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ASSESSMENT OF THE IMPACT OF INNOVATION AND INVESTMENT ACTIVITIES ON THE RESTORATION OF ECONOMIC POTENTIAL OF UKRAINIAN ENTERPRISES IN THE CONTEXT OF INDUSTRY 5.0 AND THE CIRCULAR ECONOMY

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Abstract

The purpose of this article is to assess the extent to which the activation of innovation and investment activities contributes to the restoration of the economic potential of enterprises in Ukraine under the conditions of transition to Industry 5.0 standards and the implementation of circular economy principles. The focus is placed on Ukrainian enterprises as the object of the study, considering sectoral differences and the specific challenges caused by the ongoing war. The task is to present a methodological approach that will allow us to present how to assess the significance of the influence of certain areas in the activation of innovative and investment activities of an enterprise on the restoration of economic potential. The principles of Industry 5.0 and the circular economy are also taken into account. As a result, the method of pairwise comparison was chosen and, by involving experts, to determine the most significant factors of the activation of innovative and investment activities of an enterprise that affect the restoration of economic potential, taking into account the standards of Industry 5.0 and the circular economy. The results may have practical significance in further use within the activities of enterprises of Ukraine and beyond. This article examines the impact of activating innovation and investment activities on the restoration of economic potential of Ukrainian enterprises amid the transition to Industry 5.0 and the adoption of circular economy principles.

JEL classification: O32, O33, O35

Keywords: Innovation and Investment Activity, Industry 5.0, Circular Economy, Economic Potential, Pairwise Comparison

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Introduction

The importance of innovation and investment activities for an enterprise

COVID-19, the consequences of which are still being felt, and military actions have significantly changed the financial and economic activities of Ukrainian enterprises, exacerbating the issue of resource provision, in particular that of finance. Loss-making, slowing down of economic processes in the national economy, limitations in foreign economic activity, etc. have reduced the innovative and investment activity of enterprises, and therefore formed the grounds for their termination of activities, which, taking into account the scale, provokes a deterioration of the security situation at both the micro and macro levels. The current practice of ensuring the economic security of an enterprise does not provide for due attention to issues of innovative and investment security, and is also focused on authoritarian management with strict adherence to the response regime to typical risks and threats, which, in conditions of high dynamism of changing operating conditions and shifts in the priority of the influence of individual factors, does not provide the necessary level of effectiveness of security activities. The current situation makes it urgent to fulfill the task not only of forming theoretical and methodological principles for ensuring innovation and investment security in the conditions of each enterprise, but also of focusing attention on the development and implementation of innovative approaches that would ensure changes in the activity of security entities in order to reduce innovation and investment risks, counteract threats, and determine and create a security basis for using new opportunities in interaction with objects and entities of the innovation and investment process.

The last thirty years have been marked by a gradual awareness by business representatives of the need to pay maximum attention to the issue of ensuring security. To replace the highly specialized units exclusively on issues of physical protection, services were created, where the main focus began on the issues of countering threats and creating conditions for achieving interests in the economic sphere. Despite significant progress and theoretical justification of the need to detail the conditions of Industry 5.0 by the main functional components, practical implementation has slowed down, in particular due to the lack of necessary developments in understanding the technology of isolating factors that cause changes in the safety of the enterprise, with an appropriate mechanism for developing and implementing protective measures not after the occurrence of losses and damages, but in anticipation. The use of preventive management requires focusing on the issues of each individual functional component, which requires the primary formation of an appropriate theoretical basis. Ensuring innovation and investment security is actualized, but in the theoretical sense, in addition to a general idea of its content, there is no necessary methodological basis.

