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For scientists, scholars, students, graduate students, representatives of business and public organizations and higher education institutions and a wide range of readers.

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RESTRUCTURING THE NATIONAL ECONOMY TOWARDS THE DIGITAL ECONOMY MODEL

Oleksandra Karintseva, *Dr. Sc., Prof.,*
Sumy State University, Ukraine
Volodymyr Lubchak, *Phd., Prof.,*
Sumy State University, Ukraine

Transition national farms to models digital economy requires comprehensive forecasting to ensure its efficiency and sustainability. This question closely related to the solution scientific tasks such as forecasting and analysis data, as well as practical tasks, including implementation modern technologies. Successful solution these problems will contribute increase competitiveness national economy, stimulating innovation and creation new workers Therefore, the study of the state and scenarios development digital economy Ukraine, taking into account The current state of the country is relevant for planning restoration economy.

The study showed that almost 400 thousand specialists work in the IT industry and their number is growing by 25-30% annually. Political stability, democracy, human rights and equality can also be ensured at a high level through the use of ICT. A number of directions for further growth in the development of the IT sector are outlined: the formation of a state program to improve the quality of training and the number of IT specialists in Ukraine; the formation of a system of incentives to increase demand for IT products among the business sector and the population; the development of digital infrastructure in the country to increase productivity, increase the efficiency of the IT sector and saturate the labor market with leading specialists; providing state support for the development of the IT sector in the form of simplified taxation, granting benefits, allocating grants and financing scientific and technological developments, ensuring proper protection of intellectual property rights; improving the culture of business and the population regarding the use of information and communication technologies [1].

Digital transformation is having a significant impact on the structure of the economy, changing the roles of different sectors. Research by the McKinsey Global Institute shows how digital transformation is changing the skills requirements of workers and creating new professions.

Modeling allows you to generalize the entities and relationships hidden in the data environment and create descriptive models. The model will allow you to make a forecast using a data set with known results to predict future values of target variables. For modern economics, the implementation of the principle of system modeling as multi-modeling is characteristic. Instead of searching for the optimal model, which may not be among the available options for describing the business situation under study, the results constitute a set of models, among which a rational one is chosen.

In further research, it is possible to use fuzzy logic methods to improve the model and expand its application. It is in the modern situation that there is a need to assess the state of the economy and make decisions in conditions of inaccurate information or in the presence of fuzzy goals and constraints. Fuzzy logic methods, fuzzy set and relationship theories are widely used in modeling economic process management systems and find practical application in assessing the state of economic security.

To develop scenarios for the development of the digital economy of Ukraine, it is necessary to forecast the relevant indicators. To argue the forecast indicators and expert definition of pessimistic and optimistic scenarios, we relied on economic statistical indicators for recent years and used analytical reports of the International Monetary Fund. To forecast a number of indicators of digital development based on a series of statistical data, trend lines were determined in order to identify trends in further development. Writing the equation for the trend line allows you to find the gradient of changes in the relevant indicator.

For the forecast, the value of the derivative at the last (rightmost) point of the trend line was calculated. This value was taken as the slope of the straight line for forecasting the indicator values. The optimistic (pessimistic) forecast was also performed according to a linear dependence with the slope increased (decreased) by the corresponding percentage. We propose an author's model for assessing the digital economy of Ukraine. The peculiarity is that this model aims to assess the state and trends of digital development at the current stage and is based on the available indicators of several pre-war and war years. European experience in research on assessing the digital economy is taken into account. The Digital Economy and Society Index (DESI) study is useful and recommended for implementation in Ukraine. This index summarizes relevant indicators on the effectiveness of digital technologies in Europe and tracks the development of EU countries in the field of digital competitiveness.

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DIGITAL TRANSFORMATION FOR SUSTAINABLE ENTERPRISE DEVELOPMENT

Oleksandra Diadenko, *student*
Sumy State University, Ukraine
Oleksandr Kubatko, *Dr. Sc., Prof.,*
Sumy State University, Ukraine
Oleksandra Kubatko, *PhD, As. Prof.,*
Sumy State University, Ukraine

Management organizations plays key role in provision security and effective reactions on extraordinary situation, because from him depends coordination and realization strategies aimed at on protection staff and property. Enterprises and organizations must elaborate and to implement plans extraordinary situations that cover different spheres risks. And it is with the help of digital management decisions can effectively to implement strategies software security and coordinate emergency actions situations, ensuring high level preparedness and response to danger. Digital means notification can automatically inform responsible persons about the shortage reserves or terms their suitability. Electronic means communications provide ambulance informational interaction between different departments and management regarding the status of stocks and needs for funds protection. One of important aspects digital transformation is the creation of communication systems and instant notifications that provide staff with operational information about dangerous situations. Such systems allow to avoid delays in response and quickly accept necessary measures to protect personnel.

