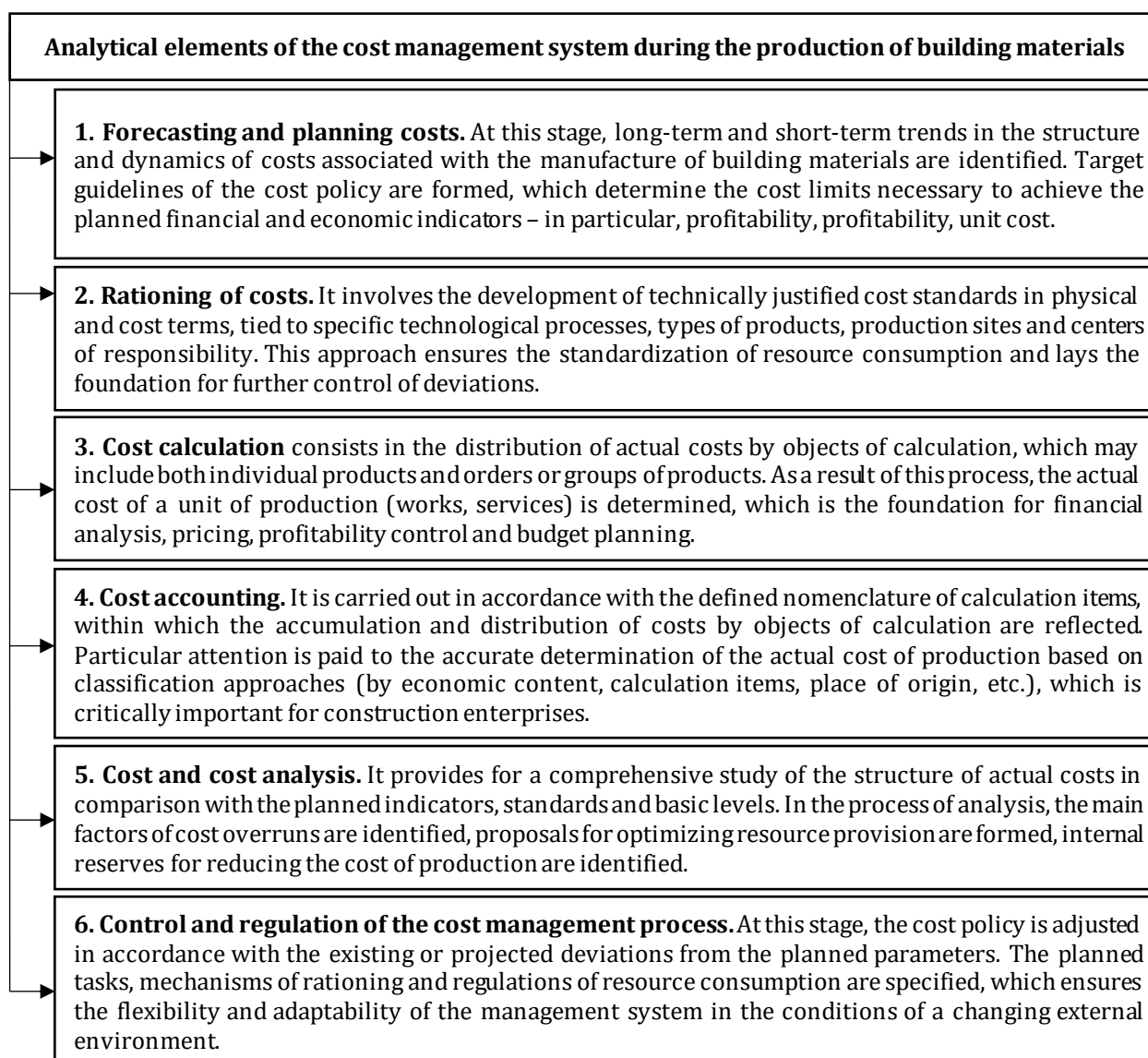


Figure 2. Analytical Elements of the Cost Management System During the Production of Building Materials

Source: Formulated by the author based on [11].

The main components of this system include functional and organizational aspects, which interact and complement each other, creating the foundation for effective cost control, planning, and regulation [4, p. 114]. The organizational structure of the cost management system distinguishes the following subsystems: identification of resource saving factors; planning and normalization of costs by category; accounting and detailed cost analysis; motivation for rational resource use and implementation of

measures for their optimization. Each subsystem performs specific functions aimed at increasing the overall efficiency of the enterprise's operations, and their interaction ensures a synergistic effect in enhancing competitiveness.

6. Conclusions

The conducted research successfully substantiated the theoretical and methodological foundations of cost management for the production of building materials and proved the necessity of transitioning from traditional accounting to a holistic, systemic control model. It was established that the key management problem lies in the absence of a mechanism capable of ensuring the functioning of control in both preventive and operational modes of influence on production activity, which complicates the timely correction of deviations.

The methodological essence of the proposed cost management system lies in forming a comprehensive mechanism for integrating the processes of supply, consumption, control, and regulation of resource flows. The system encompasses such critically important analytical elements as strategic cost forecasting, adaptive resource normalization, process-oriented costing (ABC), and real-time deviation control.

The key characteristics of the developed system are purposefulness, flexibility, adaptability, and manageability. Its implementation provides construction-profile enterprises with tools for the accurate determination of the actual product cost price, increased economic justification of management decisions, and a significant enhancement of resilience to external price risks. This is a guarantee for the rationalization of resource-intensive activities and competitiveness in conditions of market instability.

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The Impact of the Quality of Laboratory Control of Grain on the Formation of Export Prices and Discounts: Economic Analysis

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ABSTRACT

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The stability of grain quality parameters is a crucial prerequisite for ensuring the competitive position of domestic exports in the world market. The main objective of the study is to conduct an economic analysis of the impact of effective laboratory quality control of grain, focusing on pest infestation levels and other important quality parameters, on the determination of export prices and related discounts under free-on-board (FOB) contracts. The study intends to propose new methodological approaches and an econometric forecasting model aimed at increasing the accuracy of quality assessment and reducing economic risks for grain exporters. A variety of methodologies were used to facilitate this broad empirical study. These include standardized quality control protocols that comply with international standards, such as ISO, GAFTA, FOSFA and Codex Alimentarius, as well as rapid analytical methods (e.g., LFA, NIR/FT-NIR, machine vision, HSI) and advanced laboratory analyses (e.g., LC-MS/MS, HPLC, PCR). This is complemented by sophisticated econometric modeling. The scope of this study includes a systematic analysis of how critical attributes, namely moisture content, protein level, gluten content, vitreousness, impurity percentage, contamination level, and mycotoxin concentration, affect the formation of price discounts and potential economic losses incurred by exporters. The study uses both linear and log-linear regression models to predict the predicted FOB price and quantify discount adjustments, all dependent on laboratory-verified quality indicators. Finally, the authors advocate an integrated quality control paradigm. This approach combines standardized sampling protocols, automated inspection systems, and multi-level analytical algorithms to increase the accuracy of the assessment and reduce financial losses. Such a robust framework is designed to strengthen the competitiveness of Ukrainian grain exports in the global market.

KEYWORDS

quality control, infestation, grain quality, mycotoxins, ISO standards, GAFTA, FOSFA, Codex Alimentarius, grain export, econometric model, FOB.



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СОЦІАЛЬНИЙ РОЗВИТОК: економіко-правові проблеми

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Вплив якості лабораторного контролю зерна на формування експортної ціни та дисконтів: економічний аналіз

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СТАТТЯ

АНОТАЦІЯ

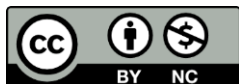
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Вважливою складовою забезпечення високого рівня конкурентоспроможності українського експорту на світовому ринку є стабільність забезпечення якісних показників продукції галузі зерновиробництва. Мета даного дослідження – аналітична оцінка впливу добротної проведення лабораторного аналізу якості експортованих партій зерна з позицій зараженості шкідниками (інфестованість) та вмісту мікотоксинів на формування цін експорту згідно контрактів FOB. Проведено бенчмаркінг-аналіз стандартів Codex Alimentarius, ISO, GAFTA, FOSFA та Codex з контролю якості зерна на світовому ринку. Серед показників якості обрано: вміст вологи, натуральна маса, протеїн, клейковина, склоподібність, засміченість, інфестованість, вміст мікотоксинів та жиру, забарвленість. Встановлено, що в світовій практиці стандартизації якості зерна не існує універсального підходу до ефективного оцінювання з 100% достовірністю. За даними експорту української пшениці та суміші пшениці й жита (меслину) за 2015–2024 рр. проведено розрахунок потенційних економічних втрат від інфестованості та невідповідності зерна міжнародним стандартам. Встановлено, що незначні порушення умов стандарту призводить до зміни дисконту на 2%. Проаналізовано існуючі методи визначення інфестованості та мікотоксинів у партіях зерна. Визнано ефективність експрес-методів контролю (LFA, NIR/FT-NIR, систем машинного зору) для оцінювання проблемних партій зерна. Доведено відсутність уніфікованого методу швидкої оцінки якості зерна з високим рівнем чутливості та низькою собівартістю. Розроблено універсальну економетричну модель з використанням двох видів формул (лінійних та лог-лінійних функцій) для подальшого прогнозування ціни FOB та визначення величини дисконту. Доведено, що в умовах обмеженості цінової кон'юнктури раціональним є використання рієсвейс-регресійного аналізу та моделей типу Tobit. Наголошується, що інтегрована економетрична модель базується на поєднанні протоколів відбору зразків зерна згідно міжнародних стандартів, автоматизованих систем менеджменту та контролю з метою підвищення конкурентоспроможності експорту української продукції на глобальному ринку.

КЛЮЧОВІ СЛОВА

контроль якості, інфестованість, якість зерна, мікотоксини, стандарти ISO, GAFTA, FOSFA, Codex Alimentarius, експорт зерна, економетрична модель, ціна FOB.

1. Introduction

In the context of the globalization of world agricultural markets and the intensification of competition between exporting countries, there has been a significant increase in the requirements for the quality characteristics of grain crops, which are a leading export resource. Under these circumstances, the laboratory control system acquires the status of not only a tool for verifying the compliance of products with international standards, but also becomes a determining factor in setting reasonable pricing for export supplies. The precision, objectivity and representativeness of the conducted analytical studies directly affect the level of trust on the part of external counterparties, the size of potential commercial risks and the tendency of importers to apply price adjustments (discounts).

Imperfection of laboratory measurements, methodological inaccuracies or non-compliance with established sampling protocols lead to systematically unreliable quality indicators. Such shortcomings inevitably lead to disputes between market participants, the spread of price compromises in commercial contracts and, in some cases, the loss of market segments. The capabilities of laboratories will contribute to a significant reduction in economic losses of exporters and increase the competitiveness of Ukrainian grain exports in the market [22].

Despite the undoubted strategic importance of the above-mentioned aspects, the problem of economic determination, which is due to the quality of laboratory assessment of grain crops, on the formation of export prices, the size of discount deductions and price risks, remains the object of further in-depth systematic study. Therefore, this determines the relevance of the study aimed at a comprehensive analysis of the relationship between laboratory control criteria and economic indicators of export operations in the grain industry.

2. Literature Review

Modern studies demonstrate that the qualitative characteristics of grain – both standard (moisture, test weight, impurities, purity) and final end-use (protein, properties for grinding, flour, sintering) – have a statistically significant and economically important impact on the market price of grain. Thus, in the study of S. Roberts et al. [29] on the example of US durum winter wheat, it was shown that the price varies depending on quality: the market adjusts the price as quality information is received during the harvest. Another study focused on the markets of middle-income countries shows that increased grain quality gives premiums of 1–8% compared to the basic standard, although not all quality characteristics are transparent to the buyer. Y. Miao et al. [21] emphasize that the growing demand for higher quality grain encourages farmers and traders to invest in standardized quality control, which opens up the possibility of price premiums (“premium pricing”) and increases the market value of products.

Studies show that quality parameters may not directly correlate with the quantity of the crop – i.e., high volume does not guarantee high quality. For example, in a study by M. J. Tilse et al. [33], it was traced that yield fluctuations do not coincide with fluctuations in protein content, and grain with higher protein receives a premium in the market. O. S. Parkhomenko and O. S. Kuleshova [27] emphasize that the formation of the export price of grain is determined by a complex of economic and political factors that affect export volumes and price dynamics. From this position, laboratory quality control is a key prerequisite for a reliable determination of grain class, the size of discounts and competitiveness in world markets. It follows that the accuracy and methodological consistency of laboratory analyses are of paramount importance for reducing price volatility and ensuring the stability of Ukraine's export operations. Therefore, the commercial attractiveness of grain depends not only on production volumes but also on verified quality control, which makes laboratory research an integral factor of successful foreign trade activity.

From the point of view of the formation of added value of grain production, the studies of O. Svitovyi et al. [32] also indicate the need to introduce organizational and economic mechanisms that ensure standardization and quality control of grain, which is a prerequisite for obtaining market premiums and competitive advantages in the international market. That is, for adequate forecasting of the export price and the level of discounts, economic models have to take into account not only yield or

market conditions, but also objective results of laboratory control – they act as an information bridge between products and the market.

3. Problem Statement

The article is aimed at carrying out an economic analysis of the impact of the quality of laboratory control of grain, in particular the determination of contamination and other critical quality indicators, on the formation of export prices and discounts under FOB contracts, as well as the development of author's methodological approaches and an econometric model for forecasting the price of grain per ton in the presence of specific deviations in quality indicators, and to convert this change into the expected absolute discount per batch to increase the accuracy of estimation and minimize economic losses of exporters.

4. Methods and Materials

To study the detection of pest infestation and the presence of mycotoxins, as well as to assess the physical and chemical properties of grain in accordance with international standards, in particular Codex Alimentarius, ISO, GAFTA and FOSTA, the information of the State Statistics Committee of Ukraine on the export of wheat and wheat-rye mixture (meslin) for the period 2015–2024 was used. These standards were selected from the point of view of the most widely used in international practice regulatory norms for sampling and methods for assessing grain quality. The study used an integrated approach of combining laboratory methods (LC-MS/MS, HPLC, PCR) with screening methods (LFA, NIR/FT-NIR, Machine Vision, HSI). Such integration makes it possible to more thoroughly assess the degree of riskiness, optimize the costs of export operations and forecast the pricing policy for the future with a probability of effectiveness of up to 70% and

To assess the impact of grain quality on FOB contract prices, an econometric (economic and mathematical) model was used. The model is based on the actual indicators of grain quality according to laboratory surveys (volume of shipped products, logistics, market indicators, adjustments for geographical location and seasonality). The model has two options: log-linear and linear. The first shows by what percentage the price changes, the second shows the estimated discount value at the FOB price. The value of the model is to forecast the price of final export products in the future with the ability to take into account predictable and unpredictable risks and develop possible scenarios for their leveling. The econometric model provides for compliance with standard sampling requirements, the use of automated control systems, laboratory analysis and analytical algorithms to increase the reliability of assessing the quality and competitiveness of Ukrainian grain in the world market

5. Results and Discussion

A high level of competitiveness of grain in the world market primarily depends on compliance with international standards and protocols according to scientifically based and standardized procedures for accurate measurement of physical and chemical parameters and the level of contamination of exported products [25]. After all, business reputation in the international arena, commercial value and further pricing policy of possible discounts under FOB contracts depend on this.

Today, ISO standards, GAFTA rules and guidelines, FOSFA requirements, as well as the provisions of the Codex Alimentarius are widely used in the world practice of grain valuation. Each of these systems regulates sampling procedures, methods for determining moisture, protein, gluten, vitreousness, impurities, as well as infestation and the presence of mycotoxins. They establish clear criteria for permissible deviations, define methodological approaches to control, and provide a framework for arbitration and certification procedures used in foreign trade transactions.

A generalized comparative analysis of the main physical and chemical indicators of grain quality demonstrates a comparison of their regulation according to the specified international systems of standards (Table 1) allows you to understand in which aspects international requirements coincide and where there are differences, which can be useful for the development of internal laboratory procedures, optimization of quality control and minimization of economic risks in the export of grain crops.

The analysis of the table data shows that all the considered international regulations have one goal

– to provide a reliable assessment of grain quality on the basis of laboratory tests in compliance with all sample requirements provided for by the regulations. The presented benchmarking analysis serves as the foundation for the formation of the standard of the national system for assessing the quality of grain, the formation of the author's approaches and methods in order to predict the value of the discount, optimize costs and ensure the competitiveness of exported products in the world market.

Table 1. Benchmarking analysis of the main international standards for grain quality control on the world market

Quality Score	ISO	GAFTA	FOSFA	Codex Alimentarius	Application features
Grain moisture	ISO 712; ISO 24333	GAFTA Sampling Rules	FOSFA Contract Terms	–	Moisture control to maintain quality and prevent mold growth.
Natural weight (test weight)	ISO 7971	GAFTA Quality Standards	FOSFA – for oilseeds	–	Determines the density and physical quality of grain, which affects the price.
Protein content	ISO 16634; ISO 12099	GAFTA – Wheat Protein Content Rules	FOSFA – Protein Content for Oilseeds	Codex Standards for Cereals	Determines the nutritional value and quality of wheat, barley and soybeans
Gluten content	ISO 21415; ICC 137	GAFTA – Gluten Quality Rules	–	–	The main indicator for the baking properties of wheat
Vitreousness of grain	ISO 520; ICC 129	GAFTA – Vitreous Kernels	–	–	Determines the varietal and technological properties of wheat
Clogging (impurities)	ISO 5223; ISO 663	GAFTA Sampling & Admixture Rules	FOSFA Contract Terms	Codex Cereal Grading	Affects batch cleanliness and commercial risks
Infestation	ISO 663; ISO 7971	GAFTA Sampling Rules; Pest Control	FOSFA Pest Control Clauses	–	Pest detection, impact on discount and export price
Mycotoxins (DON, aflatoxins)	ISO 18787	GAFTA – Mycotoxin Limits	FOSFA – Mycotoxin Limits	Codex Maximum Levels	Control of toxic substances, in accordance with legislation and contract
Oil/fat content (for oilseeds)	ISO 659	GAFTA Oil Content Rules	FOSFA Contract Terms	–	Determines the extractivity and commercial value of oilseeds
Color, characteristics of the variety	ICC 105/2; NIR	GAFTA Color & Grade Rules	FOSFA – Quality Grades	Codex Cereal Classification	Affects batch class and processing application

Source: Compiled by the author based on data from [1–20].

As a result of the study, a systematic analysis of methods for detecting infestation (pest infestation) and determination of mycotoxins in grain batches, their suitability for use in export conditions under FOB contracts and impact on the formation of discounts was carried out (Table 2).

The analysis of the table data shows the absence of a combined method for assessing the quality of grain, taking into account such important parameters as the level of sensitivity, speed of analysis, and low cost. The model should adequately reflect the results of laboratory analysis of selected samples of grain batches using screening tests, as well as appropriate quantitative methods. It is laboratory analysis that provides 50–70% of the objectivity and accuracy of the results obtained in the quality of the exported batch grain. Failure to comply with the sampling procedure and violation of international standards leads to an increase in the discount value and deterioration of partnership relations [24]. According to the results of the study, a sufficiently high level of efficiency of the use of such control express methods as NIR/FT-NIR, LFA, and machine vision systems was established. These methods make it possible to determine the quality of a particular batch of grain in a short time using minimum volumes of samples with goal of saving the total cost of expensive analyses to confirm the reliability of the data. It is the LC-MS/MS and HPLC methods that are currently the most necessary for determining the accuracy of inspection, resolving contradictory situations by counterparties to export contracts in order to comply with quality requirements in part, contamination and mycotoxin content. In the context of the development of digitalization, it is PCR diagnostics and automated optical control systems that provide a high level of efficiency in sampling for analysis in production and elevators [23].

Thus, the results of the study prove the effectiveness of a combined approach to quality control of

exported grain, which is based on the use of high-precision analysis methods using unified sampling procedures in accordance with Codex Alimentarius, ISO and other standards using multi-level digital algorithms, which include screening tests and LC-MS/MS. An important role is given to the systematic calibration of spectroscopic samples. As a result, reliable results of assessing the quality of the batch of exported grain and maximum leveling of the risk of non-compliance with the terms of concluded contracts will be obtained, and the projected export price will be determined.

Table 2. Analysis of methods for determining infestation and mycotoxins in grain batches

Method	Type	Dignity	Limitations	Applications
LFA (immunoliner tests)	Express method	Fast results; low cost; Ease of Use	Low accuracy; Needs confirmation	Preliminary screening for mycotoxins
NIR/FT-NIR	Spectroscopy	Fast; does not destroy the sample; Suitable for large batches	Requires calibration; Average accuracy	Grain quality screening, preliminary assessment of infestation
LC-MS/MS	Chromatography + Mass Spectrometry	High precision; Legally significant result	High cost; requires equipment and qualifications	Confirmation of mycotoxin levels
HPLC	Chromatography	Accurate qualitative analysis	Longevity; High cost	Confirmation of toxin concentrations
HSI	Hyperspectral inspection	Stability; automation; absence of human factor	High cost of equipment	Automatic sorting and quality control
Machine vision	The image is analyzed by a computer	Efficiency; Automation	Less accurate than laboratory methods	Detection of infected grain on the lines
PCR	Molecular diagnostics	High precision; Pathogen detection	Needs a laboratory; High cost	Identification of fungal pathogen infestation

Source: Compiled by the author based on data from [28; 30; 26].

The analysis of the dynamics of Ukrainian exports of wheat and a mixture of wheat and rye (meslin) for 2015–2024 shows a significant economic sensitivity of external supplies to grain quality parameters, primarily to indicators of infection and compliance with international standards ISO, GAFTA, FOSFA and Codex Alimentarius. Based on official data of the State Statistics Service of Ukraine [31] regarding export volumes and the average contract price, the total cost of export deliveries was calculated and potential economic losses of exporters were modeled in case of application of price discounts due to the non-compliance of grain with the regulated requirements (Table 3).

Table 3. Calculation of potential economic losses of exporters from grain contamination and non-compliance with international standards, 2015–2024

Year	Export volume, thousand tons	Price, USD/t	Export value, USD million	Losses at a discount of 2%, USD million	Losses at a discount of 5%, USD million	Losses at a discount of 10%, USD million
2015	13452	166	2233.03	44.66	111.65	223.30
2016	17921	152	2723.99	54.48	136.20	272.40
2017	17313	159	2752.77	55.06	137.64	275.28
2018	16373	183	2996.26	59.93	149.81	299.63
2019	20022	183	3664.03	73.28	183.20	366.40
2020	18060	199	3593.94	71.88	179.70	359.39
2021	20071	253	5077.96	101.56	253.90	507.80
2022	11216	239	2680.62	53.61	134.03	268.06
2023	16152	182	2939.66	58.79	146.98	293.97
2024	20665	181	3740.37	74.81	187.02	374.04

Source: Calculated by the author based on data from [31].

The results show that even minimal deviations from the standards, which lead to the application of a discount at the level of 2%, form annual direct losses in the range of 45–100 million USD. With an increase in the level of non-compliance to medium (5%) and high (10%), losses increase to USD 150–250 million and USD 300–500 million, respectively. The largest volume of potential losses was recorded in years with a high level of export revenues (2021 and 2024), which is due to both an increase in the contract price and an increase in supply volumes.

In cases of delay of a batch of goods in ports, additional costs for fumigation and testing are

incurred, and logistics costs increase (about 0.5–3% of the total cost), which negatively affects the level of profitability of exporters. The results of approbation of the econometric model show that for the period under study (2015–2024), Ukrainian producers received less than 3.4–3.7 billion. US dollars. This once again proves the importance of compliance with international standards, which can be ensured through the sustainable functioning of the certification system for grain products for export.

In order to determine the value of the future discount as close as possible to reality, it is proposed to use an econometric model, which is based on the relationship between the contract price (on FOB terms) and a set of quality indicators established by laboratory analysis. The model is of an applied nature and is designed for use by participants in export operations – manufacturers, analysts, and transport companies. The model is based on the principle of approximation, i.e., determining the impact of changes in one of the quality factors (in this case, infection and mycotoxin content) on the change in the export price (in case of a decrease in the use of discount). This allows commodity producers to neutralize the threat of loss of grain quality along the entire logistics route to the destination Free on Board.

The model takes into account that the FOB price (board price the vessel, USD/t) is formed at the intersection of supply and demand, macro-energy and logistical conditions and on the quality of a particular batch. Laboratory-determined indicators (humidity, protein content, volume of damaged or infected grains, mycotoxin level, etc.) have a direct impact on the buyer's desire to pay the full price or use a discount. controlling external factors. The log-linear variety of the model shows the price change as a percentage, which can be calculated using the formula:

$$\ln(FOB_{it}) = \alpha + \beta_1 Q_{it} + \beta_2 X_{it} + \gamma_t + \delta_j + \varepsilon_{it} \quad (1)$$

The linear variety of the model is aimed at determining the discount value (USD/t). The calculation formula is as follows:

$$FOB_{it} = \alpha + \sum_k \beta_k Z_{kit} + \sum_m \theta_m C_{mit} + \gamma_t + \delta_j + u_{it} \quad (2)$$

where:

i – supply batch index, t – time (month/year), j – importer;

Z_k – a set of laboratory-confirmed quality indicators;

C_m – controlled variables (batch volumes, market indices, port, exchange rate fluctuations, etc.);

γ_t – time fixed effects (season, year), control over market trends;

δ_j – fixed effects by directions/counterparties (different standards/terms of acceptance);

ε_{it}, u_{it} – stochastic terms.

The evaluation strategy of the model is based on a combination of classical and advanced econometric approaches, which ensure the reliability of the results obtained under conditions of heterogeneity and potential bias of the data. Baseline assessment is carried out using OLS with clustered standard errors by direction or year, which makes it possible to correct for possible autocorrelation and heteroscedasticity. In the presence of a large number of batches from the same exporters or routes, models with fixed effects are used, which make it possible to control the hidden characteristics of suppliers or logistics directions that remain unchanged over time. Since the quality of the batch can be endogenous – for example, when better samples are directed to more profitable contracts – instrumental variables are additionally used, including natural weather indices at harvest time, the duration of grain storage before shipment, or yield indicators of the region. In the case of nonlinear coupling factors (excess of mycotoxins, moisture, contamination, etc.), it is rational to use regression of the “piecewise” or “spline” type and algorithms such as Tobit. This approach is especially relevant in the case of the disqualification of a batch of exported grain due to the influence of natural factors. The reliability of such results can be verified by cross-validation using statistical testing.

After evaluating the coefficients, you can directly predict the price change (USD/t) or absolute discount for a given direction of determining quality indicators. In linear form, the expected discount (USD/t) for a batch with Z indicators is calculated according to the formula:

$$\Delta FOB = \sum_k \beta_k (Z_k - Z_k^{ref}) \quad (3)$$

where Z^{ref} – baseline values (e.g., humidity 14%; DON = 0.5 mg/kg; infestation = 0%).