In recent years, Ukrainian enterprises have faced unprecedented challenges due to the full-scale war and prolonged economic turbulence, which significantly weakened their innovation and investment capacities. The downward trend in innovation activity, as recorded by national statistics, reflects the limited availability of financial resources, destruction of infrastructure, and increased uncertainty across most sectors. Under such conditions, enterprises are forced to shift their strategic focus from development to survival, limiting investments in new technologies or long-term transformation. Nevertheless, the global transition towards Industry 5.0 and circular economy models highlights the need to rethink innovation frameworks, even in crisis conditions. Despite the difficult context, innovation and investment activities remain essential for the long-term recovery and competitiveness of enterprises. These activities create the foundation for restoring economic potential by improving technological resilience, optimizing resource use, and enabling adaptation to evolving environmental and market demands. While Industry 5.0 and the circular economy are often associated with stable, high-tech environments, their core principles - human-centeredness, sustainability, and system integration - can guide Ukrainian enterprises in rebuilding capacity, diversifying risks, and interacting more effectively with key stakeholders such as customers, suppliers, and public institutions. However, the implementation of these models in Ukraine requires a contextualized approach that accounts for war-related disruptions and sector-specific limitations.

The importance and role of the circular economy and industry 5.0

In the current conditions of economic instability, depletion of natural resources, environmental pollution, overproduction, excessive consumption and other global challenges, innovation and investment activities require rethinking and require the development of flexible reactive solutions, reorientation of the strategy not only to the development of the enterprise itself, but also to take into account the needs of stakeholders and the environment. A balanced and well-founded construction of a strategic management system plays a decisive role in the context of the emergence of sustainable development as a national priority for individual enterprises and industries, and the economy as a whole. Since innovation and investment activities are the formative key to the success of any organization operating in unpredictable and risky environmental conditions, it is advisable to introduce the circular economy and Industry 5.0 into the corporate strategy

of enterprises. The concept of the circular economy and Industry 5.0 embodies the idea of introducing a cycle (circulation) of resources to ensure sustainable economic growth. Its main essence is that resources are repeatedly returned for use in subsequent production cycles, which contributes to the preservation and more rational use of the natural resource, production, financial and human potential of the enterprise. Strategic management is a key factor in achieving success in implementing the principles of the circular economy and Industry 5.0 at enterprises, since this concept requires an integrated approach to managing various aspects of activity, including the development and implementation of new products and services, the introduction of new technologies and processes, as well as minimizing risks. In particular, innovative and investment activities allow enterprises to identify opportunities for the recovery and use of resources, develop new strategies that reduce the level of waste generation and increase the efficiency of resource use, and ensure effective interaction with stakeholders, including consumers, suppliers and government agencies.

The structure of the article

The structure of the article involves a review of the literature, presentation of key research methods, main results and their discussion, and coverage

Table 1: The results of the literature review

Reference	Impact for our topic
Melnyk et al. (2020)	Emphasizes the importance of robust HR strategies to sustain competitiveness, which can be adapted to human-centric Industry 5.0 principles and ensure economic security
Sylkin et al. (2021) and Sylkin et al. (2018)	Provides a framework for monitoring financial security, relevant for Industry 5.0 where proactive measures and real-time data are crucial for safeguarding enterprise stability
Javaid & Haleem (2020)	Highlights the synergy between human workers and smart automation, reaffirming the need for skill development and flexible organizational structures for economic security
Kopytko et al. (2024)	Demonstrates the role of government-backed financial mechanisms in supporting sustainable development - a crucial aspect of Industry 5.0 and economic security in critical sectors
Marchenko et al. (2023)	Reinforces that sustainability is an integral part of Industry 5.0, ensuring a secure, future-proof environment for enterprises seeking long-term viability
Al Azzam et al. (2022)	Indicates the need for robust legal and regulatory frameworks that integrate health, environment, and economic security - pertinent for sustainable Industry 5.0 transitions
Paschek et al. (2019)	Suggests businesses prepare for a next wave of transformation, merging advanced automation with a human-centered approach, enhancing economic and social security
Blikhar et al. (2022)	Confirms the critical need for integrating legal compliance and strategic management to sustain economic security under Industry 5.0-driven innovation

Source: Authors' own work.