Implementation digital tools allows in time detect potential threats and vulnerabilities for personnel. Automated detection abnormal deviations in personnel behavior may serve warning extraordinary situations and dangers. Application of artificial intelligence helps in forecasting risks and timely acceptance preventive events. Additionally, digital platforms can provide staff with access to training materials and simulations for evacuation preparation and other extraordinary situations. Systems monitoring and control can include video surveillance and analytics to detect dangers and avoidance traumatic situations. Use of geolocation systems allows you to accurately determine location of personnel in case of emergency situations. Effective management data and communication on digital platforms helps to provide coordination personnel actions during crises situations. Technologies tracking allow for effective personnel records during evacuation and provide necessary help. Digital technology also allow automate processes for controlling access to hazardous areas and restrictions movement. Use modern means communications contributes effective interactions between staff members during emergencies situations. Drones can be used for monitoring situations and provision assistance to personnel during crises situations. Digital technology give possibility permanent monitoring safety of personnel and ambulance reactions to any threats.

In Ukraine, the legislation establishing workplace safety requirements is based on several regulatory legal acts. One of the main laws in this context is the "Law of Ukraine on Occupational Safety and Health" [1], which defines the general principles and requirements for ensuring the safety and health of workers.

Implementation digital technologies strengthens assessment and analysis systems safety of working conditions of personnel during emergencies situations. They allow not only effectively control situation, but also in time respond to potential threats and ensure safety employees. These technologies allow effectively manage personnel by assisting in the accurate analysis of human resource needs and management number, qualifications and skills employees to achieve strategic goals. In extraordinary situations systems monitoring, GPS, and automated systems notification allow you to respond quickly, coordinate evacuation and provide personnel safety. Mobile applications and online resources help give psychological supporting staff in stressful situations situations, particularly in conditions extraordinary situations. Digital technology assist in the development and implementation plans extraordinary situations, personnel training and team management in conditions crises. Create reserves and effectively manage reserve stocks and resources protection, providing safety employees. Study past extraordinary situations, analyze them and take them out conclusions for improvement strategies management and security. General complex approach to personnel management in conditions extraordinary situations, based on digital solutions, not only provides security and readiness for action, but also contributes to development cultures security and crisis management management. This becomes important strategic an investment in stability and long-term success Enterprises. Effective personnel management in conditions extraordinary situations not only strengthens internal processes organization, but also has a positive impact on the external images company and abilities attract and retain talented employees.

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INTEGRATION OF DIGITAL TECHNOLOGIES AND DIGITAL GOVERNMENT SERVICES

Oleksandr Kubatko, *Dr. Sc., Prof.,*
Sumy State University, Ukraine
Nataliia Barchenko, *Phd, Ass. Prof.,*
Sumy State University, Ukraine

The rapid changes caused by the development of digital technologies and globalization require a thorough study of the interaction between digital technologies, public services and the digital economy model. The integration of digital technologies and public services is a key factor in the development of the digital economy. However, this process is accompanied by a number of challenges, such as ensuring cybersecurity, overcoming the digital divide and adapting legislation to new realities. The research presented in the article provides a comprehensive theoretical justification, identifies key factors influencing the successful integration of digital technologies and public services, demonstrates the impact of digital transformation on economic growth and the quality of life of the population, and identifies potential risks and barriers.

According to the NBU, in January 2024, the volume of IT exports from Ukraine decreased by $103 million, or almost 17%, to $508 million compared to December 2023, and by $20 million compared to January 2023. In January 2023, the figure was $528 million. In total, in 2023, the export of Ukrainian IT services decreased by 8.4% – to $6.7 billion compared to the record $7.3 billion in 2022. At the same time, in January 2022, the volume of exports amounted to $639 million. The IT industry's gross value added reaches $5.5 billion. The e-Government Development Index (EGDI) represents the state of development in UN member states and characterizes how a country uses information technologies to facilitate access and engage its people. The e-Government Development Index assesses patterns of website development, infrastructure access, and education. The EGDI is a composite measure of three important dimensions of e-government: online service delivery, telecommunications connectivity, and human resources. The index aims to rank national governments relative to each other. Mathematically, the EGDI is a weighted average of three normalized scores across three dimensions of e-government: 1) the volume and quality of online services (Online Services Index, OSI), 2) the state of telecommunications infrastructure (Telecommunication Infrastructure Index, TII), and 3) the internal human capital (Human Capital Index, HCI).