Table 4. Recommended list of variable indicators for the econometric model

Designation	Name	Unit of measurement	Impact on price
FOB	Price FOB	USD/t	Reduction
MOIS	Humidity	%	The higher the humidity, the lower the price
DMG	Damaged grains	%	Reduction
INF	Infestation	% or quantity (t)	Reduction
FM	Impurities (foreign matter)	%	Reduction
PROT	Protein content	%	Growth of food wheat
TW	Density (test weight)	kg/m ³	Growth
DON	Mycotoxin esoxynivalenol (DON)	mg/kg	Usually has a non-linear effect
ZEA	Various mycotoxins, including zearalenone	mg/kg	Reduction
CERT	Compliance with the standard	1 – yes, 0 – no	Growth
QTY	Batch volume	thousand tons	The effect is oscillatory
DIST	Distance to the port (additional logistics costs)	km (USD)	Reduction
WRLD	World Price Index (basis)	USD/т	Growth
EXR	Exchange rate (UAH/USD)	UAH / USD	The effect is oscillatory

Source: Developed by the author.

In the log-linear form, the percentage change in the price is calculated according to the formula:

$$\% \Delta FOB \approx 100 \times \sum_k \beta_k (Z_k - Z_k^{ref}) \quad (4)$$

In this case, the magnitude of the absolute change is calculated by the formula:

$$\Delta FOB = FOB_{pred} - FOB_{ref}. \quad (5)$$

In practice, for each batch, the “price forecast” module produces two numbers – the expected FOB price according to current laboratory data and the expected price according to the “reference” quality level; The difference is the expected discount.

With the help of the proposed econometric model, it is possible to predict in time the impact of the estimated grain quality indicators on the FOB price. The model is based on the use of correlation equations in linear on log-linear form, which helps the exporting company to determine the discount value for each specifically defined batch of grain, as well as to modify scenarios depending on the variability of indicators of laboratory analysis of product quality and the requirements of international standardization. Another advantage of the model is the formation of an effective risk management strategy and a national policy of grain quality control at the state level.

Taking into account the above, it is proposed to apply an integrative methodological approach to the sampling procedure. In the context of mass digitalization of all sectors of the economy, it is appropriate to use automated management and control systems, digital platforms with data of accurate laboratory analysis of samples of each batch of grain on a certain date, as well as an economic and mathematical model for assessing the degree of riskiness in case of changes in market conditions and force majeure. The strategic management of grain exports should be based on a single protocol for confirming the reliability of the analysis data to strengthen confidence in the implementation of the export agreement and minimize the risks of losses.

6. Conclusions

The study confirmed the importance of assessing the quality of grain using laboratory analysis to determine its export price. It has been established that the correctness of sampling and rational use of analytical methods ensures the accuracy of measuring the infestation and content of mycotoxins, which proves the reliability of the quality of the product according to international standards (Codex Alimentarius ISO, GAFTA and FOSFA. Benchmarking analysis has demonstrated the complementarity of each standard, which necessitates consistency between Ukrainian quality protocols and these standards. However, each of the universal approaches is not effective enough.

Analysis of the dynamics of grain exports in Ukraine for 2015–2024 revealed that the annual loss incurred by commodity producers due to non-compliance with international quality standards is

measured in hundreds of US dollars, resulting in a discount. This suggests the need to employ reliable laboratory analysis methods in conjunction with digital algorithms. In this regard, a combined approach is proposed, which is based on the use of rapid screening and laboratory methods with elements of accurate measurement. The approach is based on an econometric model, which includes measurement by laboratory analysis of the main quality indicators: moisture, protein, infestation, mycotoxins, etc. All of the above indicators are the basis for the formation of FOB prices in the consignment agreement, and the model allows you to predict with maximum accuracy the number of possible deductions and discounts in the future in accordance with the quality characteristics of the batch of exported grain. The integration of the national grain export quality assessment system and the international certification system will contribute to the improvement of laboratory infrastructure and the formation of a high level of competitiveness of grain products in Ukraine.

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Systemic Contradictions in the Formation and Use of Human Capital in the Conditions of the Transformational Economy of Ukraine

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ABSTRACT

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The article investigates theoretical, methodological, and applied problems of human capital development in Ukraine. The relevance of the topic is due to the dissonance between the high educational level of the population and low indicators of labor productivity and quality of life. The aim of the work is to identify systemic obstacles that make it impossible to transform the existing labor potential into real human capital and to substantiate the need to change the paradigm of labor resources management. Based on a systemic analysis of demographic processes, the state of the educational services market, and the labor market situation, it is proven that in Ukraine, human capital exists mainly as a potential opportunity, not as a functioning asset. A deep theoretical demarcation of the concepts of “labor potential”, “labor force”, and “human capital” is carried out. It is determined that the category of “human capital” is not just a metaphor, but an economic asset that requires investment and must generate income. Disproportions in education and the phenomenon of “over-education” are analyzed, as well as the impact of low wages, which do not cover the equivalent of the cost of labor force (ECLF), on the reproduction of human capital. The impact of the demographic crisis and indicators of the nation’s health on the efficiency of social investments is investigated. It is substantiated that the capitalization of knowledge is impossible without the forced modernization of the national economy and a transition from a raw material-based model to an innovation-driven one. The lack of such conditions results in the depreciation of educational potential, its obsolescence, and the outflow of skilled personnel. It is proposed to view a high quality of life not merely as a consequence, but as a fundamental prerequisite for the effective formation of human capital.

KEYWORDS

human capital, labor potential, quality of life, modernization, demographic crisis, equivalent of the cost of labor force, labor market, social investment.



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СОЦІАЛЬНИЙ РОЗВИТОК: економіко-правові проблеми

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Системні суперечності формування та використання людського капіталу в умовах трансформаційної економіки України

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СТАТТЯ

АНОТАЦІЯ

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У статті здійснено спробу комплексно дослідити теоретичні та прикладні проблеми розвитку людського капіталу в реаліях трансформаційної економіки України. Актуальність обраної теми зумовлена наявністю глибокого дисонансу між високим рівнем освіченості населення та вкрай низькими показниками продуктивності праці й якості життя. Основною метою дослідження є виявлення системних бар'єрів, які блокують перетворення наявного трудового потенціалу на реально діючий капітал, а також обґрунтування необхідності зміни парадигми управління трудовими ресурсами. Базуючись на аналітичних даних Державної служби статистики, демографічних звітах та міжнародних рейтингах, доведено, що в Україні людський капітал існує переважно як потенційна можливість, а не як функціонуючий актив. Проведено глибоку теоретичну демаркацію понять «трудова потенція», «робоча сила» та «людський капітал», визначено, що остання категорія є не просто метафорою, а економічним активом, що потребує інвестицій та має приносити дохід. Проаналізовано диспропорції в освіті та феномен «надлишкової освіти» (over-education), а також вплив низької заробітної плати, яка не покриває еквівалента вартості робочої сили (ЕВРС), на відтворення людського капіталу. Досліджено вплив демографічної кризи та показників здоров'я нації на ефективність соціальних інвестицій. Аргументовано, що капіталізація знань неможлива без форсованої модернізації національної економіки та переходу від сировинної моделі до інноваційної. Відсутність таких умов призводить до амортизації освітнього потенціалу, його морального старіння та відтоку кваліфікованих кадрів. Запропоновано розглядати високу якість життя не просто як наслідок, а як фундаментальну передумову ефективного формування людського капіталу.

КЛЮЧОВІ СЛОВА

людський капітал, трудова потенція, якість життя, модернізація, демографічна криза, еквівалент вартості робочої сили, ринок праці, соціальні інвестиції.

1. Introduction

The modern economy of Ukraine is characterized by a systemic contradiction: the leading positions of the state in the world rankings in terms of higher education coverage are not transformed into appropriate economic growth and approximation of living standards to the European level. Knowledge and professional skills, the formation of which requires significant investment resources (both public and private), do not find productive application. This actualizes the need for a critical rethinking of the category of “human capital” not as abstract wealth or a set of certified specialists, but as a real economic asset that should function in the market, bring income to its owner and create added value for the state.

The scientific problem lies in the gap between the accumulation of educational potential and the possibilities of its economic realization. In Ukraine, a mechanism of “idle” in the reproduction of human capital has been formed: investments in education are made, but due to the deformations of the labor market and the primitive structure of the economy, they are not capitalized, but turn into expenses without proper return.

2. Literature Review

The fundamental foundations of the theory of human capital are laid down in the works of Western classics, in particular G. Becker (1993) [3] and T. Schultz (1961; 1971) [18; 19]. They proved that investing in a person is no less important than investing in physical capital. However, the mechanical transfer of Western models to Ukrainian soil without taking into account the transformational specifics is erroneous.

Human resources play a strategic role in the development of the enterprise. They are a prerequisite for the successful functioning of the company and its further development [7]. In the context of the development of scientific and technological progress, human capital is the basis for the formation of economic systems and ensuring their competitiveness at the macroeconomic and microeconomic levels [20]. Sustainable development of the national economy is the central concept of modern public administration, aimed at ensuring a balanced interaction between economic growth, social justice and environmental sustainability [3].

In particular, O. Hrishnova (2001) [8] substantiates the investment essence of this category, distinguishing it from the concept of labor force. In turn, E. Libanova (2014) [11] focuses on the analysis of socio-demographic determinants, deeply exploring the impact of property inequality and poverty on the development of human potential. A. Chukhno et al. (2007) [6] consider human capital in the context of the transition to the information society, emphasizing the role of production. In turn, V. Antoniuk (2006) [1] and V. Mandybura (2009) [13] focused on the socio-economic dimension of the problem. The importance of innovative education as a key determinant of the development of labor potential in his works is also emphasized by V. Blyzniuk (2011) [8]. Scientists investigate the objective realities and specifics of the functioning of human capital in the conditions of the domestic economy. Despite the significant number of publications, there is a certain terminological uncertainty in domestic science. The concepts of “labor resources”, “labor potential” and “human capital” are often identified. A critical analysis conducted on the basis of the works of S. Melnychuk [15] and other researchers allows us to assert the need for a clear demarcation of these categories in order to build an effective state policy.

Modern scientific discourse has significantly expanded the understanding of human capital in the context of the latest challenges. In particular, M. Hitka et al. (2019) substantiate the role of knowledge as a sustainable competitive advantage [7]. The impact of digitalization on the development of human capital is studied in the work of I. Shevchenko et al. (2023) [20]. The issue of sustainable development and demographic stability in the context of the crisis is revealed in the works of O. Baula [2] and L. Bilorusets [4]. The importance of state regulation of innovation infrastructure is emphasized by A. Ilyina [9]. Studies of post-war recovery are of particular relevance: V. Sanduhei et al. (2025) consider human capital as a driver of competitiveness [17], and V. Zhuravel et al. (2023) focus on the social protection of Ukrainian migrants in the EU [22].

3. Problem Statement

In Ukraine, there is an established structural disproportion between the significant amount of accumulated educational potential of the population and the inability of the national economy to ensure its full-fledged economic conversion. The technological backwardness of the manufacturing sector, the lack of coordination between the training system and the needs of the labor market, the deepening of the demographic depression and the chronically low level of remuneration for labor make it impossible to transform knowledge and competencies into productive human capital. As a result, investments in education do not provide the expected economic returns, the scale of migration outflow increases and there is a devaluation of existing human potential. This actualizes the need to eliminate systemic institutional barriers and carry out a deep modernization of the economy aimed at increasing the demand for highly skilled labor.

4. Methods and Materials

The methodological tools of the work are based on a set of general scientific methods. In particular, the method of theoretical generalization made it possible to distinguish the essence of the concepts of "labor potential" and "human capital". With the help of system analysis, demographic and educational factors of capital formation have been studied. The processing of data from the State Statistics Service and international ratings by methods of statistical analysis made it possible to identify imbalances in the labor market, and comparative analysis was used to compare national standards of quality of life and remuneration with global trends.

5. Results and Discussion

1. Theoretical demarcation of categories: from "labor resources" to "human capital"

To understand the deep reasons for the inefficiency of the use of the human factor in Ukraine, it is necessary to clearly distinguish the basic economic categories.

The term "labor resources" is a legacy of the planned and administrative economy, where a person was considered a passive object of management, a resource available for distribution by the state. In a market economy, when citizens have the right to freely choose the type of activity, this term loses its relevance at the micro level, although it can be used for macroeconomic estimates of the working-age population.

"The category of 'labor force' should be understood as an integral set of physical and intellectual abilities of an individual, which are actualized in the production process. In a market economy, it takes the form of a commodity, the value of which (wages) must be sufficient for the full restoration of the employee's vitality and professional development". "Labor potential is an integral characteristic of the available labor opportunities of an individual or society. It accumulates professional abilities, educational level, physical condition (health) and motivational attitudes, as well as the conditions necessary for their implementation. This category acts as the foundation for the formation of human capital, but it is different from it, since it characterizes the opportunity, not the realized value".

"Human capital is a specific economic asset formed by investing in human development. It is an accumulated stock of health, knowledge, professional skills and motivations, the targeted use of which increases labor productivity and ensures the growth of income of its owner".

The fundamental difference is that knowledge and skills acquire the characteristics of capital only when they: (a) are alienated from simple consumption; (b) are involved in production (invested); (c) bring income that exceeds the ordinary cost of simple labor (receiving "rent" for knowledge).

In Ukraine, there is a situation where significant *labor potential* (educated people) is not converted into *human capital due to the* lack of economic conditions for obtaining income from this knowledge.

2. Demographic background and the crisis of reproduction

The foundation for the development of human capital is the demographic situation (demography), which in Ukraine is currently in a state of acute crisis. Since 1992, a steady trend towards depopulation has been recorded in the country, which directly narrows the base for the reproduction of labor resources. The analysis of demographic processes shows that the population decline occurs not only due to migration, but also due to negative natural growth, which is reflected in detail in the demographic

reports of the “Population of Ukraine” [16]. A critical destabilizing factor is the high premature mortality of men of working age, analyzed in the works of the Institute of Demography edited by E. Libanova [12]. The scale of human capital losses and structural changes in the labor market as a result of the war are visualized in detail in the reports of the Kyiv School of Economics [14] and UNDP analytical reports [21].

A critical destabilizing factor is the high premature mortality of men of working age (especially in the age cohort of 30–44 years), which significantly exceeds the average European indicators. Such a demographic trend makes it impossible to fully return on investments made by the family and the state at the stage of human capital formation (education and upbringing). Shortening the period of active economic life leads to “underdepreciation” of the human asset, turning investments in it into high-risk and low-effective ones.

The war in Ukraine has increased migration flows and further depleted the skilled workforce. Awareness of the factors influencing human capital development in this context is crucial for developing an effective strategy that will ensure economic sustainability and sustainable growth [6]. Labor migration is becoming a growing trend in the modern labor market. Labor migration has its positive aspects, such as the redistribution of the labor force and increasing the efficiency of the use of human capital. However, along with other aspects of the flexible labor market, labor migration can also pose a threat to the social protection of workers [22].

In addition, there is an aging of the nation, which increases the demographic burden on workers. Reducing the tax base narrows the state’s ability to finance education and healthcare, creating a vicious circle of degradation of human potential.

3. Disparities in education: The phenomenon of “educational inflation”

In parallel with the deepening of the demographic crisis, significant structural distortions in the educational sphere are recorded in Ukraine. The analysis of the data of the State Statistics Service demonstrates a steady trend towards an increase in the share of persons with complete higher education in the economically active population. However, this trend does not indicate an increase in the quality of human capital, but manifestations of “educational inflation” – the devaluation of formal qualifications.

Due to the stagnation of the real sector of the economy, in particular the light industry, the problems of which are investigated by T. Levkovska (2013) [10], the labor market demonstrates low absorption capacity, not creating sufficient demand for a significant number of graduates, primarily in the humanitarian and economic profiles. The consequence of this imbalance is the spread of the phenomenon of “over-education”, in which specialists with a master’s level of training are forced to take jobs in trade or the field of basic services, where their high qualifications remain unclaimed.

The consequence of this is:

1. Dequalification: Unused knowledge is quickly lost.
2. Depreciation of the diploma: Higher education is no longer a guarantee of a high income.
3. Cost inefficiency: Household and state resources are spent on training specialists who are not needed by the economy of the existing structure.

The education system functions independently of the labor market, focusing on the demand of entrants (“fashionable” specialties), and not on the needs of economic development. This exacerbates structural unemployment and the imbalance between labor supply and demand.

4. Economic realities: Labor cost and poverty problem

The key obstacle to the capitalization of knowledge is the primitive structure of the Ukrainian economy, where low-tech modes and raw material orientation prevail. Such sectors of the economy objectively do not need complex, high-quality human capital.

Human capital plays a key role in the formation of an innovative environment, which emphasizes the need to create favorable conditions for the training of highly qualified specialists and the development of technological entrepreneurship [9].

The most indicative indicator of the crisis is the level of wages. In Ukraine, the basic principle of labor force reproduction has been violated. The official minimum wage and subsistence minimum do not meet real needs.

The concept of “Labor Cost Equivalent” (EURRS) is introduced, which is calculated based on the real needs of households for extended reproduction (including child support, housing, recreation, and self-development). Calculations show that the average salary in Ukraine often does not cover even a simple EVRS, let alone an extended one.

This means that:

- Employees do not have free funds to invest in their own development (health, additional education).
- The low cost of labor makes the introduction of labor-saving technologies and innovations unprofitable for employers.
- The lack of fair remuneration for qualifications demotivates employees to improve their professional level.

When a highly qualified engineer or scientist receives a salary comparable to that of unskilled labor, his knowledge does not function as capital. This leads to mass labor migration – the outflow of the most active and educated part of the population abroad, where their human capital can bring a higher income.

5. Quality of life and the imperative of modernization

The goal of human capital development should be the transition from quantitative indicators to qualitative ones. Quality of life is an integral indicator that includes the quality of working life, the state of the environment, the availability of cultural goods and the level of social security.

In Ukraine, the quality of working life remains low due to unsafe working conditions, high levels of stress, legal insecurity and unfair remuneration.

The loss of quality of human capital is not only the result of the consequences of war. Also, before the outbreak of large-scale hostilities, the trend of losses was characteristic of both general human capital, which, as you know, is formed through the acquisition of education and universal skills, and specific human capital, which is formed through the acquisition of narrow-profile knowledge and skills. This is due to the fact that in the conditions of the demographic crisis, the use of outdated technologies in production, an insufficient level of innovation, the motivation to acquire new competencies necessary for the development of the modern economy, as well as incentives for learning, decrease. This, accordingly, does not contribute to the restoration of the quality of human capital [17].

A way out of this situation is possible only through forced modernization. This involves:

1. Changing the structure of the economy: The transition from the raw material model to the production of products with high added value.
2. Creation of demand for knowledge: Only high-tech industries need high-quality human capital and can pay for it.
3. Reforming the social sphere: Investments in health and education should be considered not as budget expenditures, but as investments in national wealth.

6. Conclusions

The study's results provide grounds to assert that, in modern conditions, the human capital of Ukraine primarily functions in a latent form, as labor potential that does not fully realize its potential. The deep systemic contradiction lies in the discrepancy between the high quality of labor resources (educational level) and the technological backwardness of the production sector, which is not able to effectively assimilate this resource.

The demographic crisis (depopulation, high premature mortality) undermines the physical basis for the reproduction of human capital. Investing in a person becomes risky due to the short period of their return.

The education system is idling, producing a surplus of specialists who are not used in their specialty, which leads to dequalification and social apathy.

The low cost of labor, which does not reach the level of the EURPC, is the main demotivator for innovative activity and the cause of labor migration. Labor in Ukraine is underestimated, which makes it impossible to reproduce the labor force normally.

Overcoming systemic contradictions is possible only by abandoning the inertial scenario of development in favor of the innovative one. We need a state policy aimed at creating high-tech jobs, which will automatically increase the demand for quality education and provide a decent level of wages, turning knowledge from potential into real capital.

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Accounting for Expenses and Income in Small and Medium-Sized Enterprises in the Era of Digital Platforms: Models, Risks, and Managerial Implications

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ABSTRACT

The article focuses on the specifics of accounting for expenses and income in small and medium-sized enterprises that utilize digital platforms, as well as an analysis of related models, risks, and managerial implications. The purpose of the study is to identify current models of income and expense accounting in small and medium-sized enterprises in Ukraine within the context of digital transformation and to assess their managerial implications. The study employed general scientific methods of cognition: analysis and synthesis, induction and deduction, generalization, a systems approach, comparative analysis, and modeling. The results of the study show that the digitalization of accounting in Ukraine demonstrates a steady trend toward higher levels of technological integration in the financial processes of small and medium-sized businesses. It has been proven that the most common accounting platforms include MASTER: Bukhhalteriya, M.E.Doc, Dilovod, iFin, SMARTFIN.UA, Bookkeeper, and Fairo. The study reveals that the specifics of expense accounting in digital environments lie in the automation of all stages – from the input of primary documentation to the generation of financial results. It was found that expenses are automatically aligned with the national chart of accounts, and tax reporting is generated and submitted in real time to the State Tax Service. In terms of income, the research shows that digital platforms are integrated with CRM systems and payment tools, enabling instant income recognition and control over accounts receivable. At the same time, it was found that digitalization gives rise to a number of risks and managerial challenges. The main threats identified include dependence on digital infrastructure, cybersecurity issues, potential algorithm failures, and a shortage of qualified personnel in the field of digital accounting. The practical significance of the study lies in providing a foundation for the implementation of effective digital accounting models in the small and medium-sized business sector of Ukraine.

KEYWORDS

digital platforms, accounting, small business, expenses, income.



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СОЦІАЛЬНИЙ РОЗВИТОК: економіко-правові проблеми

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Облік витрат і доходів у підприємствах малого та середнього бізнесу в епоху цифрових платформ: моделі, ризики та управлінські наслідки

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СТАТТЯ

АНОТАЦІЯ

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Стаття присвячена особливостям обліку витрат і доходів у підприємствах малого та середнього бізнесу в умовах використання цифрових платформ, а також аналізу відповідних моделей, ризиків та управлінських наслідків. Мета дослідження – виявити сучасні моделі обліку доходів і витрат малих та середніх підприємств в Україні в умовах цифрової трансформації та оцінити їхні управлінські наслідки. У ході наукового дослідження використовувалися загальнонаукові методи пізнання: аналіз і синтез, індукція та дедукція, узагальнення, системний підхід, порівняльний аналіз і моделювання. Результати дослідження показують, що цифровізація бухгалтерського обліку в Україні демонструє сталу тенденцію до зростання рівня технологічної інтеграції у фінансові процеси малих та середніх підприємств. Доведено, що найбільш розповсюдженими обліковими платформами є MASTER: Бухгалтерія, М.Е.Doc, Dilorod, iFin, SMARTFIN.UA, Bookkeeper та Fairgo. Досліджено, що специфіка обліку витрат у цифрових середовищах полягає в автоматизації всіх етапів – від введення первинної документації до формування фінансових результатів. Встановлено, що витрати автоматично узгоджуються з національним планом рахунків, а податкова звітність формується і передається в режимі реального часу до органів ДПС. У сфері доходів показано, що цифрові платформи інтегруються з CRM-системами та платіжними інструментами, що забезпечує миттєве визнання доходів і контроль за дебіторською заборгованістю. Разом із тим, досліджено, що цифровізація породжує низку ризиків і управлінських викликів. Виявлено, що основними загрозами є залежність від цифрової інфраструктури, кібербезпека, потенційні збої алгоритмів і нестача кваліфікованих кадрів у сфері цифрового обліку. Практичне значення дослідження полягає у створенні бази для впровадження ефективних цифрових моделей обліку в малому та середньому бізнесі України.

КЛЮЧОВІ СЛОВА

цифрові платформи, бухгалтерський облік, малий бізнес, витрати, доходи.

1. Introduction

In today's global economy, digitalization has become a determining factor in the development of entrepreneurial activity, particularly in the field of accounting and financial management. Global trends show a shift from traditional forms of accounting to integrated digital ecosystems in which financial information is generated, processed, and analyzed in real time. These changes are driven by the need to speed up management decisions, reduce operating costs, and increase the transparency of financial processes. According to reports by the OECD and the World Bank, digital technologies in accounting – in particular, cloud services, analytical platforms, ERP and BAS systems – have become one of the main tools for building business competitiveness in the world. Their use allows companies to optimize document flow, integrate financial reporting with government systems, and ensure continuous monitoring of performance indicators.

Ukraine is gradually becoming part of this global process of digital transformation. The active introduction of digital technologies in the field of accounting is driven not only by the desire to improve management efficiency, but also by the need to adapt to international reporting standards and the requirements of the digital economy. Of particular importance are tools for automating the accounting of income and expenses, which ensure the reliability of financial information and the speed of its processing. In the context of martial law, digitalization is becoming not only a sign of modernization but also a means of increasing business resilience: it is digital platforms that allow enterprises to maintain control over financial processes, regardless of physical or organizational constraints, creating a basis for further economic development in the post-crisis period.

2. Literature Review

The issue of cost and income accounting in small and medium-sized businesses in the era of digital platforms, their models, risks and management consequences is sufficiently covered in the domestic scientific literature. Among the authors who studied the transformation of accounting under the influence of digital technologies, an important contribution was made by both specialists in theoretical analysis and researchers of practical aspects of the application of cloud solutions in financial management. A significant contribution to the development of the topic has V. D. Bondar [1], who focuses on the automation of accounting processes, in particular about inventories, which is the basis for effective cost control. E. I. Volot examines the role of cloud technologies in improving accounting procedures at enterprises, which is especially important for SMEs in the context of digital transformation [15]. H. Hladchuk et al. reveal how automation contributes to the transparency and accuracy of financial data, which is critical for estimating income and expenses [3].

A. O. Muzychenko analyzes the dynamics of the development of accounting taking into account cloud technologies, emphasizing the change in accounting policy models [5]. Important is the study of V. V. Novikov, who focuses on the digitalization of accounting in small business, where resources for the implementation of complex systems are limited [7]. S. O. Mykhailovyna et al. also analyze the importance of cloud solutions in the modernization of accounting and taxation [6].

A view on the implementation of digital technologies from the point of view of risks and strategic management is provided by M. Sorokolit, who emphasizes the need to adapt theoretical approaches to new digital conditions [13]. Y. V. Sheverya and A. M. Shysh demonstrate how cloud technologies are changing accounting practices in Ukraine [11; 12]. Foreign experience in this context is presented by A. Wahhab et al. [14], who analyze the impact of cloud solutions on the quality of financial reporting in countries with emerging markets. The contribution to the understanding of digital transformation at the macro level is presented in the work of V. Shepeliuk, which considers national trends, challenges and security aspects of digitalization of accounting processes [10].

Despite a sufficient amount of literature on this topic, there is a lack of systematized material on the topic of research, and therefore, using various methods of scientific knowledge, information was analyzed, grouped, systematized and presented in the light of the research topic.