Literature review

While some studies (e.g., Melnyk et al., 2020; Sylkin et al., 2018, 2021) examine crisis management and economic security, and others (e.g., Javaid & Haleem, 2020; Marchenko et al., 2023) focus on Industry 5.0, there is a limited body of work that combines these perspectives into a unified framework. A more holistic approach would investigate how anti-crisis strategies and financial security models can be synchronized with human-centric and advanced technological shifts characteristic of Industry 5.0. The current body of literature often concentrates on specific industries (engineering, manufacturing) or particular regions (e.g., EU-centric studies). Broader comparative analyses - covering more diverse socioeconomic contexts and multiple industrial sectors - are lacking. An expanded scope could illuminate how Industry 5.0 transformation strategies differ across regions or how crisis factors (pandemic, geopolitical tensions, etc.) shape enterprise responses in varied cultural and regulatory environments.

Overall, addressing these gaps would strengthen the theoretical and practical frameworks guiding enterprises and policymakers as they navigate the simultaneous demands of crisis resilience, economic security, and the transition toward Industry 5.0.

Methodology

In the context of the transition to Industry 5.0, the issue of reorienting enterprises to innovative and in-

vestment development with the most efficient use of resources and the formation of a circular model of economic processes is acute. One of the effective ways to determine the priority of factors that influence the activation of innovative and investment activities in order to restore the economic potential of the enterprise is the pairwise comparison method, which is most often implemented within the framework of the analysis of hierarchies.

The methodology is designed to determine the weight and priority of factors that activate the innovative and investment activities of the enterprise in the context of the transition to Industry 5.0 standards and compliance with the principles of the circular economy in view of their impact on the restoration of the economic potential of enterprises in Ukraine.

The essence of the selected methods

The Pairwise Comparison method allows you to establish the relative advantage of one factor over another according to a certain criterion (in our case, the impact on the restoration of economic potential).

The Analytical Hierarchy Process (AHP) method allows you to structure the problem into several levels, starting with the goal, criteria (if any), factors/indicators and alternatives (if necessary). After that, the factors are compared with each other in pairs on a scale of importance intensity. Building the hierarchy:

- At the top level: the purpose of the study (determining the impact on the restoration of economic potential under the conditions of Industry 5.0 and the circular economy).
- Middle level: the main factors influencing innovation and investment activity.
- Lower level: if necessary, there may be sub-factors, but within the framework of this study we will focus on the set of main factors.

The study proceeded by constructing an expert questionnaire in which specialists compared factors in pairs, after which we compiled pairwise comparison matrices for each group of factors using the nine point classical Saati scale where 1 indicates equal importance, 3 indicates moderate importance, 5 indicates significant importance, 7 indicates very strong importance, and 9 indicates absolute importance. For each matrix we calculated local weights, also referred to as the priority vector, through the principal right eigenvector method, and we then verified the consistency of expert judgments by computing the consistency index and the consistency ratio. In the presence of several hierarchy levels we summarized priorities by multiplying local weights across the relevant levels, which yielded the final weights and supported the formulation of conclusions. To minimize subjectivity in expert evaluation during the pairwise comparison process, several methodological safeguards were implemented. First, the selection of experts was based on predefined criteria, including relevant academic background and practical experience in innovation management, financial strategy, and industrial transformation aligned with Industry 5.0 and the circular economy. Second, the classical Saaty scale was used with standardized explanations to reduce interpretative ambiguity. Third, consistency of expert judgments was verified through the calculation of the consistency index (CI) and consistency ratio (CR), with the threshold $CR \leq 0.1$ strictly applied to ensure logical coherence in responses.