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STIMULATING THE DEVELOPMENT OF RENEWABLE ENERGY STORAGE CAPACITIES IN UKRAINIAN HOUSEHOLDS

Oleksandra Kubatko, *PhD, Asst. Prof.,*
Sumy State University, Ukraine
Yaroslav Mishchenko, *student*
Sumy State University, Ukraine

Magnification available generating capacities, especially by score construction new objects on base renewable sources energy, there is important for minimization time disconnection electricity for consumers and replacement destroyed or damaged capacities in long-term perspective.

Households play an important role in this process, making a significant contribution to the development of renewable energy, especially in the field of solar energy. Private households have already installed 287 MW of solar power capacity, which indicates the active participation of the population in the transformation of the country's energy sector. This trend not only contributes to reducing dependence on traditional energy resources, but also increases the level of energy independence at the level of individual families and communities. The participation of households in the production of clean energy is also an important step in supporting national efforts to decarbonize the economy and achieve sustainable development goals.

However, along with this, the private sector faces a number of obstacles in generating electricity from renewable sources in Ukraine. The instability of the regulatory environment, delays in payments under the "green" tariff, as well as the lack of clear state support, in particular due to insufficiently developed organizational and economic mechanisms, not only hinder the development of renewable energy, but also create challenges for attracting investors to the RES sector, which, in turn, affects the overall progress in the country's post-war reconstruction and the achievement of its energy and environmental goals. In this context, the study of organizational and economic instruments for stimulating the development of energy-saving RES capacities in households, taking into account European experience and successful practices, is of particular importance. Financial incentives are a key mechanism for accelerating the restoration of energy infrastructure in Ukraine. They contribute to attracting both domestic and external investments necessary for the reconstruction and modernization of the country's energy system. This is especially important in the post-war period, when limited resources require a rapid transition to renewable energy sources. Financial instruments such as subsidies and grants help reduce the initial costs of installing RES systems, such as solar panels or heat pumps, through direct financial support; tax breaks provide a reduction in the tax burden, for example through reduced income tax or VAT exemptions for RES equipment, which incentivizes investment in environmentally friendly technologies; soft loans facilitate households' access to finance through reduced interest rates, making RES technologies more affordable;

feed-in tariffs allow households to obtain favorable terms for selling excess electricity to the grid, accelerating the return on investment; Net Metering and Net Billing mechanisms provide the opportunity to feed excess electricity into the grid with the possibility of using the accumulated kilowatt-hours (Net Metering) or funds (Net Billing) to cover future electricity costs; Feed-in Premiums provide additional financial incentives for renewable energy producers who sell electricity on the spot market, encouraging them to respond to market fluctuations and take demand into account.

The organizational mechanism is an important part of the system of measures aimed at stimulating the development of energy storage capacities and renewable energy sources in households and ensuring the effective use of such technologies. The basis of the organizational mechanism is the creation of an institutional framework. This process includes the formation and expansion of structures and organizations that can effectively manage, regulate and support the development of innovative energy technologies in households. For example, state agencies for energy and renewable energy should be responsible for the development and implementation of policies in the field of renewable energy and energy storage systems. Such agencies should have clearly defined powers and resources to ensure coordination and support for the development of these technologies [1].

Regional authorities should also be involved in the process of stimulating the development of RES, adapting national policies to local conditions and needs. This will allow taking into account the specifics of each region, which is important for the effective use of the potential of RES. For the successful implementation of projects for the development of RES, it is important to ensure coordination of actions between various state structures, such as the Ministry of Energy, the Ministry of Finance, the Ministry of Environmental Protection and Natural Resources of Ukraine. Interdepartmental working groups or councils should coordinate the implementation of projects and agree on the regulatory framework.

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FORMING THE DIGITAL ECONOMY THROUGH TRANSFORMATION PROCESSES

Oleksandr Kubatko, *Dr. Sc., Prof.,*
Sumy State University, Ukraine
Liliya Syarova, *student*
Sumy State University, Ukraine

The digital economy is a factor in the stability of the national economy. The stability of the digital sector is most noticeable in crisis conditions. Thus, in war conditions, the Ukrainian IT industry demonstrates stability and is the only industry whose export volume has increased.

The transition to a digital economy requires careful planning and forecasting. This issue is closely related to the development of technologies and data analysis. Successfully solving these tasks will contribute to economic growth and the creation of new jobs. Research on the digital transformation of Ukraine is relevant for the development of economic recovery strategies.