The article is aimed at determining modern models of accounting for income and expenses of small and medium-sized enterprises in Ukraine in the context of digital transformation and assessing their managerial consequences. The objectives of the study include: analysis of the state of digitalization

of accounting and identification of the main digital platforms used in Ukraine; determination of the features of the formation and automation of cost accounting in the digital environment; characteristics of the specifics of income accounting and their integration with electronic services; identification of the main risks and managerial consequences of the use of digital platforms in the financial management of enterprises.

3. Problem Statement

The article is aimed at determining modern models of accounting for income and expenses of small and medium-sized enterprises in Ukraine in the context of digital transformation and assessing their managerial consequences. The objectives of the study include: analysis of the state of digitalization of accounting and identification of the main digital platforms used in Ukraine; determination of the features of the formation and automation of cost accounting in the digital environment; characteristics of the specifics of income accounting and their integration with electronic services; identification of the main risks and managerial consequences of the use of digital platforms in the financial management of enterprises.

4. Methods and Materials

The methodological basis of the study consists of a complex of general scientific and special methods of cognition aimed at achieving the research objective. Analysis and synthesis were utilized to process the theoretical foundations and regulatory framework of accounting within the digital economy. Through induction and deduction, the key trends in the digitalization of Ukrainian SMEs were identified, utilizing empirical data from the European Business Association and Kyivstar Business Hub.

The systems approach allowed considering income and expense accounting as an integrated element of the corporate management system. Comparative analysis was applied to evaluate the functionality of modern digital platforms (such as MASTER: Accounting, M.E.Doc, Dilovod, iFin) regarding their compliance with tax and management accounting requirements. Furthermore, the modeling method was used to structure the specifics of accounting processes in cloud environments and to assess the managerial risks associated with the automation of financial flows. The generalization method facilitated the formulation of conclusions regarding the impact of digital transformation on financial reporting quality.

5. Results and Discussion

The conditions of the ongoing war have become a powerful catalyst for the digital transformation of the business environment in Ukraine. Despite the difficult security circumstances, the vast majority of enterprises continue to function and adapt, actively introducing modern technological models into their operational processes. According to the results of the European Business Association survey (Business in Time of War, February 2025), 75% of companies as of the beginning of 2025 are fully operational, another 24% have certain restrictions, and only 1% temporarily do not work. This indicates the high adaptability of Ukrainian business, which remains resilient and even shows signs of resumption of economic activity. Moreover, 77% of companies plan to stay in the Ukrainian market, regardless of the course of military events [2]. Against the background of these indicators, there is a gradual digitalization of key business processes. According to the analytical review of Kyivstar Business Hub, accounting and document management are among the three areas where technologies are most actively used. According to the survey, 19% of companies already use digital solutions in the field of accounting and financial reporting, which indicates the systematic implementation of automation programs, cloud services, and electronic document management [4].

According to V. D. Bondar's research, accounting automation in Ukraine became a systemic process in the late 2010s, when a stable market for accounting software products was formed [1], and during the period of digital transformations (starting from 2020) they were especially developed. The most common programs are "1C: Accounting", "Info-Accountant", "Parus-Accounting" and "Galaxy", which provide comprehensive automation of financial activities of enterprises [1].

An important component of modern digitalization is the introduction of international standards for electronic reporting, which are automatically used by accounting software products and allow you to quickly adapt reporting to European requirements. As V. V. Novikov notes, the key tool of digital unification was the IFRS XBRL Taxonomy, which was implemented in Ukraine in the UA XBRL IFRS format. It provides a single electronic window for the submission of financial statements and increases the efficiency of data processing by government agencies [7]. The XBRL format allows for automatic tagging of financial indicators, which makes the information machine-readable, comparable, and analytically accessible. Although this standard is currently mandatory mainly for large enterprises and issuers, these standards will gradually apply to small and medium-sized businesses [7].

In modern conditions, according to the conclusions of H. Hladchuk et al., domestic enterprises are increasingly introducing automated accounting systems developed taking into account the requirements of national tax legislation and International Financial Reporting Standards (IFRS). Solutions such as MASTER: Accounting, M.E.Doc, Dilovod, iFin, Debit Plus, SMARTFIN. UA and BOOKKEEPER, provide high transparency of financial data, automatic reporting generation, integration with regulatory authorities and remote access to information [3].

Studies of current trends confirm that the digitalization of accounting processes directly improves the quality of financial statements, ensuring their accuracy, transparency and timeliness. In particular, the results of the regression analysis conducted indicate the presence of a statistically significant positive relationship between the use of computer technologies in accounting and the quality of financial statements: an increase in the level of adoption of cloud solutions by one unit leads to an approximately 23.8% increase in the quality of reporting. The authors prove that digital platforms reduce the impact of the human factor, improve the availability and reliability of data, and create conditions for more effective internal control and analytics [14].

The digitalization of income and expenditure accounting in small and medium-sized businesses in Ukraine is characterized by the active implementation of integrated online platforms that automate most financial processes. As noted by N. M. Selivanova et al., modern Ukrainian services are Dilovod, iFin, SMARTFIN. UA, MASTER: Accounting, and Fairo – provide a full cycle of income and expenditure management, combining accounting, analytical, and tax functions.

For example, Dilovod is used to control financial flows, mutual settlements, purchase and sales operations, warehouse accounting and personnel management, which creates a single digital environment for the financial activities of the enterprise [9]. The iFin system is focused on simplifying the accounting of income and expenses, wages, as well as the formation of electronic reports without the need for in-depth knowledge of accounting. All data is stored on the Microsoft Azure cloud platform, which guarantees security and uninterrupted access to financial information. SMARTFIN. UA and MASTER: Accounting provide advanced opportunities for cost accounting, reporting, payroll, sick leave, vacations, and compensation. Their modular structure allows you to conduct analytical accounting by areas of activity, which is especially convenient for enterprises with several types of business. The Fairo mobile application, developed by Raiffeisen Bank, has become a universal tool for sole proprietors and freelancers: it automates invoicing, receipt control, expense accounting and tax reporting [10].

Cost accounting in Ukraine using cloud platforms is based on a combination of national accounting regulations and the possibilities of automated digital processing of financial data. As noted by E. I. Volot, the use of cloud services in the accounting system makes it possible to integrate the processes of fixing costs, processing primary documents and forming accounting entries in a single digital environment [15]. S. O. Mykhailovina et al. emphasize that such systems as M.E.Doc, SMARTFIN. UA, iFin, MASTER: Accounting and Bookkeeper provide synchronization of accounting, management and tax accounting, allowing you to conduct cost analytics by items, divisions, financial responsibility centers and counterparties [6]. A. O. Muzychenko emphasizes that cloud technologies reduce the number of manual operations and provide automatic display of expenses in real time, which increases the efficiency of financial results management [5]. U. Pelekh notes that the main advantage of cloud platforms is the compliance of their functionality with tax requirements, which simplifies reporting and increases its accuracy [8]. Y. V. Sheverya considers the implementation of cloud systems as a necessary step to increase the efficiency of cost management, since such solutions allow avoiding data duplication and generating reports automatically [11]. A. M. Shish adds that centralized storage of accounting information in cloud storage helps to increase the level of financial security and reduces the risks of data

loss [12]. Let's consider the model of cost accounting for small and medium-sized businesses in the context of the use of digital platforms.

Table 1. Specifics of cost accounting in digital platforms of Ukraine

Cost accounting element	Implementation in cloud systems	Yes / No	Application features
Chart of accounts of expenses (counts 23, 91–94, 97, 99)	Automated formation of transactions by type of operation	Yes	Coordinated with the Accounting Standards and the possibility of analytics by cost centers [11]
Primary documents (acts, invoices, timesheets)	Creating templates and signing EDS through the cloud	Yes	Implemented through integration with M.E.Doc, iFin [6]
Cost calculation	Distribution of costs by objects and items	Yes	Automation of calculation and generation of management reports [15]
Accounting for wages in expenses	Accrual and posting by items of expenditure	Yes	Modular integration with personnel accounting [5]
Tax differences and regulated reporting	Generation of tax returns automatically	Yes	The data is transmitted to the State Tax Service in XML format [8]
Data Cybersecurity	Encryption and backup in data centers	Yes	Minimizes the risks of loss of financial data [12]
Offline access	Limited or absent	Yes	Requires a stable internet connection [6]

Source: Systematized by the author.

The specifics of revenue accounting in cloud platforms are characterized by the integration of financial results with the processes of selling products and services, which ensures the efficiency of revenue recognition and improves the accuracy of reporting. As noted by E.I. Volot, cloud solutions automate the formation of primary sales documents, invoices and acts, providing electronic circulation and instant display of income in the system [15]. A. M. Shish emphasizes that such technologies provide continuous control of accounts receivable due to automatic updating of payment statuses in real time [12]. S. O. Mykhailovina et al. [6] note that income accounting in cloud platforms is closely related to CRM systems, which allow generating analytical reports on sales areas and customers. Y. V. Sheverya focuses on the fact that the platforms are adapted to the national chart of accounts, in particular accounts 70, 71, 74, 79, which ensures the correct formation of the financial result [11]. U. Pelekh points out that the integration of income accounting with state electronic services allows for reducing the time between the implementation of the transaction and its reflection in the financial statements, ensuring full transparency of the movement of funds [8]. Let us consider the specifics of income accounting in Table 2.

Table 2. Specifics of income accounting in cloud platforms of Ukraine

Element of income accounting	Implementation in cloud systems	Yes / No	Application features
Income Chart of Accounts (Accounts 70, 71, 74, 79)	Automatic posting	Yes	Aligned with the Accounting Standards and IFRS [11]
Primary documents (invoices, acts, waybills)	Electronic creation and signature of EDS	Yes	Integration with CRM and payment systems [8]
Income recognition	At the time of sale or receipt of funds	Yes	Automatic rules in accordance with accounting policies [6]
Accounts receivable accounting	Automatic update of payment statuses	Yes	Real-time control [12]
Revenue analytics	Reports on customers, products, projects	Yes	Formation of dynamic revenue indicators [5]
Electronic reporting	Formation of VAT and income tax declarations	Yes	Data is synchronized with government systems [15]
Cyber protection and data storage	Encryption and access control	Yes	High level of protection of commercial information [12]

Source: Systematized by the author.

Thus, the use of digital technologies in the accounting of income and expenses in Ukraine contributes to increasing the efficiency, transparency and reliability of financial information. Cloud solutions combine accounting, tax and management accounting in a single environment, ensure compliance with the requirements of Accounting Standards and IFRS, and support the formation of electronic reporting. This allows enterprises of any size to reduce the time spent on processing financial transactions, reduce the number of errors and create conditions for continuous control over income and expenses.

At the same time, the use of digital platforms in the system of accounting for income and expenses in Ukraine, in addition to obvious advantages, is associated with a number of risks and managerial consequences that affect the quality of financial information and the effectiveness of managerial decision-making. According to S. O. Mykhailovina et al., one of the key risks is the technological dependence of enterprises on digital infrastructure, in particular on the stability of the Internet connection, the reliability of servers and software solution providers, which can cause temporary interruptions in access to financial data [6]. A. M. Shysh emphasizes that digital accounting environments create increased requirements for information protection, because the risks of leakage of confidential financial data, unauthorized access or loss of information as a result of cyberattacks can have significant economic and reputational consequences [12]. E. I. Volot emphasizes that the automation of the processes of forming accounting indicators changes the role of the accountant from an executor to an analyst, but at the same time creates a risk of excessive trust in algorithms and a decrease in the level of critical analysis of financial information [15]. According to the observations of U. Pelekh, the digitalization of accounting requires new competencies from managers – knowledge in the field of IT accounting, cybersecurity, and data analytics, without which the effective use of digital systems is impossible [8]. Y. V. Sheverya emphasizes that the managerial consequences are the need to revise the organizational structure of the accounting service, the separation of responsibilities between IT and financial departments, as well as the introduction of systems for constant monitoring of data reliability [11]. Thus, digital platforms significantly increase the efficiency of financial management, but at the same time create new risks related to information security, technical stability and competence of personnel, which requires a strategic approach to the management of digital accounting processes.

6. Conclusions

The state of digitalization of accounting in Ukraine indicates a steady increase in the level of technological integration into the financial processes of small and medium-sized businesses. The vast majority of companies, even under martial law, continue to implement digital financial management tools. UA, Bookkeeper and Fairo, which provide a full cycle of accounting, tax and management accounting. These solutions meet the requirements of the Accounting Standards and IFRS, support electronic reporting and create a single information environment for financial transactions, which ensures transparency and timeliness of financial information.

The specificity of cost accounting in digital platforms is the automation of all stages – from fixing primary documents to forming financial results. Expenses are automatically aligned with the national chart of accounts, and digital services generate tax reporting in real time, transmitting data to the State Tax Service.

Revenue accounting in digital platforms is marked by integration with CRM systems and payment services, which provide instant recognition of income and control of accounts receivable. Electronic document management simplifies the issuance of invoices and acts, and synchronization with government electronic systems contributes to the transparency of financial flows.

At the same time, the digitalization of income and expenditure accounting is accompanied by new risks and managerial consequences. The main ones are related to technological dependence on digital infrastructure, cybersecurity threats, possible failures in automatic algorithms, and a shortage of qualified personnel in the field of IT accounting. For effective management of digital processes, it is necessary to ensure systematic monitoring of the reliability of financial data, increase the digital literacy of personnel, as well as the separation of functions between IT and financial departments.

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Green Economy in International Trade: New Regulatory Mechanisms and Impact on Competitiveness

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ABSTRACT

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The relevance of the study is due to the rapid greening of international trade, within which carbon standards, circular production models and environmental regulatory mechanisms increasingly determine the competitiveness of states. The aim of the article is a comprehensive study of the transformations of trade regimes under the influence of the green economy. The methodology is based on systemic and comparative analysis, the use of institutional and economic-ecological approaches, as well as on the generalization of international indicators. As a result of the study, it was found that green mechanisms for regulating international trade significantly reformat global trade flows, shifting the emphasis from price parameters to carbon efficiency, technological modernization and institutional transparency. The paper reveals that environmental indicators are becoming tools for redistributing competitive advantages, and the ability of national economies to integrate environmental standards and low-carbon technologies determines their positions in global value chains. The results obtained made it possible to formulate strategic recommendations for increasing the competitiveness of countries based on the decarbonization of industry, the development of clean technologies, the introduction of national carbon accounting systems and the expansion of international cooperation in the field of the green economy. The practical significance of the study lies in the possibility of using its conclusions to develop state trade and industrial strategies, improve climate policy, support exporters in the transition to low-carbon production models and optimize investment decisions in the field of green modernization.

KEYWORDS

carbon standards, circular production model, value chains, investment decisions, climate commitments.



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СОЦІАЛЬНИЙ РОЗВИТОК: економіко-правові проблеми

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Зелена економіка у міжнародній торгівлі: нові механізми регулювання та вплив на конкурентоспроможність

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СТАТТЯ

АНОТАЦІЯ

Дослідницька

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Актуальність дослідження зумовлена стрімкою екологізацією міжнародної торгівлі, у межах якої вуглецеві стандарти, циркулярні моделі виробництва та екологічні регуляторні механізми дедалі більше визначають конкурентоспроможність держав. Метою статті є комплексне дослідження трансформацій торговельних режимів під впливом зеленої економіки. Методологія ґрунтується на системному та порівняльному аналізі, використанні інституційного й економіко-екологічного підходів, а також на узагальненні міжнародних індикаторів. У результаті проведеного дослідження встановлено, що зелені механізми регулювання міжнародної торгівлі суттєво переформатовують глобальні торговельні потоки, зміщуючи акценти з цінових параметрів на вуглецеву ефективність, технологічну модернізацію та інституційну прозорість. У роботі виявлено, що екологічні індикатори стають інструментами перерозподілу конкурентних переваг, а здатність національних економік інтегрувати екологічні стандарти й низьковуглецеві технології визначає їх позиції в глобальних ланцюгах вартості. Отримані результати дали змогу сформулювати стратегічні рекомендації щодо підвищення конкурентоспроможності країн на основі декарбонізації промисловості, розвитку чистих технологій, запровадження національних систем вуглецевого обліку та розширення міжнародної кооперації у сфері зеленої економіки. Практична значущість дослідження полягає в можливості використання його висновків для розроблення державних торговельних і промислових стратегій, удосконалення кліматичної політики, підтримки експортерів у переході до низьковуглецевих моделей виробництва та оптимізації інвестиційних рішень у сфері зеленої модернізації.

КЛЮЧОВІ СЛОВА

вуглецеві стандарти, циркулярна модель виробництва, ланцюги вартості, інвестиційні рішення, кліматичні зобов'язання.

1. Introduction

The global transition to a green economy is changing the rules of international trade, forming a new architecture of regulatory approaches, where environmental standards act not only as tools for environmental protection but also as a lever of economic competition. The strengthening of climate commitments under the Paris Agreement, the implementation of the Carbon Adjustment Mechanism at the border in the European Union, the growing requirements for the decarbonization of global supply chains, and the rapid development of green financial instruments have created a situation in which traditional trade practices are no longer sufficient to ensure access to goods in foreign markets. Under these conditions, countries that do not adapt their production processes and regulatory regimes to the environmental standards of their partners risk losing some of their competitive positions.

2. Literature Review

A review of scientific sources testifies to the gradual formation of the discourse of the “green economy” and its integration into the field of international trade. At the micro and industry levels, A. Datsenko [1] examines the impact of the CBAM mechanism on the competitiveness of the Ukrainian metallurgy, showing that the increase in the “carbon price” for products imported to the EU simultaneously strengthens the incentives for decarbonization and increases the transaction costs of exporters. The author emphasizes that long-term competitive advantages are formed primarily due to technological modernization and transition to low-carbon energy carriers, and not due to temporary compensation of certification costs. The conceptual dimension of the “quality of growth” is revealed by O. M. Verstyak and A. V. Verstyak [2], who show that modern international initiatives in the field of sustainable development shift the emphasis from a simple increase in GDP to a decrease in the material and energy intensity of production. In their opinion, the integration of climate goals into trade regimes entails a redistribution of competitive advantages from “cheap resources” to “clean technologies” and the institutional capacity to comply with environmental standards.

L. M. Horbach and co-authors [3] substantiate the role of the green economy as a tool for achieving the Sustainable Development Goals, emphasizing the decisive importance of natural capital for long-term productivity and investment attractiveness of the economy. P. I. Yukhimenko and a team of authors [4], comparing the world experience and Ukrainian realities, reveal the institutional “bottlenecks” of the green transition – fragmentation of policies, gaps between fiscal incentives, technical regulation and customs procedures. They emphasize that without aligning these elements, environmental trading instruments (such as CBAM or green taxonomies) can exacerbate market access asymmetries. In the work of O. Marchenko and O. Hrabyn [5], the emphasis is placed on the combination of green and digital transformations as a prerequisite for the post-war recovery of the Ukrainian economy: the authors show that digitalized MRV systems, traceability of supply chains and automated carbon accounting reduce information asymmetries in export markets and create the basis for integration into “green” value chains. In addition, L. Horbach et al. [6] demonstrate that sustainable production is built around three key axes – resource efficiency, ecodesign and innovation capacity, and the clustering of “clean” technologies and the development of local supply networks directly affect the export potential.

The theoretical and methodological basis of the “green economy” as a separate direction of economic thought is developed by A. Samoilenko [7], who systematizes approaches to the interpretation of the green economy in the context of sustainable development and proposes structuring its principles for economic policy. K. Kuznetsova et al. [8] study global trends in the green economy and show how they transform international markets: the authors prove that the introduction of environmental standards and climate commitments gradually changes the structure of supply and demand, causing an increase in the share of “green” goods and services. The study by the GMK Center [9] analyzes the macroeconomic consequences of the introduction of CBAM for the Ukrainian economy, in particular, the risks of reducing exports of energy-intensive products and the need for accelerated industrial modernization, which directly links trade policy with climate policy.

A separate block of literature is formed by works on European climate initiatives as a new framework for international trade. A. Uniat et al. [10] consider the expansion of the EU ETS system as a

tool for global emission reduction and show that its extension to cross-border flows actually sets new standards for market access. The European Green Deal document [11] consolidates the EU's transition to a low-carbon growth model and defines a set of regulatory mechanisms (from the emissions trading system to environmental requirements in industrial policy) that have a direct impact on the conditions of international competition. Taken together, these works form a multidimensional vision of the green economy – from theoretical foundations and national strategies to specific trade instruments and sectoral effects.

Despite this, the available literature only fragmentarily covers the issue of how a set of new “green” regulatory mechanisms – from CBAM and EU ETS to complex strategies such as the European Green Deal – reformats the structure of international trade and redistributes competitive advantages between countries with different levels of institutional and technological readiness. The integral effects of these instruments on trade balances, export structure, business costs, and positioning of states in global value chains remain insufficiently studied. It is this conceptual gap that necessitates a comprehensive study on the transformation of international trade under the influence of the green economy and new environmental regulatory mechanisms.

3. Problem Statement

The article is aimed at studying the transformation of international trade under the influence of the green economy and analyzing how the introduction of new environmental regulatory mechanisms changes the competitiveness of states and enterprises in global markets. To achieve this goal, the article solves the following tasks: to clarify the conceptual foundations of the green economy as a factor in the transformation of international trade regimes; to analyze modern mechanisms of environmental regulation of foreign trade; to formulate strategic recommendations for increasing the competitiveness of national economies in the context of global trade greening.

4. Methods and Materials

The material basis of the study was official documents of the EU and Ukraine regulating climate and trade policy (in particular, acts on CBAM and the EU ETS system), statistical data on the structure of foreign trade and carbon intensity of certain industries, as well as analytical reports of international organizations and specialized research centers. Additionally, scientific publications on the green economy and the transformation of international trade are used.

The paper uses analysis and synthesis to identify the key features of “green” regulatory mechanisms and their impact on the competitiveness of exporting countries, a comparative approach to compare European and Ukrainian approaches to the integration of environmental requirements into trade, as well as elements of economic and statistical analysis to interpret data on the structure of exports and potential business costs for adaptation to new rules. This made it possible to combine regulatory, analytical and quantitative perspectives in assessing the impact of the green economy on international trade.

5. Results and Discussion

The concept of “green economy” first appeared in 1989 in the British government report “The Concept of Green Economy”, prepared by scientists D. Pearce, A. Markandya and E. Barbier. This document laid down the idea that economic growth can and should occur without harm to the environment. In official UN materials, the green economy is defined as a development model that contributes to increasing the well-being of the population and social equality, while reducing environmental risks and scarcity of natural resources. The formation of the concept of green economy was an attempt to create a new strategy for the economic development of mankind, based on harmony between man and the natural environment. This idea is closely related to the concept of sustainable development, which seeks to balance economic, social and environmental objectives. Later, tools for quantifying the “greenness” of economic systems appeared. Thus, in 2009, the international organization GRESB developed the first system of indicators for monitoring the sustainable

development of infrastructure projects in the fields of energy, transport, water supply and social infrastructure. Its rating is based on an assessment of the quality of management, the level of risks and transparency of reporting. And already in 2010, the analytical agency Dual Citizen created the Global Green Economy Index (GGEI) – a global index of the “green” economy, which is now used to measure the progress and effectiveness of green transformations in more than 130 countries around the world. This index has become one of the key tools for international comparison and assessment of the level of environmental responsibility of states [7, p. 100].

Along with the development of the “green” economy, the concept of circular (or circular) economy, which offers a new approach to the use of resources, is becoming more and more popular. Unlike the traditional linear model of “take – produce – dispose”, the circular economy is based on the principle of a closed cycle, where materials and energy are constantly returned to production. As the World Economic Forum emphasizes, the main goal of the circular economy is not just recycling, but the prevention of waste generation at all stages of production and consumption, creating a sustainable economic system that works in harmony with nature [8, p. 32]. Its essence lies in the maximum extension of the life cycle of goods, reuse, repair, recycling and recovery of resources, which reduces the need for new materials and reduces the volume of waste.

One of the key tools for the formation of a “green” economy in international trade was the European Emissions Trading System (EU ETS). Its implementation made it possible to create a market-based mechanism for regulating greenhouse gas emissions, within which enterprises buy and sell emission allowances, which stimulates investments in clean technologies and increases energy efficiency. Since its launch in 2005, the EU ETS has contributed to the reduction of industrial emissions in the European Union (EU) by almost 47%, becoming an example of an economic instrument with a powerful climate effect. One of the most important new mechanisms within the EU’s green trade policy is the Carbon Border Adjustment (CBAM) [9]. This instrument imposes a “carbon tariff” on imported products produced with high CO₂ emissions, thereby leveling the playing field between European and foreign companies. CBAM not only protects the EU internal market from carbon leakage but also encourages trading partners to switch to environmentally friendly production standards, which increases the export attractiveness of enterprises that implement low-carbon technologies. The EU ETS system is gradually being integrated into the global context – the EU is expanding cooperation with Norway, Switzerland, Iceland, and also supports green investments in developing countries through the financing of clean energy projects [10]. Such integration forms a new architecture of international green trade, where competitiveness is determined not only by economic indicators, but also by the carbon efficiency of production.

Global instability caused by the war in Ukraine, energy crises and supply chain disruptions has become a powerful catalyst for the “green transformation” of EU energy policy, directly affecting the structure of international trade and the competitiveness of European businesses. In the context of growing geoeconomics risks, the green economy is turning not only into an ecological, but also into a trade and economic strategy, which determines new rules for the participation of countries and companies in world markets. Until 2022, about 40% of natural gas in the EU was supplied from Russia, but already in 2023, this dependence was reduced to less than 10% due to the active diversification of energy supplies from the United States, Qatar and Norway. Such a reorientation not only reduced the energy vulnerability of the European Union, but also changed the structure of foreign trade flows, directing them towards more sustainable partnerships and green investments. The sharp rise in energy prices in 2022 came as a shock to industry, especially for energy-intensive sectors (metallurgy, chemicals, transport), which forced the EU to step up the implementation of the REPowerEU plan, a comprehensive initiative aimed at deploying renewable energy sources (RES), improving energy efficiency and reducing dependence on fossil fuel imports. This strategy has not only an environmental, but also a clear economic and trade dimension, because it allows you to reduce production costs, stabilize energy prices and increase the export attractiveness of “green” goods. By 2030, the EU plans to increase the share of RES in total energy consumption to 42.5%, while in 2023 this figure has already reached 24.5% (against 17.5% in 2017). The Nordic countries are demonstrating the highest rate of transformation: in Sweden, the share of “clean” energy exceeds 50%, which has made it possible to reduce CO₂ emissions and increase its “green competitiveness” in international trade. Such successes shift the emphasis in the global economy – now the value of a product is determined not only by the cost, but also by its carbon footprint, which forms new standards of market advantage. The decisive

tools of this transition were the European Green Deal [11], Fit for 55 [12] and REPowerEU [13] – a strategic framework that combines economic, environmental and trade objectives. They provide for a 55% reduction in emissions by 2030 (compared to 1990) and the achievement of carbon neutrality by 2050, which directly affects trade regulation. In particular, the CBAM mechanism introduces a carbon tax on imports of energy-intensive products (steel, cement, fertilizers, etc.), stimulating EU partners to eco-modernize. Since 2013, the EU ETS emissions trading system has already reduced industrial emissions by 47%, and in 2022 alone by 7.3%, creating an economic incentive for green investment. In total, the EU will invest more than EUR 580 billion by 2030 in the development of renewable energy, smart grids and the modernization of buildings, which consume up to 40% of all energy in the Union [14]. Thus, the green economy within international trade has become a new paradigm of global competitiveness, where benefits are determined by environmental efficiency, technological innovation and the ability to comply with high climate standards. The EU, thanks to the system of “green” regulatory mechanisms, not only reduces its own energy dependence, but also forms new global trade rules that combine economic growth with environmental responsibility.