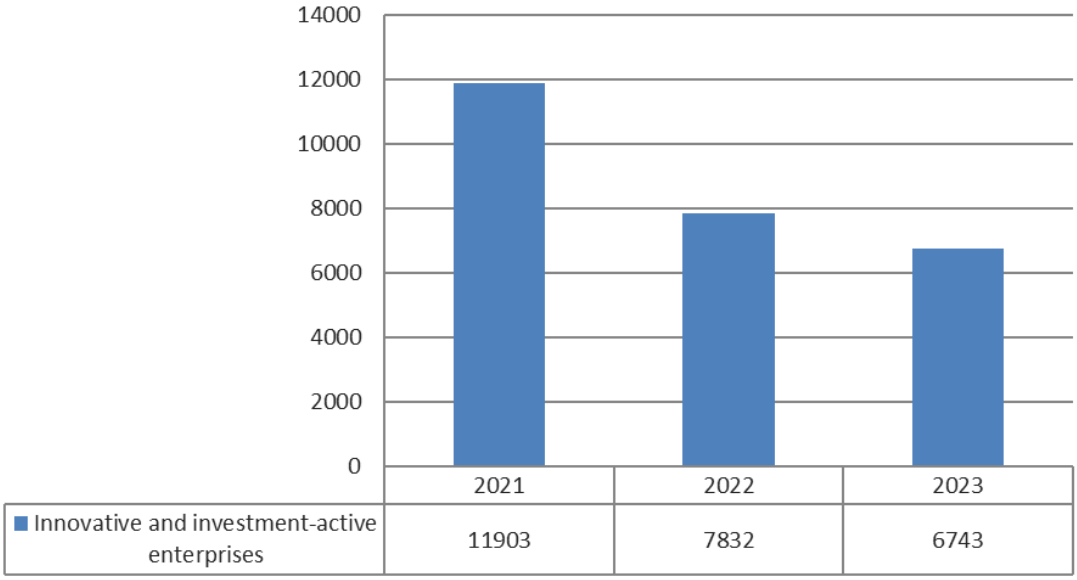
Experts performed pairwise comparisons of these factors using the full classical Saaty scale, ranging from 1 (equal importance) to 9 (absolute importance), including intermediate values (2, 4, 6, 8) to refine their assessments. Individual comparison matrices were aggregated using the geometric mean, followed by normalization and calculation of local weights (priority vectors) via the eigenvector method. To verify the internal consistency of judgments, the consistency index (CI) and consistency ratio (CR) were computed, with CR values below 0.1 confirming acceptable reliability.

Results

Current status of innovation and investment activities of Ukrainian enterprises

The decrease in innovative and investment activity of Ukrainian enterprises in recent years significantly limits the country's economic potential. Innovation is a key factor in increasing the productivity and competitiveness of enterprises in domestic and foreign markets. The lack of sufficient investment in research and development work leads to a slowdown in technological development, which, in turn, limits the opportunities for creating new products and services. This can lead to a decrease in the market share of Ukrainian companies, loss of leadership in certain industries and a decrease in overall economic activity. In addition, a decrease in innovative and investment activity negatively affects the attraction of foreign investments and partnerships, which is an important source of financial resources and technological knowledge. The lack of investment limits the possibilities of modernizing production, improving product quality and optimizing costs, which reduces the attractiveness of Ukraine as a business destination. This could lead to capital flight, job losses, and a general slowdown in economic growth. In the long term, the country risks losing its competitiveness on the global stage, which would negatively affect the standard of living of the population and the stability of the economy (Figure 2).

Figure 1: Dynamics of changes in the number of innovative and investment-active enterprises in Ukraine in 2021-2023



Source: State Statistics Service of Ukraine (2023) https://www.ukrstat.gov.ua/ (Accessed: 30.12.2024).

Based on the analysis of scientific sources and expert surveys, the following key factors have been identified (we will denote them F_1, F_2, F_3, F_4, F_5) that affect the restoration of the economic potential of the enterprise when activating innovation and investment activities in accordance with the requirements of Industry 5.0 and the principles of the circular economy:

F_1: Digitalization of production processes (implementation of the latest information systems, artificial intelligence, Big Data, etc.).

F_2: Application of resource-efficient and circular technologies (waste minimization, material reuse, Green -Tech).