To ensure the effectiveness and sustainability of digital transformation, it is necessary to solve both scientific tasks (forecasting, data analysis) and practical ones (technology implementation). This, in turn, will contribute to economic growth, innovation and the creation of new jobs. Therefore, the study of the digital transformation of Ukraine is extremely relevant, especially in the context of post-war economic recovery.

The literature review demonstrates that access to the Internet is a critical factor in the restructuring of the national economy. Digital transformation creates new opportunities for economic growth, but at the same time gives rise to new challenges, such as the digital divide and changes in the labor market. To successfully adapt to the digital economy, countries must invest in the development of digital infrastructure, promote the development of digital skills of the population, and develop effective policies to reduce the digital divide.

The components of the Digital Economy and Societies Index are: 1) fixed broadband Internet access; 2) fixed broadband Internet access coverage; 3) mobile broadband Internet access. We will conduct a study of assessments of the state and development forecasts of Internet connectivity as a component of the digital economy model of Ukraine.

For the progress of digital transformations, a high-quality and affordable Internet is necessary. According to forecasts, as the digital economy in Ukraine develops, at least 95% of the population should have access to the Internet. In 2021, among all households in Ukraine, 82.7% had access to Internet services at home: in urban areas – 87.4%, and in rural areas – 72.8% [1]. For comparison, the share of households with access to Internet services at home in 2021 in Poland was 90%, in the Czech Republic – 82%, in Hungary – 88%, in Latvia – 91%.

Access to mobile communications and Internet resources via mobile devices in Ukraine is provided at a satisfactory level and the characteristics have hardly changed over the pre-war years. Thus, in January 2020, there were 60.88 million, and in January 2021, there were 60.78 million mobile device connections in Ukraine, which is 139% of the total population, respectively [2]. Figure 1 presents the share of households that have access to Internet services at home in urban and rural settlements (as a % of the total number of households in the corresponding group).

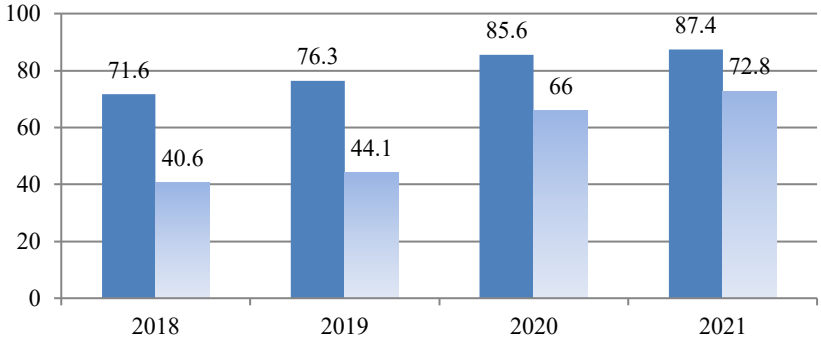

Fig. 1 Share of households with access to Internet services at home in urban and rural settlements (urban are dark and rurula are lighter color.)

Public policy plays a key role in the digital transformation process. Effective public policy aimed at developing digital infrastructure and supporting innovation is a necessary condition for successful digital transformation. Restructuring the national economy to a digital economy model is a complex and multifaceted process that requires comprehensive solutions. Successful adaptation to the digital economy requires joint efforts of the state, business and civil society, especially with regard to ensuring broad access to the Internet.

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CYBERSECURITY AND DIGITAL TRANSPARENCY: CHALLENGES FOR SMALL AND MEDIUM-SIZED ENTERPRISES IN THE DIGITAL AGE

Andrii Matsuev *student*
V.N. Karazin Kharkiv National University
Supervisor:
Liudmyla Kalinichenko
Doctor of Economics, Professor
V.N. Karazin Kharkiv National University

The digital economy is a factor in the stability of the national economy. The In the modern digital environment, startups and small businesses are among the most vulnerable to cyber threats. Every organization, regardless of its size, possesses certain vulnerabilities that hackers can exploit to gain unauthorized access to its systems. However, startups, due to their flexibility, rapid adoption of new technologies, and lack of robust cybersecurity infrastructure, have become prime targets for cybercriminals. This is not coincidental: studies show that over 43% of all cyberattacks are directed at small and medium-sized enterprises, including startups (2025 Global, 2025).

One of the primary risks for startups is the leakage of personal and confidential data. Startups often store information about their clients, which may include sensitive data such as credit card numbers, medical records, social security numbers, and personally identifiable information like birth dates, addresses, and identification numbers. This makes them an attractive target for hackers, as the stolen data can be used for criminal purposes. The problem is exacerbated by the limited preparedness of startups to counter such threats and the lack of awareness among early-stage business leaders about potential cyber risks (The State, 2024).