With the world’s population growing rapidly – projected to reach 9 billion people by 2050 – the global economy faces a double challenge: the need to maintain sustainable economic growth while preserving natural capital as the basis for future development. In this context, the international community is increasingly recognizing that the traditional focus on GDP alone as the main indicator of well-being is outdated and insufficient. The modern development paradigm is shifting towards the “green economy”, which integrates economic dynamics with indicators of environmental sustainability, social justice and efficient use of resources (Table 1).

Table 1. International Systems, Methodological Approaches and Indicators for Assessing the “Green Economy” in the Context of International Trade and Competitiveness of Countries

System	Organization	Purpose of assessment	Main indicators	Impact on competitiveness
Green Growth Indicators (OECD)	OECD	Monitoring the effectiveness of “green growth”	Resource productivity, natural assets, environmental quality, innovations	Gives a comparative assessment of eco-growth, determines the positions of countries in “green” trade
SEEA (System of Environmental-Economic Accounting)	UN	Inclusion of natural resources in national accounts	Accounting for water, energy, forests, minerals, restoration costs	Increases transparency of green accounting, supports investors and trade policy
WAVES (Wealth Accounting and Valuation of Ecosystem Services)	World Bank	Assessment of natural capital and ecosystem services	Value of ecosystems, contribution to GDP, natural assets	Promotes environmentally friendly financial policies and green investments
GGEI (Global Green Economy Index)	Dual Citizen LLC	Comparative assessment of green policies in 160 countries	Climate, ESG investments, decarbonization, eco-health	Determines the eco-positions of states, affects the attractiveness in trade and investment
LCEI (Low Carbon Economy Index)	PwC	Measurement of CO ₂ Emissions Intensity to GDP	Emissions, energy efficiency, structure of the economy	Promotes the implementation of CBAM and the assessment of carbon competitiveness
GCII (Global Cleantech Innovation Index)	Global Cleantech Group	Assessing the potential of clean technologies	Resources for innovation, results (startups, patents)	Determines the technological readiness of countries for green transformation
SWOT analysis of the “green economy”	OECD, UNEP, EU	Analysis of strengths, weaknesses, opportunities and threats	Strong: innovation, image; Weak: funding; Opportunities: employment; Threats: resistance of the “brown” sectors	Provides a strategic assessment of the development of green policy and export potential

Source: Compiled by the authors based on [15–20].

This approach forms new mechanisms for regulating international trade, where the competitiveness of states is determined not only by the volume of production, but also by carbon neutrality, the level of circularity of production and contribution to global environmental goals. Countries that adapt their financial systems, tax incentives and standards to the requirements of the green transition gain an advantage in international markets – from access to ESG investments to the growth of exports of environmentally friendly products [15]. Thus, the change of emphasis from quantitative economic growth to qualitative growth – focused on welfare and long-term ecological balance – becomes a key factor in the new global competitiveness in international trade.

A comparative analysis of international green economy assessment systems reveals that, despite varying institutional approaches and methodological frameworks, all tools concur on the importance of integrating environmental factors into the trade and competition policies of states. Indicators from the OECD, the UN, the World Bank, PwC and independent analytical platforms form a multidimensional assessment system that combines the measurement of resource efficiency, the natural and monetary valuation of natural capital, technological innovations and the level of decarbonization of economies. This allows countries to get a more accurate and structured picture of their readiness to participate in green global trade. At the same time, the results show that environmental indicators act not only as monitoring tools, but also as factors in the formation of new competitive dynamics. The SEEA and WAVES systems reinforce the importance of natural capital in macroeconomic planning, while the GGEI and GCII affect investment attractiveness by demonstrating technological readiness and the effectiveness of public policies. LCEI is directly related to foreign trade regulatory regimes, in particular CBAM, which makes a low-carbon economic model a key condition for product access to EU markets.

Strengthening environmental requirements in international trade necessitates the reorientation of national economies to long-term development models based on low-carbon technologies, innovations and increased resource efficiency. With instruments such as CBAM, ESG-focused regulation of financial markets, and the growing role of green standards in cross-border supply chains, countries' competitiveness is increasingly determined not by traditional cost factors, but by the ability to integrate environmental dimensions into economic policy and industrial strategy. Under these conditions, the formation of effective strategic approaches requires coordination of industrial, trade, financial and innovation policies in the direction of a "green" structural shift.

The key direction is the modernization of production processes based on energy-efficient and low-carbon technologies, since it is the intensity of emissions that becomes the determining criterion for the admission of products to markets with strict environmental barriers. Increasing the technological readiness of enterprises requires large-scale renewal of industrial assets, support for clean technologies, development of smart energy solutions and stimulation of circular production models that reduce dependence on resource imports and reduce environmental costs. In this context, state support for scientific developments and the implementation of applied research results aimed at decarbonizing heavy industry, agri-food chains and the transport sector are of particular importance.

An equally important strategic element is the development of institutional mechanisms of environmental regulation, which ensure predictability, transparency and compliance with international standards. The introduction of national carbon accounting systems, harmonized with EU and OECD approaches, creates conditions for controlling the real carbon intensity of products, as well as strengthening the position of exporters in negotiations with trading partners. The development of digital environmental reporting platforms, the use of MRV (monitoring, reporting, verification) tools, and the integration of ESG principles into corporate governance are becoming not only requirements of global markets but also factors in the formation of investment attractiveness.

An important role is also played by the formation of competitive "green" sectors of the economy capable of providing added value at the global level. The creation of clusters of clean technologies, the development of green engineering, the production of energy-saving equipment, the bioeconomy and renewable energy form a new industrial framework that meets global decarbonization trends. The presence of such sectors not only reduces dependence on traditional industries with a high carbon load, but also allows countries to integrate into new production chains focused on innovation and environmental efficiency.

A significant factor in increasing competitive positions is the expansion of international cooperation through participation in "green" alliances, partnerships with the EU, OECD, World Bank and other institutions that support environmental reforms. Joint decarbonization projects, the development

of transnational energy corridors, environmentally oriented investment platforms, and increased access to climate finance create opportunities to reduce technological and financial barriers inherent in countries seeking to accelerate the green transition.

It is also important to increase the adaptive capacity of enterprises, in particular small and medium-sized ones, through the development of green financing mechanisms, tax incentives, grant programs and advisory support on environmental modernization. Ensuring access to cheap financial resources is critical in the context of the need for large investments in energy efficiency, renewable energy sources and equipment upgrades. The role of the state is to create favorable conditions for the green bond market, develop guarantee mechanisms and involve international financial institutions in supporting environmental projects.

6. Conclusions

Clarification of the theoretical foundations showed that the green economy has evolved from the primary ideas of ecological balancing of production, formulated in the works of D. Peirce, A. Marchandia and E. Barbier, to a comprehensive development paradigm that integrates resource efficiency, innovation, circularity of production and carbon neutrality. Modern approaches of the UN, the OECD, the World Bank and other institutions confirm that environmental indicators are turning into key elements of economic analysis, determining the real capacity of countries to integrate into global value chains. The analysis of modern environmental mechanisms for regulating international trade has shown that tools such as EU ETS, CBAM, Fit for 55 and REPowerEU form a new architectural dimension of the global economy, where not only the price and quality of goods are important, but also their carbon footprint, energy efficiency and technological modernization. The EU, by introducing a comprehensive system of carbon incentives and barriers, is actually transforming trade rules, shifting them in the direction of environmental responsibility and low-carbon competition. This transformation already has a tangible impact on the structure of energy and trade flows, the pace of industrial modernization and investment policy, which confirms the strategic nature of the green economy as a trade model of the future.

The generalization of international systems for assessing the green economy made it possible to determine that green competitiveness is formed at the intersection of three key dimensions: resource and technological efficiency, institutional quality and innovation capacity. These systems not only record progress indicators, but also actively influence the behavior of states and corporations, as they set standards of transparency, responsibility and investment attractiveness. As a result, environmental indicators become a tool for global redistribution of trade advantages. The strategic recommendations formed in the article showed that increasing the competitiveness of national economies in the context of global greening of trade requires systematic modernization of industrial neo-cluster structures, development of low-carbon technologies, harmonization of carbon accounting with EU standards and strengthening of the institutional infrastructure of environmental management. The ability of states to create incentives for green industry, implement circular models, develop markets for green financial instruments and expand international cooperation will determine their position in the global trading system. It is important that the green transformation concerns not only the manufacturing sector, but also financial architecture, logistics flows, energy security, and digital environmental reporting platforms. Prospects for further research are an in-depth analysis of the impact of carbon regulatory instruments on the sectoral structure of exports and modeling scenarios of long-term competitiveness of countries in the context of the global green transition.

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SOCIAL DEVELOPMENT: Economic and Legal Issues

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Information and Communication Technologies in Environmental Impact Assessment and Environmental Management

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ABSTRACT

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The purpose of this study is to systematize, analyze modern information and communication technologies used in the process of environmental assessment, and develop conceptual foundations and their integration into environmental management systems. The methodology is based on a comprehensive analysis of literary sources, a critical assessment of existing technological approaches and conceptual modeling of the architecture of integrated systems. The results of the study include a functional classification of information and communication technologies tools into three categories. Four systemic problems of the current state of information and communication technologies in ecology have been identified, which create contradictions between the means and goals of environmental management, as well as qualification obstacles to the implementation of complex technologies at the regional and local levels. The central scientific result is the developed five-level conceptual model of the architecture of an integrated environmental management system, which includes a level of intelligent data aggregation with automatic format standardization, a level of adaptive processing with self-adjusting algorithms, a level of automated verification to minimize user participation, a level of intuitive management through adaptive interfaces, and a level of intelligent support with built-in learning modules. The model implements the principles of integration through standardized interfaces and provides a gradual transformation of primary environmental data into ready-made management solutions with the possibility of feedback for continuous improvement of the system. The practical significance lies in the possibility of using the developed conceptual principles to create methodological recommendations for the implementation of information and communication technologies in environmental management at different levels. The scientific novelty is due to the first proposed systemic approach to the integration of heterogeneous information and communication technologies into a single multi-level environmental management architecture, which allows overcoming existing technological barriers and creating a synergistic effect from the interaction of various digital tools.

KEYWORDS

information and communication technologies, digitalization, environmental impact assessment, environmental safety, environmental management, geographic information systems, remote sensing, sustainable development.



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СОЦІАЛЬНИЙ РОЗВИТОК: економіко-правові проблеми

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Інформаційно-комунікаційні технології в оцінці впливів на довкілля та екологічного управління

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СТАТТЯ

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Метою даного дослідження є систематизація, аналіз сучасних інформаційно-комунікаційних технологій, які використовуються в процесі екологічної оцінки, та розробка концептуальних засад і їх інтеграції в системи екологічного менеджменту. Методологія базується на комплексному аналізі літературних джерел, критичному оцінюванні існуючих технологічних підходів та концептуальному моделюванні архітектури інтегрованих систем. Результати дослідження включають функціональну класифікацію інструментів інформаційно-комунікаційних технологій за трьома категоріями. Виявлено чотири системні проблеми сучасного стану інформаційно-комунікаційно технологій в екології, що створюють протиріччя між засобами та цілями екологічного управління, а також кваліфікаційні перешкоди впровадження складних технологій на регіональному та місцевому рівнях. Центральним науковим результатом є розроблена п'ятирівнева концептуальна модель архітектури інтегрованої системи екологічного управління, яка включає рівень інтелектуального агрегування даних з автоматичною стандартизацією форматів, рівень адаптивної обробки з самоналаштовуваними алгоритмами, рівень автоматизованої верифікації для мінімізації участі користувача, рівень інтуїтивного управління через адаптивні інтерфейси та рівень інтелектуальної підтримки з вбудованими модулями навчання. Модель реалізує принципи інтеграції через стандартизовані інтерфейси та забезпечує поступове перетворення первинних екологічних даних у готові управлінські рішення з можливістю зворотного зв'язку для безперервного вдосконалення системи. Практична значущість полягає в можливості використання розроблених концептуальних засад для створення методичних рекомендацій щодо впровадження інформаційно-комунікаційних технологій в управління навколишнім середовищем різних рівнів. Наукова новизна обумовлена вперше запропонованим системним підходом до інтеграції різномірних інформаційно-комунікаційних технологій в єдину багаторівневу архітектуру екологічного управління, що дозволяє подолати існуючі технологічні бар'єри та створити синергетичний ефект від взаємодії різних цифрових інструментів.

КЛЮЧОВІ СЛОВА

інформаційно-комунікаційні технології, диджиталізація, оцінка впливу на довкілля, екологічна безпека, екологічне управління, геоінформаційні системи, дистанційне зондування, сталий розвиток.

1. Introduction

The existing problems of the global environmental crisis require a fundamental revision in approaches to environmental impact assessment and environmental management systems. According to the World Health Organization (WHO), nine million people die each year due to pollution, a quarter of the total burden of disease in the world. Traditional methods cannot efficiently process large data sets for real-time risk analysis, and hence, there is a need for new monitoring systems that will improve transformation opportunities thanks to rapidly evolving digital technologies. The increase in connected IoT-to, together with the introduction of artificial intelligence algorithms, Geographic Information Systems (GIS) development and remote sensing technology-constitutes the technological foundations for the formation of qualitatively new levels in environmental management. However, modern practice is characterized by fragmented technological solutions, interoperable problems, and the lack of a single architectural concept for integration. Thus, there is a need to develop an integrated model that integrates the different information and communication technologies (ICT) tools into a single environmental management system, aimed at achieving synergies through interaction between digital technologies, as well as overcoming existing technological barriers that block their implementation.

2. Literature Review

Research on the use of ICT in the environmental field has been characterized by active development in recent years. The analysis of the use of artificial intelligence for environmental monitoring shows that machine learning algorithms can increase the accuracy of predicting environmental parameters by 25–40% compared to traditional statistical methods [1].

European researchers are actively developing the concept of a “digital ecological twin” within the framework of the Destination Earth initiative and propose the integration of remote sensing technologies with geographic information systems to create dynamic ecosystem models. The results show that this approach provides a reduction in the time for conducting environmental assessments [2]. Further research confirms that Earth’s digital twins enable the convergence of big environmental data with physical models in interactive computing systems to monitor and predict environmental changes [3]. The practical implementation of digital twins in nature conservation areas demonstrates their effectiveness for monitoring ecosystems and informing management decisions [4].

Research on the development of IoT systems for environmental monitoring substantiates the prospects of using a network of distributed sensors for real-time monitoring of the state of the environment [5]. Further research confirms the effectiveness of wireless sensor networks for monitoring air quality and enabling the development of early detection and warning systems for environmental threats [6; 7].

According to the latest data, blockchain provides accurate monitoring of environmental components to verify environmental data and control natural resources. A number of studies propose a conceptual model for the use of a distributed ledger for the verification of environmental data, as well as transparency in the process of environmental impact assessment, in particular accounting for greenhouse gas emissions [8; 9].

Cloud computing and big data technologies have been significantly developed in the context of environmental management. Research demonstrates that cloud infrastructure provides scalability and cost-effectiveness in processing large amounts of environmental data, while posing challenges in terms of energy consumption and environmental impact [10]. Electricity consumption by data centers is projected to increase to 945 TWh by 2030, which actualizes the need to implement the concept of “green” cloud computing using renewable energy sources [11].

The issue of energy efficiency of ICT systems is of particular relevance in the context of environmental goals. The data show that the ICT sector is responsible for 567 Mt of CO₂ equivalent emissions, which is 1.7% of global emissions [12]. Green computing research offers comprehensive strategies to reduce the environmental footprint of digital technologies, including energy-efficient equipment, software optimization, and implementation of circular economy principles [13; 14].

The problem of interoperability and standardization of data remains critical for the integration of heterogeneous sources of environmental information. The analysis of the studies reveals the need to

develop uniform standards for data exchange and semantic interoperability to ensure the effective integration of multidisciplinary environmental data [15]. Modern initiatives, in particular the FAIR (Findable, Accessible, Interoperable, Reusable) principles, are aimed at improving the quality and accessibility of environmental data for scientific research and practical application [16].

The European Copernicus program within the framework of the European Green Deal demonstrates the practical implementation of integrated environmental monitoring systems, providing free access to Earth observation satellite data to support environmental policy and environmental monitoring [17].

Despite significant achievements, the analysis of the literature reveals the lack of comprehensive studies that systematize various ICT approaches and formulate the conceptual foundations of their integration into a single system of environmental management.

3. Problem Statement

It is the modern approach to global challenges in the field of environmental problems that requires a major revision of existing approaches to environmental impact assessment and management. Traditional monitoring methods have limited capabilities in dealing with significant amounts of data, as well as environmental threats, and may not be effective enough when it comes to predicting environmental risk.

Today, nine million deaths in the world are attributed to ambient air pollution, as evidenced by Global Air's comprehensive analyses of data on air quality and health impacts. It is air pollution that has become the second largest risk factor for death after high blood pressure. In February 2025, the WHO published an updated database, which notes that environmental risks account for a quarter of the total global burden of disease. [18–20]. This highlights how important environmental monitoring is. The IoT Analytics report points to a 13% growth in connected IoT devices to 18.8 billion globally by 2024. New opportunities are opening up for revolutionary changes in environmental monitoring [12].

However, the information and communication technology sector accounts for 1.5% to 4% of total global carbon emissions, which creates a paradoxical situation between technological solutions and environmental goals [12].

This makes it urgent to develop a conceptual model for combining different ICT tools within one environmental management system, for their synergistic work in helping to reduce the negative impact on the environment. In the absence of such a systemic combination, it becomes quite difficult to take full advantage of the opportunities that modern digital technologies can offer.

4. Methods and Materials

The research methodology is based on the application of a set of scientific methods that provide a comprehensive analysis of modern information and communication technologies and the conceptual architectural formation of integrated ecological systems.

For a comprehensive study of scientific publications, the method of analysis and synthesis was applied to the application of the Internet of Things, GIS, artificial intelligence, blockchain technologies and digital twins in environmental assessment and management. The strengths and weaknesses of today's digital solutions, as well as the scientific gaps in environmental assessment and management, have been identified through a critical evaluation of existing technological approaches. The study of the functionality of technologies was carried out by conducting a comparative analysis. Conceptual modeling of the architecture of integrated systems was used to develop a structural model.

Applying the method of systematization and generalization, conclusions were drawn and prospects for the use of digital technologies in processes involving environmental assessment and management were determined.

5. Results and Discussion

The study is aimed at developing conceptual foundations for the introduction of modern information and communication technologies in the system of environmental impact assessment and environmental management.

On the basis of the study of modern technological solutions, the classification of ICT tools by functional purpose is proposed: data collection technologies, processing and analysis technologies, and visualization and communication technologies (Table 1).

Table 1. Classification of ICT tools for environmental assessment

Technology Category	Tools and Methods
Data Collection Technologies	– Remote Sensing – IoT Sensors and Wireless Sensor Networks – Mobile Apps for Public Monitoring – Automated Observation Stations
Processing and Analysis Technologies	– Geographic Information Systems (GIS) – Machine Learning and Artificial Intelligence (AI) – Decision Support Systems – Cloud Computing and Big Data Analytics
Visualization and Communication Technologies	– Geovisualization and Mapping Systems – Web Platforms and Dashboards – Mobile Apps for Stakeholders – Notification and Early Warning Systems

Source: Compiled by the authors.

Data collection technologies constitute the basic level of information support for environmental monitoring. Remote sensing is carried out using satellite observation and aerial photography systems, which provide multispectral information about the state of ecosystems. Modern satellite platforms Sentinel-2 and Landsat provide a spatial resolution of up to 10 meters, which allows you to study in detail the changes occurring with the structure and functions of natural complexes.

IoT forms a technological infrastructure with the provision of sensors and wireless sensor networks that are used to develop an actual distributed system for monitoring environmental parameters. The results of practical experiments have shown high measurement accuracy, which can be achieved by the following systems: $\pm 0.5^{\circ}\text{C}$ for temperature, $\pm 2\%$ for humidity and ± 0.1 for pH [6]. Mobile monitoring applications expand the spatial coverage of observations by involving the public in the processes of collecting primary environmental data.

Processing and analysis technologies support the transformation of primary data into structured information for managerial decision-making. Geographic information systems (GIS) implement the capabilities of spatial environmental analytics and synthesis of heterogeneous information for complex modeling of the state of the environment. Systems based on ArcGIS software allow mathematical modeling of pollutant distribution processes, as well as quantitative assessment of environmental risks.

The application of machine learning algorithms and artificial intelligence methods demonstrates a statistically significant improvement in the accuracy of predicting environmental parameters by 25–40% compared to traditional statistical methods [1]. Deep learning algorithms are very useful for analyzing time series of environmental data and for discovering hidden patterns in the dynamics of natural processes.

Cloud computing technologies and big data analytics allow you to process vast amounts of environmental data while maintaining scalability and cost-effectiveness.

Verification and management technologies represent the information plus technological cycle of environmental management at its last stage. Geovisualization and mapping systems present the results of environmental monitoring in a visual way, expressed in terms understandable for making a management decision.

Blockchain technologies guarantee cryptographic immutability and transparency of environmental data, which is especially important in the field of accounting for greenhouse gas emissions and verification of environmental reporting [8; 9]. Early warning systems combine information from various sources to automatically identify and report potential environmental threats.

A critical analysis of the current state of ICT application in the field of environmental monitoring reveals a number of systemic limitations. It is these limitations that do not allow you to effectively use potential opportunities.

In particular, the fragmentation of technological solutions is understood as the lack of integration between individual ICT platforms. Existing systems mostly work as standalone solutions with minimal interoperability with other existing solutions. This leads to the creation of isolated information arrays

and does not allow for the effective use of available resources. The situation is even worse when there is no unified architectural concept for the construction of integrated environmental information systems.

The compatibility problem lies in the lack of common standards for data exchange between different ICT platforms. This is manifested in differences in data formats, information transfer protocols and program interfaces. Thus, there are serious technical obstacles to building complex systems based on environmental management. This requires the development of more levels of adaptation, and therefore makes technological solutions more complex and expensive.

The energy paradoxes of ICT systems also consist of the significant energy consumption of modern digital technologies, with the main share being machine learning systems and distributed ledgers. According to experts, it is likely that the functioning of ICT infrastructure can nullify all positive effects on the environment when it is used, creating a conceptual contradiction between its means and environmental management objectives.

It is impossible to ignore the qualification obstacles associated with the great technological complexity of modern ICT solutions, which require high professional competence from their users. This becomes an obstacle to the widespread practical implementation of innovative technologies in environmental management at the regional and local levels of government.

Based on the analysis of functional categories and the identified system limitations, a conceptual model is formulated, which consists of five interacting architectural levels (Table 2)

Table 2. Structural diagram of the multi-level system of integration of information and communication technologies for environmental assessment

Level	Description
Level 1	Intelligent data aggregation with automatic standardization of formats and information exchange protocols
Level 2	Adaptive processing and analytics, where algorithms self-adjust to the specifics of user tasks
Level 3	Automated verification, minimizing user involvement in the data validation process
Level 4	Intuitive management and visualization via adaptive interfaces that automatically assess the user's technical proficiency
Level 5	User support system with integrated training and consulting modules

Source: Compiled by the authors.

The basic level (Level 1) of the architecture carries out the basic processing and unification of heterogeneous flows of environmental information. The main function of this level is to overcome the problem of fragmentation of technological solutions through the development of a single information space.

Intelligent aggregation is carried out by automatically determining types and constructing input facts regardless of their basic form. The setup can process satellite observer information, IoT sensor data, lab test results, meteorological data, and field research details.

Automatic standardization of formats ensures that all information is brought to common technical standards, so there are no compatibility issues between different data sources. Information exchange protocols are optimized to ensure reliable and fast data transfer between system components.

The level contains mechanisms for quality control of primary data with automatic detection and correction of typical measurement errors, which increases the overall reliability of the information base of the system.

The analytical layer (Level 2) provides intelligent processing of normalized data with the automatic selection of the best analysis methods according to the nature of the tasks to be performed and the characteristics of the available information.

The adaptability of processing is expressed in the ability of the system to automatically select those analysis algorithms that are most successful, depending on the type of environmental task, the amount of information available, requirements for the accuracy of results and time constraints. The system can use a range of analytical methods, ranging from simple statistical calculations to complex machine learning models.

Query history, user activity profile, and domain features determine how algorithms can be configured automatically. The system optimizes work for different categories of users and gradually

studies their needs. Among them are scientists, heads of environmental protection agencies, and representatives of industrial enterprises.

Here, there is an automatic detection of trends, anomalies and patterns in environmental data, which creates predictive models and assesses the probability of various scenarios for the development of the environmental situation.

The validation layer (Level 3) is designed to ensure high reliability of analysis results by implementing automated mechanisms for verifying data and processing results without the need for constant user intervention.

Auto-verification involves a multi-level control system: checking input data for compliance with physical laws and environmental patterns, cross-checking the results with various analytical methods, as well as comparing with historical data and reference values.

Minimizing user participation is achieved by implementing expert systems that automatically assess the reliability of information based on accumulated experience and accepted quality criteria. The system itself identifies possible errors, inconsistencies, as well as dubious results and informs the user only those cases that require an expert decision.

This layer provides documentation at all stages of the verification process to be able to track the verification process and verify the quality of the results. Mechanisms for the versioning of data and analysis results are also implemented so that changes can be tracked and be able to return to previous states.

At the interface level (Level 4), effective interaction of users with the system is ensured by automatically adjusting the complexity of the interface to the level of technical training and professional needs of a particular user. The implementation of intuitive control takes place in natural forms of interaction: graphical interfaces with drag-and-drop elements, voice commands, gesture control, and auto-completion of requests. The system tries to minimize the number of technical operations that need to be performed to obtain the desired result.

According to user behavior, by the frequency of use of a particular function, by typical errors and methods, and by how well the work is done, the systems present a simplified interface for beginners with step-by-step instructions for using the system. For experts who may wish to never see such annoying interfaces, adaptive systems provide all the advanced features that help you get quick access to professional tools.