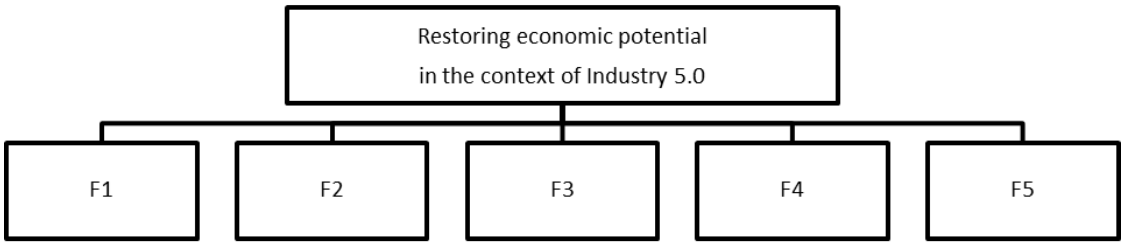
F_3: Flexibility of the organizational structure and management (adaptive business models, rapid response to changing market conditions).

F_4: Level of human resources potential (personnel development, STEM education, professional development in the areas of Industry 5.0).

F_5: Innovation and investment financial instruments (availability of specialized funds, venture capital, targeted investments in research and development).

In the future, we will rely on these five factors (Figure 2).

Figure 2: Basic model hierarchy



Source: Authors' own work.

The selection of five key factors (F_1 - F_5) influencing the restoration of the economic potential of Ukrainian enterprises was grounded in a comprehensive literature review and aligned with the strategic priorities outlined in Industry 5.0 and circular economy frameworks. While other factors could also influence innovation and investment activation, such as regulatory frameworks or international partnerships, the selected five were prioritized based on frequency, relevance, and direct operational impact. Each factor was defined and operationalized in the AHP model, with experts comparing their relative importance using a structured 5 × 5 pairwise comparison matrix.

Form a matrix of pairwise comparisons of size n × n (for 5 factors n = 5):

$$A = \begin{pmatrix} a11 & a12 & a13 & a14 & a15 \\ a21 & a22 & a23 & a24 & a25 \\ a31 & a32 & a33 & a34 & a35 \\ a41 & a42 & a43 & a44 & a45 \\ a51 & a52 & a53 & a54 & a55 \end{pmatrix} \quad (1)$$

Where:

$$a_{ii} = 1,$$

$$a_{ji} = \frac{1}{a_{ij}}$$

Determining the weight vector w (eigenvector) using normalization:

1. Sum the elements of each column.
2. Divide each element of the column by the sum of this column (normalization).
3. Calculate the arithmetic mean in each row.

Or you can apply the eigenvalue method, where the weights are the eigenvector corresponding to the largest eigenvalue λmax of the matrix A.

Consistency check: Calculate λmax – the largest eigenvalue of the matrix A.

$$Consistency\ index\ CI = \frac{\lambda max - n}{n-1} \quad (2)$$

$$Consistency\ ratio\ CR = \frac{CI}{RI} \quad (3)$$

If CR ≤ 0.1 (i.e. does not exceed 10%), the matrix is considered consistent.

Modeling results

First, let's present the pairwise comparison matrix (Table 2).

Table 2: Pairwise comparison matrix

F	F_1	F_2	F_3	F_4	F_5
F_1	1	3	5	1	1/3
F_2	1/3	1	3	1/2	1/5
F_3	1/5	1/3	1	1/7	1/5
F_4	1	2	7	1	1/2
F_5	3	5	5	2	1

Source: Authors' own work.

Where:

a12 = 3 (i.e. F1 is 3 times more important than F2).

a21 = 1/3 is the inverse value.

a14 = 1 (approximately equal in importance to F1 and F4).

The rest is filled in according to the logic of pairwise comparisons, in agreement with the experts' judgments. We find the sum of the elements of each column:

F_1 = 5.53
F_2 = 11.33
F_3 = 21
F_4 = 4.64
F_5 = 2.23.

Normalization of the elements (dividing each element of the column by the sum of the column):

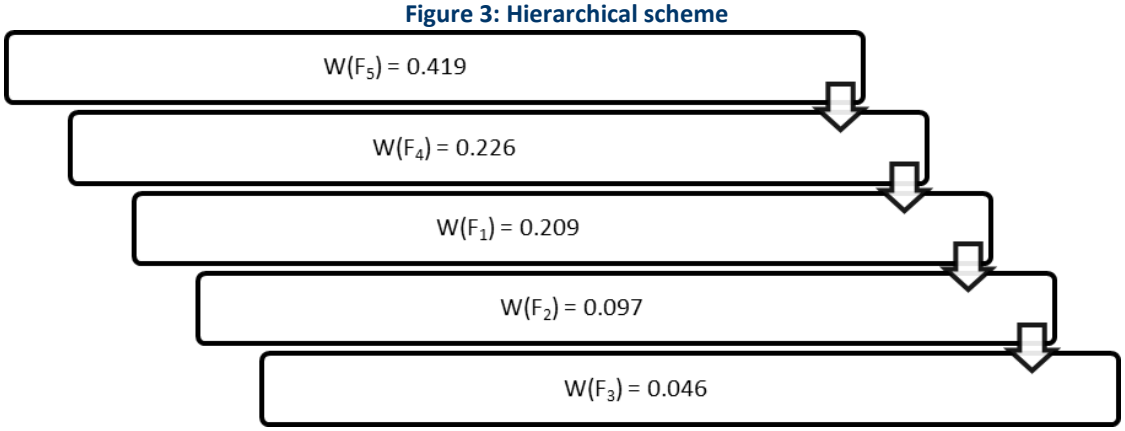
w1, 1 = 0.18; w1, 2 = 0.26; w1, 3 = 0.23; w1, 4 = 0.21; w1, 5 = 0.14.
w1, 1 = 0.18; w1, 2 = 0.26; w1, 3 = 0.23; w1, 4 = 0.21; w1, 5 = 0.14.
w2, 1 = 0.18; w2, 2 = 0.26; w2, 3 = 0.23; w2, 4 = 0.21; w2, 5 = 0.14.
w3, 1 = 0.18; w3, 2 = 0.26; w3, 3 = 0.23; w3, 4 = 0.21; w3, 5 = 0.14.
w4, 1 = 0.18; w4, 2 = 0.26; w4, 3 = 0.23; w4, 4 = 0.21; w4, 5 = 0.14.
w5, 1 = 0.18; w5, 2 = 0.26; w5, 3 = 0.23; w5, 4 = 0.21; w5, 5 = 0.14.

Determination of local weights (arithmetic mean for each row). We will present this through a hierarchical scheme (Figure 3).

From this it follows that according to the given estimates, F_5 (innovative and investment financial instruments) received the greatest weight = 0.419, and the smallest - F_3 (flexibility of the organizational structure), = 0.046. At the same time, the consistency index was 0.055 and the consistency ratio: 0.049. Since CR = 0.049 < 0.1, the matrix is consistent. In real practice, there may be other values, but the point is that CR ≤ 0.1 is considered acceptable.

The greatest weight was given to factor F_5 (innovation and investment financial instruments), which emphasizes the importance of access to specialized funds, venture capital, and an effective system of financing research and development. This is naturally explained by the fact that without proper financial injections (in particular, targeted investments) it is difficult to launch a full cycle of innovative development.

Figure 3: Hierarchical scheme



Source: Authors' own work.

Key thoughts on the results

The use of pairwise comparison within the framework of hierarchy analysis allows not only qualitatively, but also quantitatively to systematize expert assessments. Thanks to this, enterprise management can more effectively allocate limited resources (financial, material, human) for accelerated recovery and strengthening of economic potential. This technique is especially useful in the context of the transition to Industry 5.0 standards and the application of circular principles in the activities of the enterprise, since it takes into account the complex nature of innovations and investments.

The results of the pairwise comparison can be used by managers and investors to determine the sequence of measures to activate innovation and investment activities. Classification by weights allows you to develop a roadmap for the implementation of Industry 5.0 technologies and elements of the circular economy aimed at increasing economic potential. Generalization of the weight coefficients will help in the formation of national and corporate innovation support programs.