Analysis of the speed of execution of operations, the use of complex functions, understanding of terminology, as well as the interpretation of the results automatically assesses the level of technical training. Based on this, the system automatically adjusts the level of detail of the information to be provided, the complexity of the tools that may be available, and even the amount of reference information.

Visualizing the results automatically selects the best ways to display information: maps, graphs, charts, 3D shapes, and videos. The setting looks at how different people see things and what information about the environment exists for the most informative visual display.

The User Support System (Level 5) provides complete assistance to the user by mixing training materials, consulting services, and expert help systems directly in the stages of using the system.

The support system works like a smart assistant that always monitors what the user is doing, detects possible problems, and provides assistance even before it is asked. Help comes right in the center of the task at hand, without distracting from the main work.

Training modules are built into apply the concept of continuous professional development by combining the content of education with the work process. The system automatically detects gaps in the user's knowledge and learning materials, including interactive lessons, practical tasks, and thematic webinars.

Consulting modules unlock expert knowledge through multiple channels: automatic answers to frequently asked questions, access to a knowledge base of best practices, and the ability to connect with experts in real time. The system stores its consultation history and thereby creates a personal knowledge base for each user.

This level involves the establishment of feedback mechanisms that would constantly update the support system based on the user's experience and any changes noticed in the subject area. Tools for self-assessment of competencies and tools for planning professional development have been introduced.

The proposed five-level architecture acts as one whole system, where each layer receives the results of the previous one and passes the processed information to the next. This setting ensures a continuous improvement in both the quality and value of information at every step of processing.

Standardized interfaces and data exchange protocols ensure vertical integration of layers. Quality control at each transition between levels and verification of processing results accompany every step taken. Horizontal integration allows information to be exchanged between all components within any given level for a synergy effect that optimizes the overall performance of the system. The proposed architecture supports this principle, whereby feedback from higher-level decision-makers can be used to optimize the performance of lower-level decision-makers. This will make this architecture dynamic with respect to continuous improvement.

6. Conclusions

The conducted research made it possible to systematize modern information and communication technologies of environmental assessment, as well as to develop conceptual foundations for their integration into environmental management systems. A functional classification of ICT tools into three main categories has been developed, which provides a structured approach to the selection of technological solutions in accordance with the specifics of environmental tasks.

A conceptual model of a five-level architecture of an integrated environmental management system is proposed, which provides the transformation of raw environmental data into ready-made results of a management decision using intelligent aggregation, adaptive analytics, automated verification, intuitive control, as well as intelligent user support. Further research prospects in this direction include the development of appropriate interaction standards for different ICT platforms, the improvement of artificial intelligence methodologies, the study of energy efficiency in information technology, and the study of ethical aspects of the application of artificial intelligence within the framework of environmental management.

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Artificial Intelligence in Auditing: Challenges of Developing Countries

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ABSTRACT

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The rapid development of artificial intelligence (AI) is radically transforming auditing activities, ensuring not only the automation of routine processes and the transition to continuous monitoring, but also changing the role of the auditor. Technologies such as big data analysis, machine learning, and Explainable AI (XAI) are becoming more and more commonplace in the audit community. Meanwhile, for developing countries, the process of integrating AI auditing poses a double challenge. On the one hand, technological advances, increasing data volume, and rapid globalization make the integration of AI into human activities not just a desirable improvement, but also a prerequisite for competitiveness. Moreover, AI allows not only to improve productivity, but also to compensate for human resources to some extent. On the other hand, there are a number of systemic limitations to the implementation of AI, which not only slow down the integration process but also make it impossible in some places. All this requires an integrated approach to the application of AI technologies in these countries. The available publications in this area are mostly focused on developed economies, leaving a research gap on a comprehensive model for implementing AI audits in resource-constrained settings. The purpose of this article is to identify key system barriers and develop a practical integrated framework for AI audit readiness in these countries. The study conducted in this article identifies and systematizes the systemic gap between global AI audit models, based mainly on developed infrastructure, and the realities of developing countries. Five interdependent key factors were identified, such as data infrastructure (fragmentation, poor quality, unstable power supply), technological readiness (lack of computing resources, need for new software solutions, weak cybersecurity), human resources (critical shortage of specialists, insufficient adaptation of educational programs), organizational capacity (lack of holistic strategies, informal procedures) and regulatory support (lack of comprehensive laws, non-compliance of internal norms with international standards). To overcome this fragmentation, a practical integrated readiness framework is proposed, which unites all these components and can serve as a tool for diagnosing and planning AI integration. Thus, the study comprehensively analyzed and systematized the key barriers to the implementation of AI in auditing in developing countries, confirming the incompatibility of Western models with their resources. It showed that the successful digital transformation of audit requires not only technological investments but also the parallel strengthening of data infrastructure, staff training, and the creation of a strong regulatory framework. The proposed readiness framework is the basic guide that facilitates this process.

KEYWORDS

artificial intelligence in auditing; AI audit; developing countries; data infrastructure; technological readiness; Explainable AI (XAI); human resources; regulatory support; integrated readiness framework; Digital transformation of auditing.



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Штучний інтелект в аудиті: виклики країн, що розвиваються

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СТАТТЯ

АНОТАЦІЯ

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Стрімкий розвиток штучного інтелекту (ШІ) радикальним чином трансформує аудиторську діяльність, забезпечуючи не тільки автоматизацію рутинних процесів та перехід до безперервного моніторингу, а й змінюючи саму роль аудитора. Такі технології як аналіз великих даних (Big Data), машинне навчання та пояснювальний ШІ стають все більше буденними в аудиторській спільноті. Тим часом, для країн, що розвиваються, процес інтеграції ШІ-аудиту створює подвійний виклик. З одного боку технологічний прогрес, збільшення об'єму даних та швидка глобалізація роблять інтеграцію ШІ в людську діяльність не просто бажаним покращенням, а й необхідною умовою конкурентоздатності. При чому ШІ дозволяє не тільки покращити продуктивність, але й певною мірою компенсувати людські ресурси. З іншого боку існує ряд системних обмежень впровадження ШІ, які не тільки сповільнюють процес інтеграції, але й подекуди роблять його неможливим. Це все вимагає комплексного підходу до застосування ШІ технологій в цих країнах. Наявні публікації в цій сфері здебільшого орієнтовані на розвинені економіки, залишаючи дослідницький розрив щодо комплексної моделі впровадження ШІ-аудиту в умовах обмежених ресурсів. Метою даної статті є визначення ключових системних бар'єрів та розробка практичної інтегрованої рамки готовності до ШІ-аудиту в цих країнах. Дослідженням, проведеним у даній статті, виявлено та систематизовано системний розрив між глобальними моделями ШІ-аудиту, що базуються здебільшого на розвиненій інфраструктурі, та реаліями країн, що розвиваються. Було визначено п'ять взаємозалежних ключових факторів, таких як інфраструктура даних (фрагментарність, низька якість, нестабільне енергопостачання), технологічна готовність (брак обчислювальних ресурсів, необхідність нових програмних рішень, слабка кібербезпека), кадрова спроможність (критичний дефіцит фахівців, недостатня адаптація освітніх програм), організаційна спроможність (відсутність цілісних стратегій, неформалізовані процедури) та регуляторне забезпечення (брак комплексних законів, невідповідність внутрішніх норм міжнародним стандартам). Для подолання цієї фрагментарності запропоновано практичну інтегровану рамку готовності, яка об'єднує усі ці компоненти і може слугувати інструментом діагностики та планування інтеграції ШІ. Отже, проведене дослідження комплексно проаналізувало та систематизувало ключові бар'єри на шляху впровадження ШІ в аудит в країнах, що розвиваються, підтвердивши несумісність західних моделей з їхніми ресурсами. Воно показало, що успішна цифрова трансформація аудиту вимагає не лише технологічних інвестицій, але й паралельного зміцнення інфраструктури даних, підвищення кваліфікації кадрів та створення міцної регуляторної бази. Запропонована рамка готовності є тим базовим путівником, який полегшує цей процес.

КЛЮЧОВІ СЛОВА

штучний інтелект в аудиті; ШІ-аудит; країни, що розвиваються; інфраструктура даних; технологічна готовність; пояснювальний ШІ (XAI); кадрова спроможність; регуляторне забезпечення; інтегрована рамка готовності; цифрова трансформація аудиту.

1. Introduction

In recent years, there has been a rapid development of artificial intelligence (AI), which has had a significant impact on auditing activities. Thanks to AI, routine processes are automated in auditing and the accuracy of inspections is increased. In addition, the audit made it possible to analyze large amounts of data, which became possible thanks to big data. Leading audit firms are actively implementing machine learning tools into standard procedures, increasingly integrating intelligent audit into their activities [5; 15]. At the same time, in addition to the means of verification, their very logic changes. Data sampling is replaced by continuous monitoring and supervision of risky transactions [5; 15]. Also worth noting is the emergence of Explainable AI (XAI), which makes all decisions of AI models transparent and understandable. This allows the auditor to provide reasonable conclusions to all stakeholders [28].

In parallel with the increase in productivity, new challenges and risks appear, in particular, the need for new competencies [25]. No less important is the issue of control and responsibility for decisions. As the developers of the concept of "internal algorithmic auditing" emphasize, without clearly defined rules for controlling models, old problems will only be transferred to a new environment [24]. Therefore, international organizations in the regulatory sphere are increasingly focusing on the requirements for transparency and accountability, although they are mostly focused on countries with developed economies.

Also, the ability of organizations to use AI depends on the level of readiness of digital infrastructure and human resources and can differ significantly even within the same industry [10]. For developing countries, this forms a double challenge. On the one hand, AI audit allows you to compensate for the lack of human resources and cover large amounts of data. On the other hand, it is these countries that often face a lack of quality data, limited computing capabilities, and a lack of clear regulatory mechanisms.

Despite the large number of publications available, most of them focus either on AI audit implementation technologies or on issues of ethics, trust, transparency, accountability, and control. There is a lack of a comprehensive system analysis that would take into account all these aspects. In addition, there is still not enough research in the literature that takes into account the specific limitations of developing countries.

2. Literature Review

The topic of AI in auditing is currently widely covered on all platforms and has been sufficiently researched in scientific papers. Basic research by D. Appelbaum et al., and others, describe the technological capabilities of AI auditing, changes in audit procedures and the role of the auditor under the influence of automation and big data [5; 11; 13; 15; 25; 26; 27]. In particular, the use of big data stands out as a new type of audit evidence. The authors focus their main attention on the integration of machine learning and data analytics into audit processes and show the transition of audit from random testing to real-time monitoring. C. Zhang et al., in their work, focus on XAI as the main condition for transparency and accountability of model decisions in audit [28]. They emphasize that the lack of explainability is a major obstacle to AI adoption. The authors show that the use of XAI allows auditors to understand the logic of the models and assess the reliability of the analysis. Other authors describe how the integration of AI and blockchain affects the architecture of accounting systems [29]. The ability of AI technologies to significantly expand audit functions to ensure continuous and high-quality data control is emphasized.

R. Libby and P. D. Witz, using the example of an experiment with "mock jurors" in a case of audit negligence, investigate how the use of AI in auditing affects the auditor's perception of objectivity [19]. They demonstrate that the use of AI reduces assessment bias and increases trust in the audit process. At the same time, it is emphasized that the effective use of AI in auditing requires a deeper understanding of risks, ethical constraints, and the formation of critical thinking, since these factors directly affect the quality of the auditor's profession.

Other authors show how the professions of auditor and accountant are changing under the influence of the development of AI. In particular, S. Greenman et al. emphasize that AI redistributes the functions of specialists, reducing routine tasks [11]. In turn, they address the ethical challenges

associated with the adoption of AI, including job losses and dependence on technology. Review by E. Ahmed and G. Japee demonstrates that in the context of digital transformation, internal audit is gradually shifting from a controlling role to a partner role [2]. L. E. Fotoh and Y. I. Lorentzon emphasize that the impact of AI on auditing will be gradual, and propose a transitional framework for development to ensure the competitiveness of the audit profession [9]. This, in turn, will require the profession to acquire new skills, as well as change the business models themselves.

D. Leocádio et al. propose the concept of integrating AI into audit, which covers all stages of implementation and the role of management and control in it [18]. In turn, D. Kokina et al., based on field data, emphasize the need for a structural approach to management [16]. Their work also notes the importance of reviewing the roles of auditors and adapting all procedures to the practical use of AI in auditing. I. D. Raji et al., in their work on internal algorithmic auditing, they propose a control model that covers the entire cycle of AI implementation, including design, training, deployment, and monitoring [24]. The authors emphasize that algorithms can create risks of bias, opacity, and lack of accountability. To prevent this, they propose the introduction of internal AI audit mechanisms. Similar principles are laid down in the OECD Framework for the Classification of AI Systems, developed by the international organization OECD [23].

At the same time, most studies are based on the examples of countries with developed digital infrastructure, relatively high-quality data, and more mature regulatory institutions. They assume the presence of a sufficient technological base, even at the stage of analyzing the risks of AI implementation and scaling [5; 8; 15; 16; 23; 25; 27]. They also rely on developed human and institutional resources [8; 9; 11; 16; 19; 23, 24]. On the other hand, the issue of limited resources and weak institutions, which is typical for developing countries, remains less researched, even though some works already record critical personnel, economic and institutional barriers [1; 3; 4; 6; 7; 10; 12; 14; 17; 20; 21; 22].

Thus, D. Genaro-Moya et al. in their article show that in Latin America, the potential of AI to increase the effectiveness of public control is quite high [10]. It is recognized by the highest audit institutions, but faces a shortage of personnel, weak infrastructure and frequent delays in the implementation of digital technologies. S. Anomah's study on Ghana also highlights the low level of readiness for AI adoption [4]. Among the influencing factors, the author highlights the lack of resources, competencies and poor quality of management in public audit. Analysis by A. Nyamawe et al. demonstrates that in sub-Saharan Africa, there is a high interest of governments in AI technologies [22]. However, their implementation is hampered by a combination of staffing shortages, unstable digital infrastructure, and uncertain regulatory policies.

Broader cross-regional reviews also confirm the systemic nature of the various limitations faced by AI initiatives. Thus, in the article by M. S. Khan et al. It is emphasized that in low-income countries, one of the key obstacles is the lack of cloud solutions and low data quality [14]. In the study of A. Ateeq et al. note that in South Asian countries, on the one hand, there is a critical shortage of competent personnel in the digital field, and on the other hand, funding for educational programs with AI remains insufficient [6]. Similar conclusions are made by the authors A. O. Aderibigbe et al., who describe the cumulative technological, personnel, and institutional constraints that hinder the development of AI in Africa [1]. In turn, M. Maghsoudi and others. show that in developing countries, unresolved problems of weak infrastructure and low control are superimposed on issues of ethics, risk assessment, and trust in AI algorithms [20].

At the level of private business, the article by S. G. Ayinaddis shows that small and medium-sized enterprises lag significantly behind large companies due to limited digital resources, lack of infrastructure, low level of digital literacy and lack of adequate support from the state and its institutions [7]. The author directly emphasizes that typical models of AI implementation, developed for the conditions of developed countries, do not work in the real conditions of countries, developing. In this way, the incompatibility of the models developed and the socioeconomic environment in which they are used is demonstrated. Research in the field of accounting information systems and business analytics also confirms this gap. In particular, T. H. Y. Nguyen notes in his work that accounting systems in Southeast Asian countries are not ready for AI technologies due to a lack of skills in working with them, low data quality, and weak cybersecurity [21]. Similar conclusions are made by V. Iatsiuta and V. Kobets in their article, which describes the architecture of AI as a Service (AI-as-a-Service) for Ukraine [12]. The authors emphasize that the implementation of such a service is constrained by the lack of unified data and limited IT resources of the business.

In another Ukrainian study, O. Kondratiuk et al. The authors emphasize the indispensability of the human factor due to organizational and technological limitations [17]. While AI can improve the quality of data analysis in audits, its application cannot completely replace the auditor's professional assessment. In turn, the Malaysian researcher M. Akpa proposes a model for evaluating performance in the context of the use of AI. The model proposed by him takes into account human and organizational factors, emphasizing the importance of harmonization of technological and human resources [3].

A literature review shows that despite the high relevance of the topic and the growing number of publications on the use of AI in auditing, most of the available research remains scattered. In addition, they are not sufficiently adapted to the conditions of developing countries. Firstly, there is a clear gap between typical AI audit models, formed mostly in developed countries, and real constraints in low- and middle-income economies. Existing approaches, in particular to risk management and XAI, do not take into account the poor data quality, limited IT infrastructure, and lack of specialists typical of countries with weak economies. Secondly, the existing works do not form a holistic model for implementing AI audits in conditions of limited resources, despite the fact that they cover the issues of infrastructure readiness, social and economic challenges, as well as personnel shortages. Thirdly, the identified need for new roles and skills of the auditor is almost not considered in the context of the regional shortage of personnel and inequality of access to education. Fourthly, modern approaches to ethics, accountability and governance in the field of AI auditing, widely described in the literature, often do not contain practical mechanisms for adapting to the conditions of weak supervisory systems in developing countries.

Summarizing the results of the literature review, we can say that modern research does not form a holistic and practically applicable model for the implementation of AI audit in developing countries. This emphasizes the relevance of the research aimed at systematizing existing approaches, identifying key challenges and forming recommendations for minimizing risks and increasing trust in AI.

3. Problem Statement

This article aims to determine to which the implementation of AI in auditing is possible in the real constraints of developing countries. Most of the existing approaches to AI auditing are formed in countries with developed digital infrastructure, high economic indicators, high-quality data, and extensive human resources. On the other hand, in Africa, Latin America, Asia and Eastern Europe, there is a shortage of qualified personnel, inconsistency of information systems, limited budgets and uncertainty of the regulatory framework, which often makes it impossible to implement Western models. The research conducted in the article is aimed at solving three key tasks: to identify and systematize the key barriers to the implementation of AI auditing, as well as to show their interdependence; to bridge the research gap on a comprehensive model of AI adoption in resource-constrained settings; develop a practical integration framework for the audit environment that can serve as a tool for planning and implementing AI audits in developing countries.

The object of this study is the process of integrating AI into audit and financial control, which is considered a complex system that includes technological, organizational, personnel and regulatory components. The subject of the study is the limiting factors that affect this process.

4. Methods and Materials

The methodological basis of the study of the implementation of AI audit in developing countries is based on a systematic analysis of scientific publications, analytical reports, regulatory documents and reports of leading industry specialists. This approach ensures transparency, impartiality and reproducibility of research results, as well as allows for a comprehensive assessment of key aspects of the research process.

5. Results and Discussion

5.1. The Gap Between Global Models and the Reality of Developing Countries

A literature review revealed a significant imbalance between conceptual AI models and the conditions in which they are implemented. On the one hand, we have the technological potential of

machine learning, big data, XAI, and various digital platforms [5; 13; 15; 26; 27; 28; 29]. On the other hand, empirical studies conducted in developing countries demonstrate various limitations that significantly narrow the possibilities of implementing and scaling such technologies [1; 4; 6; 10; 14; 20; 22]. The authors emphasize that weak infrastructure, lack of quality data, computing resources, and skilled personnel limit the use of AI in key sectors of the economy and public administration [1; 6; 14].

There is also a significant inequality in the participation of developing countries in the global development of AI. They have a rather small share in the volume of scientific publications, which is why their needs remain underrepresented [14; 20; 22].

In addition, there is a difference in the priorities of countries with different levels of development. For developing countries, access to basic services and technological infrastructure is one of the central issues, while the interests of countries with higher economies may lie elsewhere (e.g., regulation and ethics of AI) [1; 4; 6; 7; 10; 14; 16; 17; 20; 22].

In this way, we can see that this gap is systemic and multidimensional. For developing countries, this means that any framework for the introduction of AI, in particular in the field of auditing, should be based not only on global models, but also on the limitations recorded in studies [4; 6; 10; 14; 20; 22].

5.2. Key Challenges of AI Audit Implementation in Developing Countries

5.2.1. Data infrastructure

Most AI audit models developed in developed countries are based on the availability of standardized information flows, developed data infrastructure, relatively high-quality data, and unified recording formats [5; 12; 13; 15; 16; 25; 29]. They are considered as a reliable basis for the deployment of algorithms for monitoring transactions, analyzing financial flows, detecting anomalies and generating analytical reports [12; 13; 16; 29].

On the other hand, for developing countries, a different situation is quite typical. In the public sector of Latin America, information systems are still scattered, and integration between databases is limited [10]. In Africa and South Asia, incomplete or inaccurate data are common, and there are no uniform standards for their collection, analysis and coding [1; 6; 14; 22]. For example, in the public sector in sub-Saharan Africa, the prevalence of unbalanced, biased, and low-quality data hinders the deployment of machine learning models [22].

An additional complicating factor is periodic interruptions in power supply and Internet connection, which are typical, in particular, for African countries [1; 22]. For example, as of 2022, 43% of Africa's population still did not have access to electricity [22]. This makes data transmission not only unreliable and fragmented but often impossible.

Under such conditions, even relatively simple machine learning models are sensitive to errors, which in turn affects the accuracy of their work [10; 16; 21; 22]. Auditors often distrust AI recommendations and conclusions due to a clear inconsistency with their experience with manual audits [10]. This often leads to the fact that AI solutions remain at the stage of pilot projects without further scaling and operation [10; 14; 20; 22].

Thus, the data infrastructure in developing countries is a critical bottleneck that determines not only the effectiveness of AI audit models but also the very possibility of their practical application in these countries.

5.2.2. Technological readiness

Modern AI audit models perform many complex tasks, such as automated transaction monitoring, analysis of large amounts of data, the use of blockchain to confirm audit evidence, and the support of continuous control [5; 13; 15; 16; 17; 25; 26; 28; 29]. An important condition for trust in these models is not only the accuracy of the results obtained, but also the auditor's ability to interpret the results [5; 9; 16; 17; 18; 19; 24; 28]. This reinforces the role of XAI, which provides transparency of models and allows you to understand the logic of decision-making [12; 15; 16; 24; 28]. All these technologies form a solid foundation for the implementation of AI in auditing.

In developing countries, the implementation of such solutions faces a number of technological challenges, which are reflected in regional studies. In Ukraine, there is an increase in the amount of data received from customers, which is why there is a need for high-quality AI-based solutions. But to use AI in auditing, new software is needed [17]. Often, in the process of developing AI solutions, there are problems in optimization, limitations in support of multiple sources, and potential security

vulnerabilities [12]. Therefore, AI integration requires addressing key issues, including cybersecurity [17].

The example of Vietnam shows that companies face significant challenges in adapting to new technologies. Overcoming them requires not only methodological support, but also serious investments in technological infrastructure [18; 21]. In the public sector of Ghana, there is also a need to adapt technological resources to the changes associated with the use of AI [4]. Similar conclusions are drawn for Latin American countries, emphasizing that supreme audit institutions must respond to technological advances. They should ensure the openness of data and expand the possibilities of using analytics in auditing [10]. This will allow auditors to improve the quality of control, reduce the risks of errors and increase the transparency of conclusions.

In the broader context of developing countries, there is a lack of reliable computing resources and access to high-speed Internet [1; 4; 6; 14; 20; 22]. Common challenges in AI adoption include insufficient technical capacity and limitations in data management [10]. There is often a lack of modern formalized procedures that would turn the results of AI models into a real tool that helps in decision-making. Policies related to documentation, review, verification, transfer to a higher level, etc., often remain informal and fragmented [1; 6; 20]. Without this, the work of AI becomes an incomprehensible and uncontrollable process.

Technological readiness is closely related to financial resources and IT infrastructure, which is especially important for small and medium-sized enterprises, as they often face high barriers to access the necessary infrastructure [7].

As a result of all the above factors, even where such approaches as XAI could theoretically increase the credibility of AI audits, their large-scale implementation is hampered by technological unpreparedness [1; 4; 10; 20; 21; 22].

5.2.3. Lack of skills

The role of the auditor is gradually changing from classical sample analysis to analytical work with data [2; 18; 25]. This requires an increasingly higher level of professionalism and the acquisition of new skills that combine technical and auditing knowledge [13; 17; 18]. The auditor must not only be able to apply modern technologies in practical work, but also critically evaluate, interpret and question the recommendations of models [13; 16; 17]. This, in turn, requires changes in the requirements for auditor training and adaptation of training programs to modern challenges [13; 25].

Studies conducted for developing countries describe the key factors that determine the industry's readiness to implement AI in accounting and auditing processes. An analysis of the impact of AI on the profession of auditors and accountants conducted in Ghana showed the difficulty of transitioning to new technological approaches, in particular due to the insufficient qualification of personnel [4]. There is also a need for skilled personnel with AI skills in Vietnam, as traditional training programs often do not provide these competencies. [18; 21]. The lack of qualified personnel is also one of the barriers to integrating AI into auditing in Nigeria [21]. Due to the lack of personnel, audit bodies often involve international specialists for the implementation of projects, which further increases the costs of their implementation [10].

As we can see, having a skilled workforce with AI skills is critical for developing countries. These countries are significantly lagging in the adoption of AI, in particular due to the lack of specialists in the field of machine learning, data science, and AI engineering [1; 4; 6; 14; 20; 22]. According to a Ukrainian study, 30% of representatives of the financial sector have only heard the term "machine learning", without having a real idea of its mechanisms [17]. This creates a need for the systematic development of technical literacy of specialists, which is one of the key factors in the integration of AI into auditing [2; 4; 9; 10; 13; 15; 16; 17; 25].

Despite the urgent need, there is an insufficiency of local educational programs in developing countries, which causes or deepens the structural personnel shortage [1; 4; 6; 14; 20; 22; 27]. In addition, there are a number of other factors that affect personnel training. In African countries, for example, the integration of AI into educational programs is complicated by financial constraints and the need for proper teacher training [14]. In a broader context, educational institutions often work with limited digital infrastructure and do not have access to modern analytical tools [1; 4; 6; 14; 22]. Systems of retraining of current employees of state institutions are often isolated and limited [1; 10; 14; 17; 20; 22; 27].

Thus, the lack of qualified personnel becomes the main obstacle to the successful implementation of AI, especially in those areas where AI could theoretically compensate for human deficits [1; 4; 6; 7; 10; 11; 13; 14; 17; 22]. This requires the development of training programs and serious investment in technical education and training of personnel [1–9; 10; 11; 13; 14; 17; 18; 21; 22; 25; 27; 29].

5.2.4. Organizational capacity

The scientific literature on audit and accounting information systems describes modern approaches to the creation of special bodies and roles, the development of policies that help integrate AI into existing control systems [5; 13; 15; 16; 24; 25; 26; 28]. This helps developed countries to ensure that new initiatives really work, and not remain only on paper.

The Ukrainian example shows the importance of the country's government facilitating the implementation of AI initiatives. The country has established an Expert Committee on the Development of AI under the Ministry of Digital Transformation, which presented a draft concept of this development for public discussion [17]. Thus, the state demonstrates its readiness for the further implementation of AI and forms a stable institutional foundation for this.