Discussions

Comparison of the results with previous studies

The results of the analysis using pairwise comparison and the analytic hierarchy process (AHP) method demonstrate a high priority for such areas as the use of innovative investment financial instruments and the development of human resources. This statement is consistent with studies that pay significant attention to the human factor, namely the training of highly qualified specialists to ensure the competitiveness of enterprises. In particular, Julhadi and Ritonga (2023) emphasize human resource management in order to increase competitiveness in the context of society 5.0, emphasizing the importance of transforming educational and organizational approaches. In our study, the level of human resources potential (F_4) was also included in the key factors, which is consistent with the authors' observations about the need to develop human capital for the successful implementation of the "post-4.0" and "5.0" concepts. For their part, Nikonenko et al. (2022) investigated the policy of attracting investments in different sectors of the economy within the framework of Industry 4.0 and confirmed the importance of targeted investments for accelerating technological change. Our results of the pairwise comparison revealed that innovation-investment financial instruments (F_5) are the most influential for restoring economic potential. This correlates with the findings of Nikonenko et al. (2022), emphasizing that without proper investment support, even advanced technological developments remain unrealized. In a similar vein, the studies of Blikhar et al. (2021) and Kopytko et al. (2024) draw attention to economic security and optimization of financial resources in a dynamic external environment, which further confirms the thesis of the primacy of proper financial support for innovation activities. Similarly, our conclusion about the increasing importance of digitalization (F_1) as one of the priorities echoes the position of El Jazzar et al. (2021), where the authors develop a phased plan for the implementation of "Industry 4.0" technologies in construction, emphasizing digital transformation as a necessary condition for increasing the efficiency of the industry. In the "fifth" iteration of the industry development (Industry 5.0), these digital elements are enhanced by additional cooperation between humans and high technologies, as noted, in particular, by Xu et al. (2021) in their analysis of the differences between Industry 4.0 and 5.0.

Contextualizing the research in the context of the transition to Industry 5.0

The transition from Industry 4.0 to Industry 5.0, according to Kagermann et al. (2013), involves not only the automation and digitalization of production, but

also the integration of a human-centric approach, where humans and high technologies are in close symbiosis. Our results on the importance of human resource development (F_4) fully reflect this logic, as specialists capable of working with modern technologies (artificial intelligence, big data, robotics) become the cornerstone of success in the "5.0 world". Similarly, Todoshchuk et al. (2023) indicate that the implementation of HR information systems is becoming a key component of maintaining the economic security of the enterprise in the transition period, which is consistent with our data on the increasing importance of HR competencies. Another common vector recorded in the literature is the focus on combining economic efficiency with environmental and social components. Castillo et al. (2023) propose lean methods in the context of Industry 5.0 to optimize resources and minimize negative environmental impact, which correlates with our idea of including "resource-efficient and circular technologies" (F_2) in the list of main factors. At the same time, Sylkin et al. (2021) emphasize the relevance of building economic security management systems in the post-pandemic space, and their findings reinforce our assertions about the importance of effective investment and human resource management for restoring economic potential.

Conclusions

Significance and implications

The results of the pairwise comparison using the analysis of hierarchies method showed the priority of individual factors in activating the innovation and investment activities of enterprises in the conditions of Industry 5.0 and the circular economy. The highest weights were given to innovation and investment financial instruments and the level of human resources potential, which indicates the need for increased attention to the development of modern financial mechanisms and training of specialists for the implementation of future technologies. The practical significance of the results lies in the formation of a roadmap for enterprise modernization, which can be used by managers to prioritize projects and direct limited resources in the most effective directions.

Limitations of the study

First, the study was based on expert assessments, which, although they allow us to quantitatively assess the importance of factors, may contain subjective biases. Secondly, the limited number of factors (five key ones) may not cover all possible aspects of the impact of Industry 5.0 and the circular economy on the restoration of the economic potential of the enterprise.

Prospects for future research

In the future, it is advisable to expand the set of factors (for example, to take into account the role of government regulation, international cooperation and technological partnerships). It is also promising to combine traditional analysis of hierarchies with fuzzy logic (Fuzzy AHP) or the Analytical Network Process (ANP) network to take into account the complex interactions between factors. In addition, it may be useful to expand the circle of experts by representatives of different sectors of the economy and international specialists to increase the representativeness and accuracy of the results obtained.

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