However, developing countries are mostly characterized by limited readiness to implement complex technologies in the field of AI. Studies show that governments in low-income African countries are at the lowest levels of AI readiness rankings [14; 22]. These countries, as well as Latin American countries, are characterized by weak digital reforms, low integration of information systems, uneven infrastructure development and insufficient strategic planning [1; 4; 10; 22]. Part of this problem is the lack of clearly defined procedures, roles, and tools that would support the systematic implementation of AI [1; 4; 6].

A study in Ghana showed that despite the existence of initiatives, the readiness of audit institutions to implement AI remains limited due to the lack of a holistic strategy, uneven support for reforms, and a lack of skilled workers [4]. In Latin America, there is a problem with the consistency of information standards and risk assessment when using algorithms [10]. Such conditions inhibit the further development and scaling of AI projects [1; 4; 22]. In turn, this requires additional efforts and measures from countries with limited resources to increase their readiness for AI initiatives.

In addition to readiness for new technologies, comprehensive interaction between government agencies, educational institutions, IT companies and international organizations is necessary. Such forms of interaction contribute to the exchange of experience, the formation of standards and the strengthening of human resources, which are key conditions for the successful implementation of AI in audit [1; 4; 10; 20; 22].

5.2.5. Regulatory restrictions

The international AI regulatory environment shows significant unevenness, which is particularly acute for developing countries. The world's first EU AI Act has been created in the EU countries, which establishes risk classification, conformity assessment mechanisms, requirements for transparency, data management, model security, and post-implementation monitoring [8]. EU countries have followed the path of regulatory policy, which, on the one hand, lays a solid foundation for the further development of AI, and on the other hand, can slow down the development of AI technologies and investment in the industry. The United States has followed the path of market expediency, in which innovation and billions of dollars in investments in them dominate preventive regulation. There are industry regulations (FTC, FDA, HUD, etc.) and a set of recommendations NIST AI RMF (AI Risk Management Framework from the US National Institute of Standards and Technology). Already at this level, there is a gap between the regulatory European model and the American market model.

In developing countries, there is a lack of comprehensive laws and mandatory AI regulations. Instead of special laws, the most common format is codes of ethics, general IT strategies and principles of responsibility, which do not have the legal force of law [1; 4; 20; 22]. Some countries, including Latin American regions, take the EU AI Act as a guideline, but the status of adoption of similar acts in individual countries is not determined [10; 14; 18; 20].

As a result, a triple regulatory gap is formed for these countries:

- between the EU and the USA, where there are fundamentally different regulatory models;
- between developed and developing countries in the context of access to quality standards and regulations;

- within the countries themselves, where the state often faces difficulties in implementing even basic norms for the responsible use of AI [1; 4; 10; 14; 20; 22; 24].

For the field of financial audit, the discrepancy between internal regulations and external regulations is especially critical, because, according to the EU AI Act, this area belongs to the high-risk category. In practice, for developing countries, this means that any organizations that interact with European counterparties (audit outsourcing, financial analytics, internal control, etc.) actually face the requirements laid down in this act. In the absence of mature infrastructure and quality data in these countries, the EU AI Act becomes an indirect external regulatory pressure on them. They have to adapt to European standards under the influence of external requirements, which often do not take into account their real capacity.

5.3. Integrated AI Audit Readiness Framework in Developing Countries

A generalization of the literature review shows that considering all aspects separately does not allow for fully assessing the readiness of developing countries to implement AI audits. Most modern approaches are based on selective solutions to problems, while these countries are forced to work with all constraints together, while overcoming fragmentation in research.

To overcome this fragmentation, an integrated preparedness framework is proposed, which consists of five interrelated components: infrastructure readiness; technological readiness and XAI; human resources; institutional architecture; regulatory framework and governance. This framework is aimed at low- and middle-income countries and can be used as a tool to diagnose problem areas in specific sectors of the economy. It can also be considered as a methodological basis for the systematic implementation of AI audit.

5.3.1. Infrastructure readiness

For developing countries, infrastructure readiness first of all means step-by-step structuring of data, and only then the gradual complication of models. It includes, first of all, the availability and quality of data, the availability of basic computing resources and minimum data management standards. Also, the level of integration of accounting systems is no less important. Data structuring can be divided into two stages.

At the first stage, uniform rules are established for key data elements. Such accounts as dates, currencies, account codes, counterparty identifiers, etc., are brought to a single format. A minimum set of required fields for each operation is defined. It can include the date, amount, type of transaction, counterparty, comment, etc. Then a register of data sources and routes of their movement is built, namely: where data is generated and stored, and how it is transmitted between systems. At the end, the rules of inspections are established.

In the second stage, all key sources are connected to a single intermediate storage using simple ETL (Extract-Transform-Load) processes. In practice, this means setting up systematic uploading of data from the accounting system, banking services, and tax reporting to a single repository. Thanks to the preliminary unification, all data can be combined with shared keys and brought to the agreed format. Next, ETL processes clean the data from duplicates, bring all indicators to a single unit of measurement, check if all fields are filled in, and upload the results to a shared repository. For organizations with limited resources, it can be a separate server or an inexpensive cloud database, and the integration with AI models is carried out using scripts or available solutions.

Such data preparation not only reduces the risks of skewed training of Sh-algorithms, but also builds a solid foundation for further gradual increase in their complexity.

5.3.2. Technology Readiness and XAI

The ability of organizations to select and adapt AI models that provide a basic explanatory layer and are resilient to low-quality data defines the second component. Developed countries tend to opt for the latest and most sophisticated algorithms, but this approach cannot be mechanically transferred to developing countries. Here, too, it is advisable to move in stages. It is recommended to start with algorithms that are least sensitive to omissions and noise. Such models include systems of classification of operations by risk level (decision trees and rule-based), simple statistical methods for determining anomalies, and regression models.

With improvements in infrastructure and data quality, it becomes possible to move to more complex models. Organizations can use ensemble methods (Random Forest, Gradient Boosting, AdaBoost) that combine many simple models into one, as well as apply deep neural networks to solve specific problems.

XAI deserves special attention, since its implementation is also advisable to carry out from simple to complex. At the minimum level, basic explanations are carried out in the form of simple tables and histograms, and key risk factors are listed. At the intermediate level, tools such as LIME (Local Interpretable Model-agnostic Explanations) are used to explain individual decisions in a format understandable to the auditor. And finally, at an advanced level, interactive dashboards are integrated into workflows.

This step-by-step approach allows you to give preference to understandable models over opaque algorithms and gradually increase complexity without losing control.

5.3.3. Personnel capacity

The third component of the framework combines auditing and technical knowledge, as well as educational programs. There is quite a significant inequality here. For developed countries is simply improving the level of skills and acquiring additional skills; for many developing countries can mean learning from scratch. Therefore, education in these countries requires not only targeted investments but also the implementation of a whole action plan.

At the university level, AI and analytics modules should be included in educational programs. Educational institutions should form partnerships with international universities. The focus of training should be on practical cases, not on the mathematical details of algorithms. In parallel, short (3–6 months) refresher courses for auditors already working in the private and public sectors should be introduced. In addition, the most trained specialists can act as trainers for their colleagues during training programs. This reduces dependence on the participation of international consultants.

And finally, most importantly, any form of training should be aimed at the formation and development of critical thinking in auditors. Because it is important for them to be able to check the quality of data, detect biases in algorithms, understand situations in which the model can make a mistake, and not take all AI recommendations as truth without verification.

5.3.4. Institutional architecture

The fourth component of the framework is the presence of structures that are responsible for managing AI. This includes committees, working groups, and centers of competence. It also includes management procedures and coordination mechanisms between financial, audit and IT departments.

For developing countries, a two-tier approach is advisable. At the first level, small functional groups (3–5 people) are created, which act as a center. They coordinate all pilot projects and summarize the experiences of different institutions, determining which conditions affect implementation, what typical errors occur during launch, and which budgets are realistic. They also develop standard policies and templates, which include documenting the operation of models, test procedures, reporting formats, etc. In addition, they act as intermediaries between technical suppliers, regulators, and end users. The effectiveness of such focal points increases significantly if they are embedded in the system of public-private, regional and global partnerships, which avoids their isolation and overload.

The second level is strategic. In parallel with the creation of coordination groups, a written strategy for the implementation of AI audits should be developed with a defined time frame in years. It defines the distribution of responsibility, mechanisms of communication within the organization and with stakeholders. In addition, a plan for managing personnel, technical and other risks is drawn up.

5.3.5. Regulatory framework

The last component consists of a set of rules and procedures for documenting models, fixing their decisions, defining accountability, and ensuring transparency to stakeholders. Obviously, a full framework like the EU AI Act is difficult to implement right away, so it is advisable to apply a minimum package of management policies.

To begin with, a simple register of AI models must be compiled, which records the name of the model, its purpose, the data used, the developer, the person responsible, the date of the last check, etc. Before implementation, the model must be tested on historical data and on well-known cases. All model

recommendations should be recorded along with an explanation. This will create a basis for further analysis and correct operation. For each model, a person or a separate unit is assigned who is responsible for supervision, control, notification of failures, as well as regular updates. In case of incorrect operation of the model or doubts about its decisions, there should be a clear procedure for contacting the specialists of the IT department and temporarily limiting the operation of the model.

Generalized practical steps and tools of the integrated AI audit readiness framework are presented in Table 1.

Table 1. Integrated AI Audit Readiness Framework

Component	Practical steps	Tools
Infrastructure readiness	Approve a single data standard (dates, currencies, accounts, counterparties, minimum set of fields); compile a register of all systems and data sources with responsible persons; set up regular automatic data transfer to a single repository with clearing duplicates and unifying formats; launch regular quality checks; organize backup and control access to storage.	A document that describes the standards; a tabular register of data sources (Excel or a simple database); ETL scripts or processing (SQL, Python, BAS, etc.); intermediate storage (SQL server or cloud database); a set of data quality control rules; backup and access policy.
Institutional architecture	Create a coordination group or AI audit center (3–5 people) and formally approve its competencies; describe the distribution of roles and responsibilities (audit, IT, finance, management); maintain a register of pilot AI audit projects with fixation of results; hold regular coordination meetings; Establish 1-2 partnerships with universities or professional associations.	Order or regulation on the AI audit center; tabular register of projects (Excel, project management system); template of minutes of coordination meetings; cooperation agreements with partners; internal portal or knowledge base of the organization.
Technology readiness and XAI	Select 2–3 simple tasks to start with (risky operations, anomalies, basic forecasts); implement simple models based on rules and threshold statistical tests and simple regressions; for each model, issue a short card (purpose, data, restrictions, owner); test on historical data and compare with manual audit; provide minimal explanatory XAI in the form of a list of risk factors and simple tables or graphs for users.	Model catalog in the form of a table; model card template for 1–2 pages; SQL, Python, BAS, or other scripts to implement rules and tests; a test environment with historical data; standard reporting forms (tables, histograms, simple panels); a documented procedure for checking the correctness and quality of models and a log of its decisions.
Staffing capacity	Draw up a competency matrix for auditors, IT professionals and analysts (data, models, XAI, ethics, etc.); conduct a quick assessment of skills through surveys or tests and highlight critical gaps; update the curricula of universities and internal courses with an emphasis on practical cases of AI audit; launch short practical trainings for current auditors; form a group of trainers and a community to share experiences.	Competency table; online or offline tests and questionnaires for skills assessment; updated work programs of academic disciplines, presentations, practical tasks; schedule of trainings and training sessions; regulations on trainers; internal chats or forums for discussion.
Regulatory framework	Adopt a short audit policy (model scopes, approval procedure, periodic review, prohibited practices, etc.); create a registry of AI models with purpose, data, owner, risk level, and status; define rules for documenting model decisions and explanations; response procedure (response to errors, complaints, the possibility of temporarily shutting down the model, etc.); schedule regular review or audit of models.	Document “Policy on the use of AI in auditing”; standardized pattern of entry in the model registry; regulations for documenting results and explanations; response instructions with a description of actions and forms of reports; checklist or program for independent audit of models; References to relevant auditing standards and data protection legislation.

Source: Developed by the author.

5.4 Research Limitations and Future Prospects

The study carried out has a number of limitations. It is based on the analysis of scientific publications, analytical reports and regulations, and does not include the verification of the proposed framework in real projects. In addition, AI regulation regulations are constantly changing, and this may require individual proposals to be updated in the medium term. Another limitation is that the focus has been on the public sector and supreme audit institutions, while private companies in developing countries may face other constraints and have different opportunities.

Given these limitations, it is advisable to direct further research to test the proposed framework in practice in several selected countries. At the same time, it is necessary to cover both the public and private sectors. It is also important to compare how the management and control of the use of AI are organized in different structures, and how these approaches are suitable for the conditions of limited resources. In addition, it is necessary to analyze how the implementation of AI audits in these structures

is influenced by global regulatory policies, and what mechanisms can be to adapt to them without undue pressure. A separate area concerns the development of a system of indicators for the effectiveness of an AI audit and the analysis of the level of trust in it by auditors. Finally, the development and implementation of local educational programs for auditors of public and private companies with further assessment of their effectiveness in practice is promising.

6. Conclusions

The study shows the complexity of integrating AI into the audit of developing countries and highlights various obstacles that arise along the way. The gap between global AI audit models and the real capabilities of countries with weak economies is manifested through systemic constraints in data infrastructure, organizational capacity, technological readiness, human resources, and regulatory environment. The presence of these limitations confirms that the implementation of AI is a complex task, and must cover different sectors and levels of government.

The proposed integrated readiness framework demonstrates that successful implementation requires not only consistency, but also simultaneous interaction and strengthening of all its components. Countries need to simultaneously unify data, build governance institutions, choose affordable technological solutions, develop human resources competencies, and develop regulatory mechanisms. In this context, the framework acts as a diagnostic and planning tool that allows organizations to identify their weaknesses and work systematically to eliminate them.

The practical content of the framework is that it allows you to build an AI audit in stages, from simple to complex, without trying to immediately reproduce Western samples. Case studies from different regions show that starting with simple models, basic tools, minimal documentation, and small coordination structures provides more sustainable results and increases the level of trust in AI solutions. This is especially important in countries where the external regulatory framework is developing faster than the local infrastructure, because these countries are forced to adapt to international standards without sufficient resources. This, in turn, requires the development of flexible adaptation mechanisms and further empirical research on how the proposed framework works in various areas of the economy.

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Retreat Tourism as a Strategy for Sustainable Development of Tourist Destinations

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ABSTRACT

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The article conceptualizes retreat tourism as a vector for the sustainable development of Ukrainian tourist territories, which becomes particularly relevant under the conditions of post-war socio-economic transformations and the escalating societal demand for psychophysiological rehabilitation. The aim of the study is to provide a theoretical and methodological justification for the institutionalization models of retreat destinations through the synthesis of natural-resource potential, environmental quality standards, socio-psychological determinants of demand, and the adaptation of European practices. The results indicate that retreat tourism functions as an innovative, low-invasive paradigm of tourism activity aimed at minimizing anthropogenic pressure on ecosystems and forming an ecologically balanced "tourist-nature" interface. It is identified that the natural and landscape heterogeneity of Ukraine creates favourable prerequisites for diversifying retreat-program formats. It is demonstrated that the determinants of demand formation for retreat services include post-war psychotraumatic effects, digital oversaturation, growing interest in mindfulness practices, and the need to restore psych emotional homeostasis. Practical models of sustainable management for retreat destinations are proposed, integrating eco-housing, renewable energy sources, localized food supply chains, multi-actor coordination among the state, businesses, and communities, as well as the formation of regional clusters based on the experiences of Italy, Portugal, Poland, and Germany. The applied validity of the study lies in the possibility of translating the proposed models into tools for activating new segments of the tourist market, stimulating local economic systems, and institutionalizing innovative formats of recreational services. Prospective vectors for further scientific inquiry focus on constructing a system of performance indicators for retreat destinations and modelling their impact on regional socio-economic development. The study also highlights the need for deeper investigation into the integration of retreat tourism into the post-war rehabilitation system and its institutional incorporation into the national tourism strategy.

KEYWORDS

retreat tourism, sustainable development, tourist destinations, nature therapy, digital detox, post-war rehabilitation.



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СОЦІАЛЬНИЙ РОЗВИТОК: економіко-правові проблеми

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Ретрит-туризм як стратегія сталого розвитку туристичних дестинацій

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СТАТТЯ

АНОТАЦІЯ

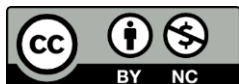
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Стаття концептуалізує ретрит-туризм як вектор сталого розвитку українських туристичних територій, що актуалізується в умовах поствоєнних соціально-економічних трансформацій та ескалації суспільного запиту на психофізіологічну реабілітацію. Метою дослідження є теоретико-методологічне обґрунтування моделей інституціоналізації ретрит-дестинацій шляхом синтезу природно-ресурсного потенціалу, екологічних стандартів якості, соціально-психологічних домінант попиту та адаптації європейських практик. Отримані результати свідчать, що ретрит-туризм функціонує як інноваційна низькоінвазивна парадигма туристичної діяльності, спрямована на мінімізацію антропогенного пресу на екосистеми та формування екологічно збалансованого інтерфейсу «турист–природа». Виявлено, що природно-ландшафтна гетерогенність території України генерує сприятливі передумови для диверсифікації форматів ретрит-програм. Доведено, що детермінантами формування попиту на ретрит-послуги є поствоєнні психотравматичні ефекти, цифрова перенасиченість, зростання зацікавленості в практиках усвідомленості та потреба у відновленні психоемоційної гомеостазу. Запропоновано практичні моделі сталого управління ретрит-дестинаціями, що інтегрують екологічне житлове господарство, відновлювані джерела енергії, локалізовані продовольчі ланцюги, багатоакторну координацію держави, бізнесу та громад, а також формування регіональних кластерів з урахуванням досвіду Італії, Португалії, Польщі та Німеччини. Прикладна валідність дослідження полягає у можливості трансляції розроблених моделей для активації нових сегментів туристичного ринку, стимулювання локальних економічних систем та інституціоналізації інноваційних форматів рекреаційного обслуговування. Перспективні вектори подальших наукових розвідок фокусуються на конструюванні системи індикаторів ефективності функціонування ретрит-дестинацій та моделюванні їхнього впливу на регіональний соціально-економічний розвиток. Актуалізується необхідність глибшого дослідження інтеграції ретрит-туризму в поствоєнну систему реабілітації та його інституційного впровадження у національну туристичну стратегію.

КЛЮЧОВІ СЛОВА

ретрит-туризм, сталий розвиток, туристичні дестинації, природотерапія, digital-detox, поствоєнна реабілітація.

1. Introduction

In the plane of deepening global environmental challenges, increasing the level of psycho-emotional exhaustion among the population, transformation of tourist preferences and structural transformations in the economy of post-war Ukraine, scientific interest in retreat tourism as an innovative and resource-efficient model of sustainable development of tourist territories is actualized. In contrast to mass tourism, which often leads to an excessive load on natural complexes, increased anthropogenic impact and destruction of ecosystems, retreat tourism is based on the principles of environmental responsibility, minimization of anthropogenic interference in natural landscapes, support of the local economy and cultivation of environmental awareness among tourists. The problem of the study is that in Ukraine, despite the presence of a significant natural and recreational resource, the sustainable development of retreat destinations is characterized by an insufficient level of structuring: there is a lack of standardized models of organizational and management activities, mechanisms for adapting international experience, certification systems for environmental standards and tools for state and regional support. This necessitates the development of applied foundations for the development of retreat tourism as a strategic vector for the development of tourism in the regions of Ukraine.

2. Literature Review

The systematization of the published work shows that in the scientific discourse, retreat tourism is conceptualized as a multifaceted phenomenon that integrates psychological rehabilitation, environmental ethics, spatial localization and strategies for ensuring the sustainability of tourist areas. A significant block of foreign studies from the authors: R. Butler [5], M. Lyulicheva et al. [11] concentrates on the study of transformational tourism, within which the retreat is interpreted as a form of travel with an enhanced therapeutic, meditative and mindfulness-oriented component, which contributes to the reduction of stressful states, increase cognitive plasticity and restoration of psychological resilience. Scientific research from A. Ashton [1], B. Guardini et al. [7], M. Puchan [14], devoted to the practices of forest therapy and ecological retreats, substantiates the significant influence of the natural environment on the functioning of the nervous system, which creates prerequisites for the development of specialized routes and therapeutic programs.

The scientific works of S. Butchak et al. [4], T. Hassan, M. I. Saleh [8] indicate that retreat tourism is constituted as a component of regional strategies for sustainable development: it provides decarbonization of tourism infrastructure, support of local economic systems, formation of alternative employment models and preservation of natural landscapes due to minimal infrastructure intervention. Ukrainian researchers S. Babushko and S. Popovych [2], I. Shamara [16] focus on the significant recreational potential of the Carpathian region, Polissia, Podillia and the Black Sea zone, emphasizing the readiness of these territories for the formation of specialized retreat destinations. The synthesis of the results obtained demonstrates that modern scientific discourse qualifies retreat tourism as a promising form of sustainable and environmentally responsible development, which requires adaptive implementation of European models in the specific conditions of Ukraine.

3. Problem Statement

The purpose of the article is to substantiate the conceptual foundations of the formation, functioning and sustainable management of retreat tourist destinations in Ukraine.

4. Methods and Materials

The methodological basis of the study was formed by an integrated interdisciplinary approach that integrates the methods of tourism economics, rational nature management, social psychology and regional spatial planning. In the process of the study, a system analysis was applied to identify the interdependencies between retreat tourism, natural resource basis and socio-economic parameters of territories; comparative analysis to evaluate international organizational models of retreat destinations

and establish prospects for their adaptation in the Ukrainian context. The method of geospatial analysis was used to identify territories with increased recreational potential, while statistical analysis served as a tool for identifying the leading trends in demand for recreational tourist services. Content analysis is used to systematize scientific publications, analytical reports, strategic documents for the development of tourism in the European Union and Ukraine.

5. Results and Discussion

Retreat tourism as an innovative form of tourism practice is gradually being transformed from a poorly developed segment of the tourism market into a strategically significant direction that will be able to provide not only deep psychological rehabilitation of the individual, but also a comprehensive ecological, social and economic effect for local territorial systems. The actualization of trends is due to the growth of global environmental risks, increased urbanization pressures and conceptual rethinking of the nature of human interaction with the natural environment, since retreat practices focused on reducing the information and emotional load are integrated into the broader paradigm of sustainable development. Retreat tourism functions as a mediation mechanism between the anthropogenic system and the natural environment, because the organizational models of retreat trips are based on a departure from mass tourism, which is characterized by intensive resource consumption, infrastructural oversaturation and significant anthropogenic pressure on ecosystems. Instead, the retreat as a format of tourist activity is based on the principles of low invasiveness, minimal infrastructural intervention, locality, autonomy and natural acoustic silence, which is problematic to provide in traditional tourist destinations.

The relationship between retreats and environmental responsibility is especially evident in the way in which space is organized, in approaches to nutrition, mobility and the choice of materials. Most retreat centers focus on the use of local resources, organic products, renewable energy sources and environmentally friendly materials, which not only reduces the ecological footprint but also creates a sustainable local economic environment in which local communities, farmers and artisans have the opportunity to earn sustainable incomes. At the same time, certain formats, such as forest-bathing, green-care, yoga retreats, or spiritual retreats, demonstrate that a retreat can be not just a type of recreation, but an ecologically ethical practice aimed at restoring the natural balance of a person and the environment in which he or she is [1].

Low rates of invasiveness of retreats, which is realized due to the limitation of the number of groups, minimization of infrastructure support, the absence of mass tourist flows and orientation to the most natural environment, constitutes a qualitatively new tourist product. It does not require large-scale capital construction, urbanization transformations or intensive traffic load, and it is under such conditions that retreat programs demonstrate a significantly higher level of environmental sustainability compared to common forms of recreation, in particular beach, health or ski tourism, which require significant material and resource costs and provoke degradation of natural complexes. Instead, the retreat is characterized by minimal environmental impact and can be integrated into local landscape systems without disturbing ecosystem relationships. Studying the natural-resource and recreational potential of Ukraine in the context of the formation of retreat tourism as an innovative component of health and spiritual tourism, we must emphasize that the territory of the country is characterized by exceptional landscape and ecosystem diversity. It creates unique prerequisites for the spatial organization of retreats of various concepts, ranging from meditation and yoga programs to forest-bathing practices, digital detox trips, and mixed formats of psycho-emotional recovery [5]. Diversity allows Ukraine to claim the place of one of the leading destinations in Central and Eastern Europe in terms of the development of nature-oriented tourism.

The Carpathians, which combine mountain landscapes, coniferous and beech forests, and a high level of biodiversity, are of leading importance for the market formation of retreat products. The presence of mineral springs and traditional healing practices, which are located at a relative distance from large industrial centers, can provide a unique recovery space, where natural silence, the absence of man-made load and high air quality create optimal conditions for mountain retreats. They can integrate yoga sessions at height, meditative walks, ethno-ritual practices, "wellness-detox" programs and "forest-retreat" formats, similar to those actively used in a number of tourist countries in Europe [8].

The Polissia region constitutes another valuable natural resource for retreat tourism, as it preserves large expanses of pine wet and dry forests, swamps, sparse ecosystems and authentic Polissia villages, which are key components for creating deep practices of “total immersion” in natural space. In these locations, it is easy to adapt the “forest-bathing” concepts (*shinrin-yoku*), which have long proven their effectiveness in Japan and Western Europe, since the natural conditions of Polissia contribute to the restoration of the nervous system, reducing stress levels, stabilizing cardiovascular functions and supporting mindfulness practices due to spatial isolation and minimal man-made impact [7].

The Podillia region, with its picturesque canyons, karst formations, river valleys and warm, mild climate, is the most promising territory for creating retreats focused on a combination of spiritual practices, soft physical activities (hiking trails, Nordic walking, yoga in nature) and gastronomic components. Because the Podillia cuisine and organic farming create the prerequisites for the formation of food detox programs and local “slow-food” tourism, a similar format has long been used in Portugal and Italy, where the natural and cultural complex becomes the basis of transformational retreats [5].

A separate group is the Black Sea coast, which, with its steppe landscapes, mild maritime climate, salt lakes, mud and opportunities for thalassotherapy, provides multifunctional opportunities for retreat programs. In the future, programs can be focused on breathing practices, meditations by the sea, wave watching, therapeutic walking along the coast, as well as digital detox programs, since sea noise and the absence of an intense urban environment contribute to reducing the level of stress and psycho-emotional stress [9, p. 228].

Table 1. Potential of Ukrainian regions for the development of retreats

Region	Key natural resources	Potential Retreat Formats	Practical value
Carpathians	Mountains, coniferous forests, mineral springs	Mountain yoga retreats; forest retreats; Spiritual practices	High level of nervous system recovery; clean air; Adventure component capability
Polissia	Pine forests, swamps, lakes	Forest-bathing; digital-detox; Mindfulness Retreats	Spatial distancing; minimal man-made noise; Conditions for deep meditation
Podillia	Canyons, river valleys, caves	Transformational retreats, slow-food, ethno-retreats	Synergy of nature and gastronomy; calm climatic conditions
Black Sea coast	Sea, steppes, salt lakes	Thalassotherapy retreats, breathing practices, meditations	Therapeutic sound of the sea; the possibility of seasonal wellness tours

Source: systematized by the author according to the data given in [13; 16].

The leading factor driving the growing demand for retreat tours is post-war psychological trauma, which covers a wide range of conditions, from chronic stress and emotional exhaustion to anxiety disorders, sleep disorders and cognitive decline. Under such conditions, high-quality retreat practices, involving acoustic silence, work with corporeality, mindfulness practices, therapeutic stay in the natural environment and psycho-emotional rehabilitation, function as a kind of “social antidote” to the collective trauma of post-war Ukrainian society. There is also an increase in the popularity of yoga, meditation, mindfulness practices and breathing techniques among young people and representatives of the IT sector and creative industries. These practices are focused on cultivating self-awareness, and the retreat appears as a logical continuation of these daily practices, providing an opportunity for in-depth immersion in the appropriate techniques. To a large extent, demand is increasing due to digital overload, which manifests itself in constant access to social networks, work chats, news, and information noise, which provokes chronic overstrain of the nervous system. This is how we remove the direction of “digital-free” tourism, when tourists seek to find a space where they can leave their smartphones, turn off information flows and return to the natural rhythm of life [10, p. 84].

The management of retreat territories within the country is conceptualized through the institutionalization of environmental standards that integrate the principles of eco-housing, renewable energy and eco-food into a single low-carbon paradigm. Such an approach transforms the material infrastructure of retreat centers into a resource-efficient system, which simultaneously functions as a mechanism of psychosensory recapitulation “man-nature”. Domestic practice demonstrates the gradual adaptation of natural construction technologies (straw panels, local wood, clay composites), autonomous water supply systems with biofiltration, as well as solar and heat pumps, which cumulatively reduce operating costs and minimize anthropogenic pressure on ecosystems [12, p. 245].

The ecological component of food policy (eco-food) replicates the model of organic farming, local food chains and seasonal menus, which generates a multiplier effect for local agricultural producers and increases the reputational capital of the destination.

Institutional sustainability is achieved through a partnership (state-business-community) that synthesizes investment, natural and regulatory resources into a common asset of tourism infrastructure. Business structures mobilize financial capital to create retreat complexes, communities transform natural and cultural capital into a comfortable environment, while the state provides institutional support through tax incentives, environmental financing, and regulatory legitimation. In the post-war context for Ukraine, the key agents of this format of interaction are amalgamated territorial communities (ATCs). They will be able to concentrate ownership of natural assets (forests, mountain locations, hydro resources), which is a prerequisite for the design of retreat programs. The geospatial diversity of Ukraine (Carpathians, Podillia, Polissia, Black Sea region) creates prerequisites for the formation of differentiated clusters specializing in “forest-bathing”, prayer retreats, “wellness centers”, “digital detoxification” and complex wellness practices that expose natural capital as the main factor of tourist advantage (Table 2) [4].

Table 2. Improved Practical Models of Sustainable Management of Retreat Destinations in Ukraine

Model direction	Extended practical content (suggestions)	Expected effect for the retreat destination
1. Eco-housing	Use of low-waste construction technologies, local materials (wood, clay, adobe), introduction of “green roofs”, natural ventilation, water biopurification systems; arrangement of modular retreat cabins that can be easily dismantled without harming the landscape	Reducing the environmental burden on natural areas; improving the energy efficiency of facilities; formation of the “eco-image” of the destination
2. Renewable energy	Use of solar panels, heat pumps, microturbines in forest and mountain locations; accumulation of excess energy for autonomous operation of the retreat complex; Integration of smart energy systems	Energy independence of retreat locations; reduction of maintenance costs; increasing resilience during possible crises
3. Eco-food & local supply chains	Forming partnerships with local farms; creation of organic kitchens “from bed to table”; transition to seasonal menus, herbal preparations and local superfoods; implementation of zero-waste practices in nutrition	Support for the local economy; increasing the level of trust of tourists; reduction of food waste; improving the image of the region as a wellness center
4. Partnership between business and communities	Joint creation of infrastructure projects (routes, water supply, eco-mobility); organization of training of guides, yoga instructors, mindfulness consultants; formation of common rules of conduct in natural territories	Increase in the quality of tourist services; formation of responsible management of territories; increasing employment of the local population
5. Partnership between the state and ATCs	Implementation of eco-standards for retreat centers, tax incentives for “green” projects; creation of state grants for regions with high recreational potential; inventory of natural areas suitable for retreats	Expansion of investment attractiveness; streamlining the use of natural resources; infrastructure development at the state level
6. Wellness & Retreat Clusters	Formation of regional clusters in the Carpathians, Podillia and Polissia; launch of joint marketing platforms; cooperation of hotels, farms, wellness centers; creation of “paths of silence”, “forest-bathing routes”, meditation eco-trails; development of specialized retreat festivals	Increasing the competitiveness of the region; increase in tourist flows; strengthening the brand of Ukraine as an ecologically oriented wellness destination

Source: Systematized by the author according to the data given in [2; 13; 15].

Thanks to a systematic approach, models of sustainable management of retreat destinations should move into the status of platforms for long-term socio-economic development of the regions of Ukraine. Because it is retreat tourism that can provide high added value, create new jobs, stimulate the development of small businesses, and also harmonize the relationship between man and nature. At the same time, the effectiveness of the above list of models is possible only under the condition of integrated planning of territories, the introduction of public monitoring of the state of natural resources, the improvement of service standards and the integration of eco-educational programs into the activities of retreat centers, in order to achieve both a social effect and ensure the sustainable development of the tourism sector in Ukraine [13].

In the direction of developing an innovative policy in the field of tourism, based on the principles of sustainable development, environmental responsibility and psycho-emotional health of the population, the study of the successful experience of retreat tourism in the Member States of the European Union is of paramount importance. The analysis will help not only to identify the diversity of organizational models of restorative practices, but also to determine the possibilities of adaptation of strategic mechanisms for their implementation to the conditions of Ukraine [6, pp. 70–71]. Given the war circumstances, the growing need for rehabilitation services and significant natural and recreational potential, Ukrainian territories demonstrate high suitability for the formation of retreat destinations based on the principles of integration, locality, network interaction and environmental balance (Fig. 1).

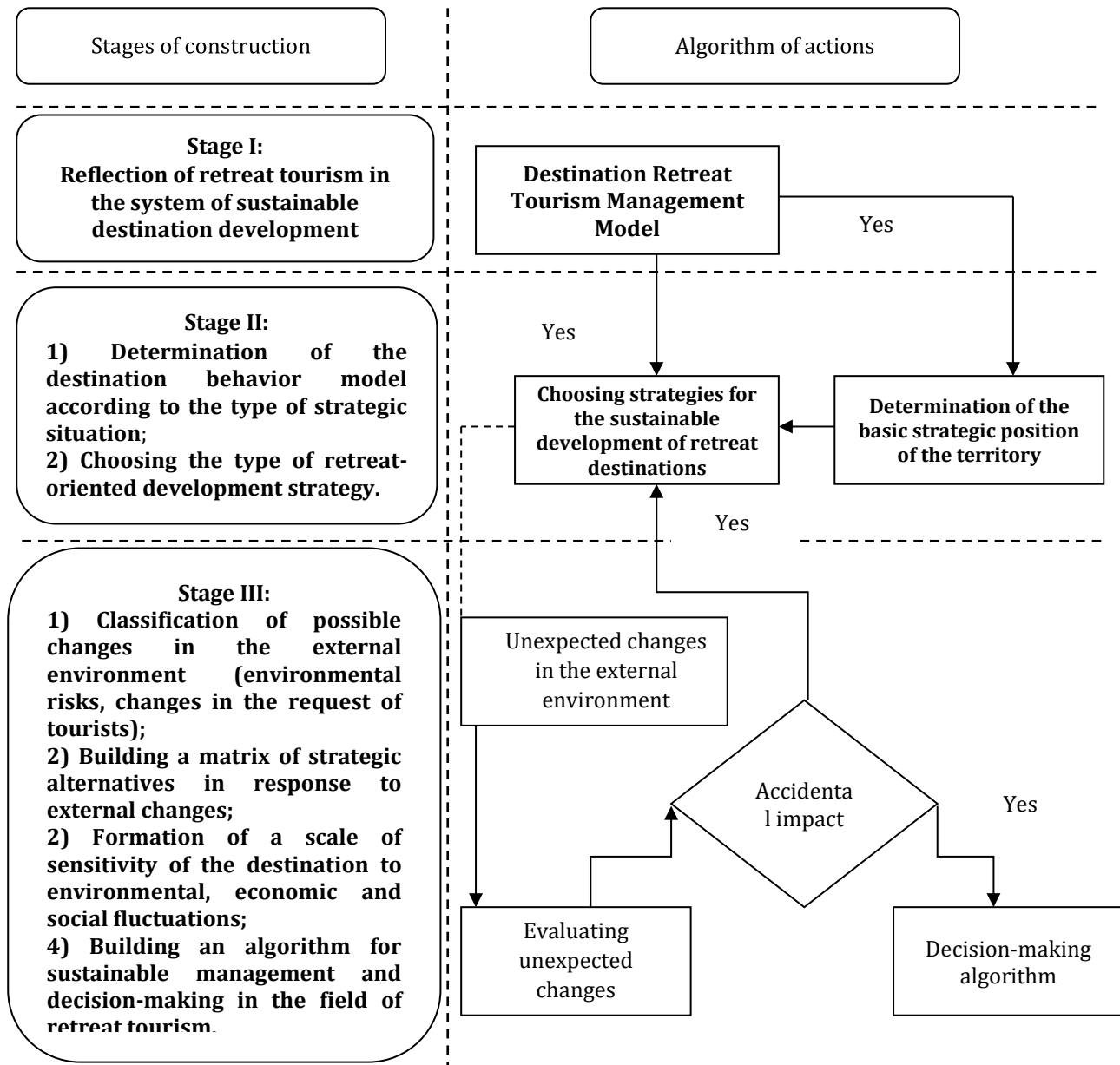


Figure 1. Level model of choosing a strategy for managing retreat tourism in the context of sustainable development of destinations

Source: Developed by the author.

The experience of European countries convincingly shows that the most effective models of retreat tourism are those that combine natural resources with therapeutic practices, local products, high-quality infrastructure and cultural authenticity of territories. Thus, the leader, Italy, which has become one of the leading centers of “forest-bathing” practices, has created a whole network of “forest thermal zones” and natural therapeutic trails, integrating the Japanese “shinrin-yoku” technique into the national ecotourism policy. Italian retreat centers combine low building density with a high level of

ecoplanning based on microlocations in the Dolomites, alpine forests or coastal natural parks. Portugal has established itself as a European leader in the development of “yoga retreats”, which are located both on the Atlantic coast and in the interior of the Alentejo. In these regions, specialized ecological retreat complexes have been created, focused on the use of local building materials, natural ventilation and organic nutrition. The Portuguese experience shows that even territories with limited economic potential are able to transform into international wellness hubs, subject to the implementation of a well-thought-out marketing strategy and effective cross-sectoral cooperation.

Poland and Germany are actively developing wellness centers based on forests, mineral springs and rural areas, integrating medical and paramedical wellness programs. These countries have a comprehensive system of certification of wellness services, which increases competitiveness and ensures a high level of trust from tourists [3]. German practices, in turn, demonstrate that the combination of “digital-free” formats, mineral waters, special trekking routes and psychological support creates an authentic, effective sustainable retreat model. All these cases are indicative for Ukraine, which has no less unique resource potential, which was presented above: forests of Polissia, mountain ranges of the Carpathians, mineral springs of the Carpathian region and ecologically clean territories of Podillia. That is why the adaptive implementation of the European experience can become the basis for the development of new forms of retreat tourism, which will be able to transform the natural regions of Ukraine into competitive international destinations [17, p. 64–65].

Within the Ukrainian tourism sector, a number of practices have already been formed that can be considered as a basis for the development of full-fledged retreat destinations, although so far, their scale is much lower compared to European countries. Firstly, the Carpathian retreat programs, which operate in the mountainous areas of Lviv, Zakarpattia and Ivano-Frankivsk regions, demonstrate the successful integration of natural resources (mountain slopes, spruce forests, mineral springs) with mindfulness programs, yoga and meditation, which brings them closer to the forest-bathing models common in Northern Italy and Austria. The Carpathian retreat locations, due to the high level of silence and low density of anthropogenic load, have all the prerequisites for positioning themselves as ecologically clean “recovery zones”. Secondly, New Level Travel programs, which create systematized tours with elements of yoga retreats, trekking and breathing practices, demonstrate the commercially successful format of Ukrainian retreat tourism [16]. Their experience really demonstrates that the demand for travel with high therapeutic and psychological content is growing rapidly, especially among young people and middle-aged people who seek to gain experience of “escaping digital noise”. Thirdly, youth adventure retreats, combining camping, light extreme, group psychological support and “outdoor-mindfulness” practices indicate the emergence of a new market segment – hybrid retreat products that combine activity, environmental education and emotional recovery (Table 3).

Table 3. Practical Models of Strategic Implementation of the European Retreat Experience in Ukraine

European model	A practical element for adaptation in Ukraine	Expected strategic effect
1. Forest-bathing retreats (Italy)	Creation of a network of “forest therapeutic trails” in the Carpathians and Polissia with certified guides in mindfulness and nature therapy	Formation of a new national tourist brand; growing demand for environmental services
2. Yoga-retreat villages (Portugal)	Development of “retreat villages” in Podillia and on the Black Sea coast with local architecture, eco-housing and organic nutrition	Revival of the economy of depressed regions; Increasing employment
3. Wellness medical complexes (Poland, Germany)	Creation of medical and health retreats based on mineral springs of the Carpathian region with programs for veterans and civilians	Integration of retreat tourism into the rehabilitation system; improving the level of public health
4. Digital-detox centers (Germany)	Introduction of digital-free zones in mountainous and forest locations of Ukraine with strict rules for disabling gadgets	Increasing the attractiveness of Ukrainian destinations among European youth
5. Wellness tourism clusters (Spain, Italy)	Formation of clusters “Carpathian Recovery Zone”, “Podillia Natural Practices”, “Polissia Forest Retreats”	Growth of Ukraine's international competitiveness in the field of wellness tourism
6. Eco infrastructure (Scandinavia)	Introduction of eco-hubs, autonomous retreat cabins, micro-hotels with RES in natural areas	Reducing the anthropogenic load, developing a sustainable economy

Source: Developed by the author.

Based on the research of the tourist potential of natural territories of Ukraine, we make a reasonable conclusion: the country is characterized by a unique landscape diversity, covering mountain, forest, steppe, marine and canyon ecosystems. These facts become the source of the development of diversified retreat tourism products adapted to different segments of tourists and aimed at solving specific psychophysiological problems.

6. Conclusions

The results of the study confirm that retreat tourism is an innovative and highly effective form of tourism activity that provides a synergistic psychological, environmental and socio-economic effect. It contributes to the formation of a new type of tourist behavior, focused on the deep restoration of the personality under the conditions of rational use of natural resources. It has been proven that the implementation of such principles as minimal interference with natural ecosystems, locality, environmental ethics and limited infrastructural expansion contributes to reducing the anthropogenic load on retreat destinations, increasing the environmental sustainability of the natural environment and simultaneously creating added value for local communities. Thus, retreat tourism is an effective tool for sustainable regional development in Ukraine.

The potential opportunities of Ukraine in the formation of differentiated retreat destinations based on the natural and ecosystem potential of the Carpathian region, Polissia, Podillia and the Black Sea zone were highlighted. It is argued that geolandscape diversity creates prerequisites for the development of multifunctional retreats, from forest therapy and digital detox to spiritual-relaxation, gastronomic and medical-health programs. It has been established that such landscape polystructurality provides Ukraine with the opportunity to position itself as a leading destination in the Central and Eastern European region, which is able to offer tourists a variety of restorative practices adapted to international environmental standards and current social needs.

It is substantiated that the sustainable development of retreat tourism in Ukraine can be implemented only under the condition of institutional coordination between government agencies, business entities and territorial communities, which provides a synergistic effect from the combination of natural resources, investment capital and regulatory support. Generalization of European experience shows that the most effective models are those that integrate environmental infrastructure, local production chains and environmental management standards. The proposed models: ecological housing, renewable energy, organic nutrition, clustering of retreat destinations form a mechanism for long-term socio-economic growth, contribute to the strengthening of the local economy and ensure the integration of retreat tourism into the post-war rehabilitation system.

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SOCIAL DEVELOPMENT: Economic and Legal Issues

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Inclusive Practices in Tourism: International Experience and Implementation Opportunities in Ukraine for Tourists with Reduced Mobility

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ABSTRACT

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The tourism sector today needs to review management approaches in order to increase inclusiveness to maximize the needs of tourists with special needs, including low-mobility population groups. Tourism infrastructure and the hospitality sector need to be upgraded to ensure the accessibility of recreational services and eliminate social barriers. The article is devoted to the formation of a comprehensive approach to the development of inclusive practices in the tourism industry in Ukraine, drawing on successful international experience. The study found that the development of ecological and inclusive tourism services involves the stimulation of "green" routes, rural tourism and ecological trails, the development of programs to support interaction between stakeholders, attracting investment, and adapting industry infrastructure to fully serve and meet the needs of clients with disabilities and special needs. The impact of digitalization on changes in the tourism business has been clarified, the need to create a barrier-free information environment has been proven by forming target hubs and platforms, developing special mobile applications and "smart" service solutions, which, in synergy, will allow for maximum personalization of services and increase their accessibility for all social groups. The development of the tourism and hospitality sector in Ukraine in the context of environmental friendliness and inclusiveness should be based on the implementation of online information platforms and mobile applications for better feedback and independent travel planning. It is also important to adapt infrastructure and transport provision to maximize the needs of the audience, which requires combining offers in the tourism industry and in the hospitality sector.

KEYWORDS

green tourism, inclusive tourism, tourists with reduced mobility, people with disabilities, accessibility, adaptation, digitalization, tourismology, tourism theory.



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СОЦІАЛЬНИЙ РОЗВИТОК: економіко-правові проблеми

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Інклюзивні практики у туризмі: міжнародний досвід і можливості впровадження в Україні для маломобільних туристів

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СТАТТЯ

АНОТАЦІЯ

Дослідниця

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Туристична сфера на сьогодні потребує перегляду підходів до управління з метою підвищення інклюзивності для максимального задоволення потреб туристів з особливими потребами, у тому числі, маломобільних груп населення. Туристична інфраструктура та сфера гостинності потребують апгрейду для забезпечення доступності рекреаційних послуг та нівелювання соціальних бар'єрів. Стаття присвячена формуванню комплексного підходу до розвитку інклюзивних практик в туристичній галузі України з залученням успішного міжнародного досвіду. У дослідженні встановлено, що розвиток екологічних та інклюзивних туристичних послуг передбачає стимулювання "зелених" маршрутів, сільського туризму та екологічних стежок, розвиток програм підтримки взаємодії між стейкхолдерами, залучення інвестицій, адаптації галузевої інфраструктури для повноцінного обслуговування та задоволення потреб клієнтів з інвалідністю та особливими потребами. З'ясовано вплив цифровізації на зміни у туристичному бізнесі, доведено необхідність створення безбар'єрного інформаційного середовища шляхом формування цільових хабів і платформ, розроблення спеціальних мобільних застосунків і "розумних" сервісних рішень, що в синергії дозволить максимально персоналізувати послуги, підвищить рівень їх доступності для усіх соціальних груп. Розвиток сфери туризму та гостинності в Україні в контексті екологічності та інклюзивності має базуватись на впровадженні інформаційних онлайн-платформ та мобільних застосунків для кращого зворотного зв'язку та самостійного планування подорожей. Важливою є також адаптація інфраструктурного і транспортного забезпечення для максимального задоволення потреб аудиторії, що потребує об'єднання пропозицій у туристичній галузі та у сфері гостинності.

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зелений туризм, інклюзивний туризм, маломобільні туристи, люди з інвалідністю, доступність, адаптація, цифровізація, туризмологія, теорія туризмознавства.

1. Introduction

The need to transform tourism and hospitality development strategies in Ukraine is due to the intensive growth in the number of people with disabilities as a result of the war and other negative social phenomena. Currently, the postulate of equal access to recreation and tourism among the public remains rather a slogan, which means that the question of state stimulation of the process and strengthening institutional support arises. The infrastructure of the industry today, for the most part, is not adapted to serve customers with special needs, which is due to the low level of industry funding and the lack of incentives for the development of the target tourist product.

Another trend in the field of tourism today is “green” tourism, as a result of the intensification of the process of implementing the principles of sustainable growth in all spheres of social life. Tourists, including young people, are actively interested in new ecological trails, rural tourism and the possibility of full integration into the wild, using the opportunities of unusual activities and visiting atypical destinations. In this regard, it is considered necessary to explore international inclusive concepts in the area under study in order to further integrate into national practice.

2. Literature Review

The problems are studied in the scientific developments of several modern scientists. X. Font et al. [5], O. Oliynyk et al. [10] found that the key obstacles to the development of initiatives in the field of tourism activities are ignoring sustainable development patterns, the lack of mechanisms to stimulate regional destinations and local natural conditions, which significantly narrows the range of inclusive tourism services. Problematic aspects, also, D. Streimikiene et al. [13] highlight low recreational potential and insufficient staffing of the industry.

I. Kravchuk et al. [8], O. Mozolev et al. [9], C. Yang, J. Hu [18] focus on the need to implement international experience in the development of inclusive tourism services and “green” tourism, which includes the design of support programs for tourism market entities and the hotel and restaurant business, practical interaction between individual stakeholders in the field of mutual support of activities, the formation of tourist demand for visiting destinations and memorable routes, the search for innovative conceptual approaches to stimulation “green”, rural and ecotourism, as well as the currently relevant inclusive direction of recreation.

At the same time, A. Elshaer and A. Marzouk [3], S. Rasoolimanesh et al. [12], C. Wang [17] emphasize that new business models of tourism and hospitality development can contribute to obtaining such results in the context of corporate and social responsibility, such as: elimination of imbalances in the development of individual regions, optimization of the investment climate for greater attraction of financial injections, improvement of the infrastructure landscape for maximum satisfaction of customers with special needs.

Extended scientific discourse in the context of the studied problems is present in the publications of K. Pletsan et al. [11], C. Azevedo et al. [1], O. Sukach et al. [14], which are dedicated to digitalization, targeting, and personalization. Scientists are actualizing the possibilities of augmented reality for greater inclusiveness of the hotel, restaurant and tourism business, the formation of sustainable commitment and trust of the audience, and ensuring compliance with the principles of sustainable development.

At the same time, a number of aspects of the studied problems remain poorly studied. The tourism business needs practical solutions in the field of innovation and inclusive practices. Gaps in existing research are, first of all, the low level of practical orientation of the proposed strategies, as well as insignificant attention to the crisis circumstances of the development of the modern tourism sector, due to the growth in the number of clients with special needs.

3. Problem Statement

The purpose of the study is a comprehensive analysis of advanced solutions to increase the inclusiveness of tourism and ensure the availability of recreational services for tourists with limited mobility in Ukraine.

4. Methods and Materials

In the course of the study, several methods were used, including:

- analysis and synthesis to study the main aspects of the phenomenon under study;
- systematization and generalization, for structuring key categories and approaches;
- structural and logical method – development of proposals for improving the organizational

mechanism for the transformation of the tourism business in the direction of inclusiveness and “green” tourism.

5. Results and Discussion

The European Agenda for Tourism 2030 [4] sets out the roadmap for sustainable, inclusive, innovative and sustainable tourism in the EU by 2030. The main objectives of the agenda are to minimize the impact on the environment and increase corporate social responsibility in the industry, ensure social inclusion, support regional destinations, and stimulate the development of the sphere in a year-round operation. The EU is developing lending, investment and grant programs to stimulate the development of sustainable tourism through a number of programs, including Horizon Europe (promoting sustainable tourism concepts), NextGenerationEU to support green tourism, etc.

The growth in the number of tourists with limited mobility in Ukraine necessitates the implementation of inclusive practices of international experience. In particular, in European countries, there are special online resources dedicated to inclusive tourism, infrastructure support and specialized services are being developed, personalized routes are being developed, etc.

An example is the portal of inclusive tourism in Catalonia (Spain), where all possible elimination of architectural and communication barriers for people with limited mobility are localized [2]. In addition, considerable attention is paid to the formation of ecological trails and green roads, and active recreation activities for all categories of the population, including people with disabilities, are being developed [6].

One of the examples of effective development of inclusive tourism is the UK. The tourism sector here involves adapting transport to the needs of people with disabilities, special excursions in museums, and even the functioning of a specialized tour operator, Tourism for all [15], specializing in planning vacations for people with disabilities, ensuring accessible domestic tourism. England's Inclusive Tourism Action Group (EITAG) has been established in England [16], which focuses on expanding inclusive tourism destinations and raising public awareness of tourism opportunities among people with disabilities.

The experience of Israel is seen as important in the context of the introduction of inclusive practices in tourism in Ukraine, where a targeted large-scale campaign Israel4All is developing its activities especially for tourists with disabilities [7]. The key mission of the platform is to provide maximum practical support for tourists with disabilities and inclusive categories of the population, adaptation of popular tourist routes, improvement of staff competencies in the field of tourism and hospitality, etc.

It is not advisable to narrow inclusive practices in the tourism sector only to the level of service innovations, because this industry is a multi-vector production complex. At the same time, it seems appropriate to classify the key types of innovations in the inclusive tourism business, which are closely related to each other (Table 1).

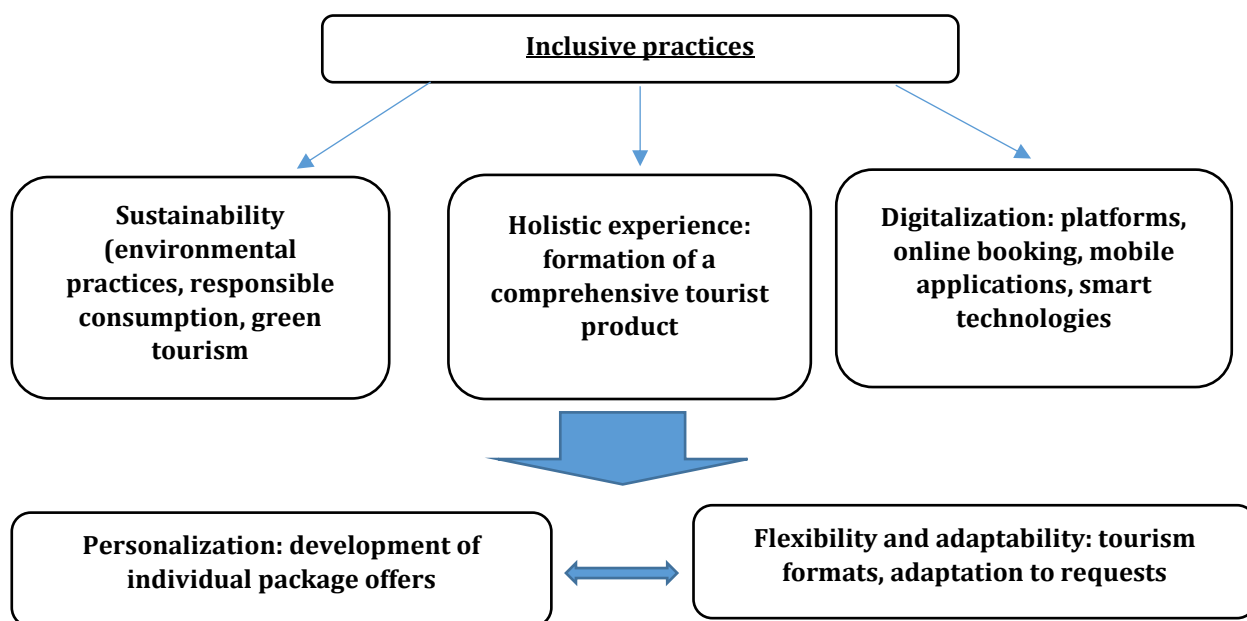
Innovative approaches to business development in developed chains include cooperation and integration of the hotel and restaurant business with other service areas, a personalized approach to meeting customer expectations and needs, and diversification of internal business segments through mobile applications and loyalty programs. “Smart” hotels with the use of voice activation tools, audiovisual equipment management, and means for a better rest are also gaining popularity and sleep (for example, the Dodow metronome). It is obvious that the variability of modern digital solutions makes it possible to improve the aspects of ensuring the inclusiveness of tourist offers, which allows people with disabilities to independently plan trips, discover new destinations, and successfully level social barriers.

Table 1. Directions of innovation in inclusive tourism

Direction of innovation	The essence of innovation	Examples of implementation
Offer	Introduction of a new or improved product, development of new tourist and recreational destinations, routes or types of tourist activities	Eco-tours to the wildlife, wellness in hospitality, gastronomic and event tourism
Resources	New natural, historical and cultural sites, infrastructure	Green tourism, event tourism, health and recreation
Technology	Introduction of new technology for the promotion and implementation of services, customer service, transport services for tourists with inclusion	Digital booking systems and ticketing systems; integrated hotel management and virtual concierges; Touch information displays
Marketing	Development of new market segments, expansion of the client audience by people with limited mobility	Advanced service: early booking, transportation ordering, food delivery and e-menu, social tour development
Management	Improvement of management and organization structures, creation of new requirements for the qualification of personnel in the context of inclusion	Implementation of integrated hotel chains, use of contract approaches to the management of hospitality establishments
Logistics	Improvements in supply chains, delivery and distribution systems; integrated destination information systems.	A concept called “Pull System”, which is an effective coordination of tourist flows based on the principles of quality and sustainable development.

Source: Compiled by the author.

Innovations of digital potential make it possible to significantly simplify the process of developing an innovative tourist product and expand the information capabilities of a client with special needs regarding the independent organization of a tour, the choice of optimal conditions for infrastructure support, and the formation of the final price of a complex of services. This line of innovation is aimed at the development of smart tourism. Taking into account the above, it is advisable to propose a basic model for the development of inclusive tourism in Ukraine, based on the principles of joint production (Fig. 1).

**Figure 1. Model of formation of inclusive practices in the tourism sector of Ukraine**

Source: compiled by the author.

The formation of complex tourism services according to the model of “joint consumption” in the inclusion sector covers a significant variability of services. An example of the practical implementation of the proposed models in Fig. 1 can be modern “green” hotels that assimilate comfort into the bosom of

nature, offering quality service, unique activities and locations, with maximum personalization of the service package.

It can be summarized that in Ukraine there are a number of problems in the development of inclusiveness of the tourism sector. Among them are weak regulatory and institutional support, low level of sectoral investment, unwillingness of society to implement inclusive practices, stagnation and lack of interest of stakeholders. It is necessary to focus on the creation of centralized platforms and hubs, the activities of which should be devoted to the adaptation of tourism infrastructure and the hospitality sector to the needs of people with limited mobility, digital improvement and the implementation of sustainable green tourism practices in national realities.

6. Conclusions

As the practice of developed European countries demonstrates, today the priorities of tourism development in the context of inclusiveness are seen in the creation and popularization of targeted online resources, the development and adaptation of infrastructure support, the development of personalized routes to meet the needs of the audience as much as possible. At the same time, it is important to pay attention to transport systems, the possibility of combining tourist offers with the field of hospitality and service establishments.

The development of the inclusive aspect of tourism activities in Ukraine, given the growth in the number of tourists with limited mobility, should be preceded by the creation of a barrier-free information environment through the formation of target hubs and platforms, the development of special mobile applications and “smart” service solutions, which, in synergy, will allow for the maximum personalization of services, increase the level of their accessibility for all social groups.

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Mechanisms of Constitutional Control in the Field of Defense and Mobilization: A Comparative Legal Analysis

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ABSTRACT

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The relevance of the study is due to the need to ensure a balanced combination of defense management efficiency and compliance with constitutional guarantees in a period of large-scale security threats. The aim of the article is to find out how national mechanisms of constitutional control can ensure the proper balance between mobilization needs and the requirements of the rule of law, as well as what foreign practices can be useful for improving the Ukrainian model. The methodological basis of the study is comparative legal analysis, formal legal method, structural-functional approach and elements of the theory of constitutional control, which allowed for a comprehensive assessment of both regulatory and practical aspects of oversight in the defense sector. The study identified the strengths and weaknesses of the national model, revealed the specifics of the interaction between political and judicial control mechanisms, analyzed the impact of executive decisions on the state of constitutional guarantees, and outlined promising areas of reform using the experience of EU countries, NATO and states with developed crisis management systems. The results obtained demonstrate the need to modernize constitutional control procedures, increase the transparency of mobilization decisions, and strengthen the institutional capacity of bodies responsible for protecting rights and freedoms in wartime. The practical significance lies in the fact that the formulated conclusions and recommendations can be used by the legislator to update defense and constitutional legislation, in particular when improving mobilization procedures and parliamentary oversight. The results have practical significance for executive bodies that carry out defense planning and implement mobilization policy decisions. The proposed approaches can serve as the basis for developing new standards of openness, accountability, and proportionality in the field of national security.

KEYWORDS

security environment, power, executive bodies, public administration, political culture.



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СОЦІАЛЬНИЙ РОЗВИТОК: економіко-правові проблеми

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Механізми конституційного контролю у сфері оборони та мобілізації: порівняльно-правовий аналіз

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СТАТТЯ

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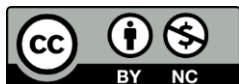
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Актуальність дослідження полягає з одного боку у необхідності досягнути збалансованого поєднання ефективності управління оборонним комплексом, а з іншого – у забезпеченні дотримання гарантованих державою прав в умовах безпекових викликів. Мета статті – з'ясувати, яким чином національні механізми конституційного контролю можуть забезпечувати належний баланс між потребами мобілізації та вимогами верховенства права. Методологічну основу дослідження становили порівняльно-правовий аналіз та формально-юридичний метод. У ході дослідження визначено сильні та слабкі сторони національної моделі. Виявлено специфіку взаємодії між політичними та судовими механізмами контролю. Проаналізовано вплив рішень виконавчої влади на стан конституційних гарантій, а також окреслено перспективні напрями реформ із використанням досвіду країн ЄС, НАТО та держав з розвиненими системами кризового управління. Отримані результати вказують на необхідність модернізації процедур конституційного контролю. Необхідно забезпечити підвищення прозорості мобілізаційних рішень і зміцнення інституційної спроможності органів, відповідальних за захист прав і свобод у воєнний час. Практична значимість дослідження полягає в тому, що сформульовані висновки можуть бути використані законодавцем для оновлення законодавства у сфері оборони та мобілізації. Зокрема у процесі вдосконалення процедур парламентського нагляду. Також результати мають прикладне значення для органів виконавчої влади, які здійснюють оборонне планування та реалізують рішення з мобілізаційної політики.

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безпекове середовище, владні повноваження, виконавчі органи, публічне управління, політична культура.

1. Introduction

The issue of constitutional control in the field of defense and mobilization has become important in the last decade. External threats, which have become a familiar element of the security environment of many states, have forced to rethinking of traditional approaches to the organization of defense institutions. Ukraine is no exception. Rapid changes in legislation under the pressure of military circumstances create situations in which compliance with constitutional principles is sometimes at risk. That is why the issue of the adequacy of control mechanisms and their ability to protect the state from mistakes looks practically significant.

At the same time, constitutional control in the field of defense has another feature. It concerns ensuring the safety of the population and guaranteeing its rights and freedoms. This creates a difficult research situation: it is necessary to simultaneously assess the effectiveness of legal remedies and not forget about the human dimension of these decisions. On the other hand, there is still a certain fragmentation of approaches in the scientific literature. Some of the authors focus on the procedural aspects of the work of constitutional courts. Others are exploring individual elements of mobilization policy. But the relationship between these two dimensions – control and defense-mobilization – remains insufficiently meaningful.

2. Literature Review

In the world discussion about emergency powers and constitutional control around them, the study of T. Ginsburg and M. Versteeg is especially noticeable [5]. The authors showed that in times of crisis, the executive branch tends to “expand” to limits that seemed incredible yesterday, but the nature and duration of such expansion significantly depend on built-in institutional safeguards. They record a key cause-and-effect relationship: where clear rules of proportionality, parliamentary oversight and judicial “stop-stops” work, the wave of emergency powers quickly descends to the constitutional “norm”.

A kind of “map of the area” for the European continent is the comparative work of A. Horváth [6]. The researcher systematizes models of the constitutional regime of states of emergency in European countries and highlights the tendency towards institutional hybridization: formally rigid procedures are often combined with flexible political practices. An important result is the identification of “zones of uncertainty”, where the constitutional text does not answer key issues of proportionality, and therefore, decisions are actually transferred to post-crisis judicial review.

In the supranational dimension of the EU, C. Cinnirella offers a significant fulcrum [2]. The author shows that the real architecture of emergency powers in the European Union is built not so much by the text of the founding treaties as by their interpretation in times of crisis and the interaction of institutions. The conclusion is disappointing for supporters of “hard” law: the lack of a clear, unified model entails the risk of fragmented application of restrictions on rights and provokes competition between jurisdictions. Therefore, for the Member States (and for Ukraine as a potential member), not only the national, but also the integration dimension of constitutional control is important.

From the Ukrainian perspective, the study of K. Trykhlil [19] is directly important. The author notes that in wartime, the tension between the “speed” of state decisions and the “quality” of constitutional guarantees increases exponentially, and the practical balance is often achieved not by the norm, but by the practice of post-facto judicial review. The key conclusion is the need for procedural tools capable of providing control in a near-real-time dimension.

V. Kovalchuk also works on a similar topic [7], but with an emphasis on the value framework of Ukrainian constitutionalism during the war. The author shows that the protection of statehood and the protection of rights are not mutually exclusive goals: in the context of institutional reform, they are mutually reinforcing. The result obtained is a conceptual model of “double loyalty” of law: to security and to human dignity. This optics allows you to evaluate mobilization decisions in a new way: not only in form, but also in terms of their ability to maintain the trust of citizens.

Outside the European borders, a valuable comparative corpus is formed by C. M. Fombad and L. A. Abdulrauf [4]. Based on the material of African countries, the author demonstrates that the formal presence of emergency regimes without clearly defined “safety valves” naturally leads to a drift towards

executive dominance. A fundamental conclusion: the effectiveness of control is ensured not by declarations, but by procedural trifles – term limits, independent review mechanisms, requirements for justification of restrictions on rights.

A broader political picture of the consequences of emergency regimes is given by A. Lührmann and B. Rooney [14]. Researchers establish a stable correlation between frequent or prolonged states of emergency and a decline in the quality of democracy, with the key channel of this influence being “decree governance”. The conclusion is rigid: without institutional counterweights, emergency powers tend to “freeze” and turn into a norm of governance.

The internal Ukrainian dimension of constitutional security is addressed by O. M. Svitlyk [17]. At the center of its analysis is the real ability of the Constitutional Court to play the role of an institutional “watchdog” in times of crisis. The main conclusion is functional asymmetry: the Court is strong in retrospective control, but weak in quick response, which creates the risk of approving practices that are only later recognized as unconstitutional.

Finally, two works – J. Bellenghi [1] and K. Kreuder-Sonnen [8] clarify the fundamental definitions. The first proves that “extraordinariness” in European law is marked by the instability of the definition: from vague criteria at the entrance to unpredictable consequences at the exit. The second raises a provocative question: does Europe need a “constitution of emergency”, and the answer is actually “yes, but with clear limits” to avoid the normalization of the exception. Together, these findings send another signal to Ukraine: without conceptual clarity on the thresholds and limits of emergency solutions, institutional practice will inevitably fluctuate.

3. Problem Statement

The purpose of the article is to identify and substantiate how the mechanisms of constitutional control can ensure a balance between the needs of defense management and the observance of citizens’ rights.

4. Methods and Materials

The research methodology was based on a combination of several complementary approaches. The comparative legal analysis was the leading one, which made it possible to compare Ukrainian control mechanisms with the models of different states and identify those institutional decisions that may be relevant for reforming the national system. An auxiliary, but important role was played by the formal-legal method, which ensured the exact reproduction of the content of legal norms and made it possible to outline the logic of their internal coordination or conflict.

5. Results and Discussion

The understanding of constitutional control in the defense sector is heterogeneous. It largely depends on the historical experience of the state, political culture and the dominant model of public administration. That is why a modern researcher, considering this phenomenon, inevitably plunges into the interdisciplinary space. In it, constitutional law, the theory of the state, military law and even political philosophy interact. In this diversity, it is important to single out the basic conceptual approaches that form a general picture of what constitutional control in the field of defense is – and can be – (Table 1).

The first of these approaches can be conditionally called the model of the supremacy of the constitution. It is based on the idea of a rigid normative hierarchy, when any decisions related to mobilization, defense organization or the use of military force are thoroughly checked for compliance with the basic law. This approach originates in the continental legal tradition, primarily in Kelsen’s vision of constitutional justice as a “pure” legal function [5]. Constitutional courts working within such a paradigm stand guard over the normative logic: it is important for them whether the procedure is followed, whether the powers have not been exceeded, and whether the restriction of rights fits into the constitutionally permissible framework. They almost do not take into account the political motives of decisions, since they believe that control should be primarily legal. Such formalism is sometimes

criticized, but it provides clarity and predictability in law enforcement, which is extremely important in situations of military danger.

Table 1. Comparative characteristics of conceptual approaches to constitutional control in the defense sector

Conceptual approach	Brief description	Key accents of control	Typical legal traditions / examples of states
Model of the supremacy of the constitution	It is based on a rigid normative hierarchy, where every defense or mobilization decision must comply with the letter of the Constitution	Formal verification of the procedure; strict adherence to competencies; minimizing political discretion	Continental Europe: Austria, Germany (partially), Czech Republic
Rights-oriented approach	Grew up as a reaction to the risks of state arbitrariness and restriction of rights under the guise of "security"	Proportionality analysis; priority of dignity and fundamental freedoms; Assessment of the excessiveness of restrictions during mobilization	Germany, Italy, Spain, post-war European democracies
Security Priority Doctrine	He prefers the efficiency of government actions in emergency conditions, sometimes with a decrease in "instantaneous" judicial control	Broad discretion of the executive branch; judicial control of a deferred nature; Flexibility of solutions	USA, Israel, France of the Fifth Republic period
Institutional balance approach (checks and balances)	Control is carried out not only by the courts, but also by the parliament, committees, and public institutions	Mutual supervision of different authorities; parliamentary and public control; less formalization of judicial intervention	Great Britain, Canada, Australia, USA (in terms of parliamentary oversight)
The Approach of Constitutional Moderation in Crisis States	Emphasizes the temporality and proportionality of emergency powers; emphasizes that the Constitution "does not remain silent" in times of crisis	Control over emergency regimes; prevention of the transformation of temporary solutions into permanent ones; parliamentary oversight	Latin America (Chile, Colombia), selected European countries

Source: Compiled by the author based on [5; 14; 19].

Another approach – focused on the protection of fundamental rights – grew out of the deep historical traumas of the twentieth century. After World War II, European constitutionalists realized that the threat to freedoms could come not only from an external enemy but also from their own state, which, under the guise of military necessity, was capable of violating basic standards of human dignity. Hence, the dominance of right-human-centered logic in the activities of the constitutional courts of Germany, Italy, and Spain [2, p. 636]. Within this approach, any military or mobilization decision must be not only "legal" but also "proportionate". Judges focus on whether the restriction of rights is becoming excessive, whether groups in need of special protection are being infringed, and whether there are less invasive alternatives.

Next to it, there is an approach based on the concept of institutional balance. It grew up primarily in common law countries and assumes that constitutional control is not only a court, but a complex system of checks and balances. Parliamentary committees, security commissioners, ombudsmen, special supervisory structures – all of them together form a network that keeps the defense sector within constitutional boundaries [19, p. 249]. In such systems, courts intervene less often, but their decisions carry significant weight because they usually relate to the most fundamental issues. The logic of this approach is that a wide range of control institutions provides different points of view and minimizes the risk of excessive concentration of power in one hand.

Despite the diversity of models, one fundamental idea is common: defense is not an "extra-constitutional" sphere. Even in the most difficult times, it must remain within the scope of the supreme law. The constitutions of different states have developed their own ways of ensuring this principle, and

it is their evolution that is important to take into account when analyzing modern mechanisms of constitutional control [7]. After all, without an understanding of history, it is difficult to explain why states today respond so differently to the same challenges – large-scale mobilization, the widespread use of emergency powers, or the expansion of the discretion of the military command.

The national model of constitutional control in Ukraine in the field of defense and mobilization was formed under the influence of difficult historical circumstances, and in the last decade, under the pressure of real military threats. Therefore, it has a character that can hardly be called established: rather, it is a flexible, often reactive system that adapts to the conditions of the security crisis. At the same time, its architecture is not chaotic [4]. On the contrary, it consists of a whole set of institutional mechanisms, each of which performs its share of control functions. The Ukrainian model combines the features of classical judicial constitutional supervision with elements of political control, as well as with a wide range of distributed, “local” forms of protection of rights that arise in the process of mobilization. It is this layering that creates both its strengths and problematic sides.

First of all, it is worth outlining the main elements of the system. The Constitutional Court of Ukraine, which checks laws and individual acts of the supreme authorities, is traditionally placed at the top of control. The Verkhovna Rada of Ukraine operates nearby, which approves decrees on martial law and mobilization, as well as resolves the issue of the defense budget and supervises the activities of the executive branch through relevant committees. The President of Ukraine plays a significant role, because it is he who makes decisions that actually launch mobilization mechanisms and shape defense policy. The functional center for the implementation of these decisions is concentrated in the Cabinet of Ministers, the Ministry of Defense and the General Staff, and at the level of individual citizens, in the work of territorial recruitment and social support centers (TR and SSC), which make practical mobilization decisions. The courts of general jurisdiction, which consider thousands of individual disputes in this area, as well as the Verkhovna Rada Commissioner for Human Rights, who acts as an institutional “watchman” for compliance with humanitarian and social standards, cannot be ignored.

The constitutional principles of mobilization and defense decisions are outlined quite clearly [3]. The Basic Law defines the competence of the President to manage the security and defense sector, the parliament to legitimize and control such decisions, and the government to implement defense policy. At the same time, the Constitution contains a number of significant restrictions: a ban on changing it under martial law, the definition of rights that cannot be restricted, and a strict procedure for introducing and approving special legal regimes. That is, formally, the Ukrainian model provides for a rather strict system of checks and balances. It makes it possible to coordinate the efficiency of decisions with the requirements of constitutional stability – at least at the regulatory level.

Let's start with the Constitutional Court [12]. Its mission in this area is fundamental, but at the same time not easy. The court may declare unconstitutional laws or decrees regulating mobilization, the procedure for military service or the application of emergency restrictions. However, this mechanism has an obvious limitation: it is slow. Decisions are made for months, and often years. In a situation where defense management requires quick decisions, such temporality can neutralize the effectiveness of control. Therefore, the Constitutional Court actually plays the role of retrospective supervision, which corrects legal errors “after the fact”, and does not prevent them at the time of their occurrence.

Another plane of control is provided by the parliament. The Verkhovna Rada formally has enough leverage of influence: it approves presidential decrees, controls the activities of the government, adopts legal acts on defense policy, and can create temporary investigative commissions. In peacetime, this system works as an effective balance between the executive and legislative branches [10]. In wartime, the situation changes. Parliamentary procedures are reduced, discussions are decreasing, and control often becomes more declarative. This is not evidence of negligence; Rather, it is a forced reaction to circumstances.

An additional dimension of control is provided by the Verkhovna Rada Commissioner for Human Rights. The Ombudsman can respond to systemic violations, monitor the activities of TRs and SSCs, and appeal to the authorities with a demand to eliminate shortcomings [11]. The significance of this institution is especially noticeable in aspects that go beyond formal law – in humanitarian, social and ethical issues of mobilization practice [14, p. 628].

All these mechanisms form a fairly complex system in which it is possible to identify strengths (Table 2). First, the constitutional architecture of Ukraine provides for a clear delimitation of powers,

which reduces the risk of institutional conflicts in the field of defense. Secondly, the parliament remains an important balance-forming element: it does not lose control even in wartime.

Table 2. Strengths and weaknesses of the national model of constitutional control in the field of mobilization and defense management

Category	Contents
Strengths	
1. Clear constitutional separation of powers	The Constitution of Ukraine quite accurately defines the competence of the President, the Parliament and the Government in matters of defense and mobilization, which reduces the risk of institutional conflicts
2. Parliamentary scrutiny of key defense decisions	The Verkhovna Rada approves decrees on mobilization and martial law, as well as exercises supervision through relevant committees, which ensures political restraint of the executive branch
3. Developed system of individual judicial protection	Administrative courts consider a large number of disputes regarding mobilization, which actually forms an effective tool for protecting the rights of persons liable for military service
4. Availability of humanitarian and human rights control mechanisms	The Ombudsman's institution and public monitoring initiatives complement judicial and political oversight, focusing on the social and humanitarian aspects of mobilization policies
Weaknesses	
1. Slowness and limited efficiency of the Constitutional Court	The Constitutional Court of Ukraine has been making decisions for a long time, which does not allow for an effective response to legal problems during the war. Control is mostly retrospective in nature
2. Excessive concentration of powers in the executive branch during the war	Presidential decrees and decisions of the National Security and Defense Council, implemented by the government, are adopted quickly, sometimes without proper parliamentary discussion, which increases the risks of power imbalance
3. Insufficient control over the activities of TR and SSC	In practice, these bodies make the most sensitive decisions on mobilization, but they are not directly covered by the system of constitutional oversight, and their activities are often non-transparent
4. Formalized nature of parliamentary control in wartime	The need for quick decisions reduces the depth and content of parliamentary discussions, which actually narrows the possibilities of real political control
5. Limited openness of defense procedures	A significant number of acts have a restricted access stamp, which complicates public control, and sometimes the activities of courts in cases related to mobilization
6. Indirect controllability of NSDC decisions	Decisions of the National Security and Defense Council are enacted by decrees of the President and cannot be the subject of direct constitutional verification, which creates a "gray zone" in the sphere of control

Source: Compiled by the author based on [9; 10; 11; 13].

However, along with these advantages, there are also problematic elements. They not only describe the weaknesses of the system, but also explain why certain decisions in the field of defense become conflictual.

First of all, it should be recognized that the Constitutional Court of Ukraine does not perform the functions of operational supervision. Its decisions cannot affect the course of mobilization measures in real time. This means that even in the presence of serious constitutional doubts, certain acts can be valid for a long time, creating legal uncertainty.

The second problem concerns TR and SSC. It is these bodies that make decisions that directly affect people's lives, but the mechanisms of control over their activities are fragmentary [15, p. 114]. The work of the TR and SSC is not subject to direct constitutional supervision, and administrative courts often face a lack of information or a vague regulatory framework. Added to this is another weakness – the limited openness of defense procedures. A large part of the acts has limited access, which complicates both public control and scientific analysis in this area. The transparency of decisions decreases, which is natural in times of war, but at the same time creates a noticeable deficit of trust between citizens and the state.

All this determines the relevance of an in-depth analysis and further improvement of the system, in particular by strengthening parliamentary oversight, increasing the transparency of defense

procedures and modernizing the powers of the Constitutional Court [18, p. 3]. The strategic direction of modernization is to increase the efficiency and effectiveness of constitutional control. The experience of democratic states shows that control over acts adopted under states of emergency or martial law requires a special procedural regime. For example, Germany and Spain use “priority consideration” – a mechanism that allows constitutional courts to consider urgent cases out of turn [16, p. 41]. In Ukraine, there is no such tool: decisions of the Constitutional Court are made slowly, as a result of which control becomes purely retrospective. The introduction of an accelerated procedure for consideration of acts related to mobilization, legal regimes and restriction of rights could significantly strengthen the preventive potential of constitutional control.

6. Conclusions

The study of the mechanisms of constitutional control in the field of defense and mobilization showed that this area of legal regulation is one of the most sensitive. Ukraine actually functions in conditions of constant testing of the endurance of its constitutional institutions. That is why the interaction between the needs of defense and the requirements of the constitutional order acquires not only theoretical, but also strategic importance.

The analysis showed that the national model of constitutional supervision is mixed. It relies on judicial and political control mechanisms, complemented by individual judicial protection and human rights institutions. Such a multi-level nature is its strength, as it provides different channels for responding to potential violations. At the same time, this same feature also reveals the weaknesses of the system – first of all, the slowness of constitutional jurisdiction, excessive concentration of powers in the executive branch, insufficiently structured control over the activities of TR and SSC, as well as limited transparency of defense decisions. These problems are not accidental. They reflect the deep tension between the need of the state to act quickly and the duty to act within the framework of the Constitution.

Comparative legal analysis allowed us to notice that democratic institutions in other countries also face similar challenges, but have developed different formulas for overcoming them. Some states apply models of accelerated constitutional control, others strengthen parliamentary oversight, and still others create special institutions to assess the proportionality of restrictions on rights. This experience proves that an effective defense system does not contradict an effective system of constitutional control. On the contrary, they mutually reinforce each other if they are built harmoniously.

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