Throughout the 2020s, startups will face several key cybersecurity threats. To mitigate these risks and protect their operations, entrepreneurs must acknowledge these challenges and take appropriate action. It is projected that cyberattacks on startups and small businesses will only increase unless adequate cybersecurity measures are implemented (Cybersecurity Ventures, 2022).

A fundamental principle of digital security is the protection of data privacy, which underpins trust in digital technologies. Privacy ensures users' rights to control their personal information, reducing risks related to digital surveillance, fraud, and discrimination. This is achieved through mechanisms such as data encryption, online anonymity, and the regulation of personal data (e.g., GDPR). However, absolute privacy may pose difficulties in ensuring public safety, combating cybercrime, and effectively regulating the digital space (General Data, 2016). A lack of oversight over anonymous transactions, for instance, may facilitate the funding of illicit activities.

Transparency is another key element in fostering trust in digital technologies. It enables oversight of digital processes by opening up algorithms, governmental digital platforms, and personal data processing to public scrutiny. This facilitates democratic governance of technology, counters digital inequality and corruption. However, excessive transparency also entails risks, such as the misuse of large datasets for manipulation or breaches of personal data that may jeopardize user security (Bekele, 2023).

Striking an effective balance between privacy and transparency is crucial to creating a secure digital environment. This requires innovative approaches, including:

– Ethical regulation of technology, involving the development of clear standards for data usage;

– Digital literacy, empowering users to manage their privacy and assess the openness of digital processes;

– Trust in technology, which can only be ensured through transparency in operations and the protection of personal data.

Thus, finding the right balance between privacy and transparency is an ongoing process that requires continuous innovation in digital policy, cyber ethics, and technological development.

In the context of today's digital technologies, it is essential to implement robust methods to protect data from leakage and unauthorized access. Several fundamental practices can be adopted:

Data Discovery. The first step toward data protection is gaining a clear understanding of what data is being stored and how it is used. This enables the implementation of effective privacy and security measures: Review the personal information shared online; Audit devices to determine what data is stored on smartphones, laptops, and tablets; Manage application permissions on your devices.

Use of Automated Detection Tools. Automated tools help identify sensitive information and take necessary steps to protect it. Use reliable tools like Varonis Data Classification Engine or Spirion to scan devices and cloud storage. Classify data by sensitivity level to apply appropriate security measures.

Monitoring and Alert Review. Implement robust monitoring to detect anomalies and potential threats. Use intrusion detection systems (IDS), such as Snort or Suricata, to detect unauthorized access attempts. Regularly review activity logs and alerts to ensure timely response to breaches.

Use of Antivirus and Anti-Malware Software. This is a basic but essential step for data security. Keep software updated. Use real-time scanning to detect emerging threats. Use of Secure Storage Solutions

Choosing reliable data storage solutions provides an additional layer of security. Utilize cloud services such as Google Drive or iCloud with built-in encryption features.

Authentication and Authorization. Implementing multi-factor authentication (MFA) and access control increases data protection. Use MFA to add an extra layer of security. Apply role-based access controls to restrict access to sensitive data.

These strategies help ensure robust protection of confidential information and reduce the risk of data breaches in the digital era.

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SUSTAINABLE DEVELOPMENT MANAGEMENT FOR ECONOMIC SECURITY

Liliya Syarova, *student*
Sumy State University, Ukraine
Oleksandr Kubatko, *Dr. Sc., Prof.,*
Sumy State University, Ukraine

The modern era is characterized by a close intertwining of confrontation and cooperation in international relations. Countries that pay attention to universal values, such as freedom, democracy and human rights, have focused on creating an international environment of coexistence and co-prosperity. These efforts contribute to the development of international peace, stability and economic growth in a globalized world. Globalization and interdependence of economic systems, on the one hand, are a factor in increasing the well-being of the population through the benefits of specialization, but the emergence of problems or challenges in one of the countries inevitably affects others. The current dynamics of changes in the balance of power and increased geopolitical competition threaten the free, open and stable international order that emerged after the end of the Cold War. Given that ensuring sustainable development in the military and post-war economy is a poorly studied phenomenon, there is a need to obtain information about the critical global and local challenges of ensuring economic security in the direction of sustainable development.

An effective national security system is a prerequisite for international cooperation and solving global problems. Without stability at the national level, it is difficult to achieve peaceful coexistence on the world stage. A decrease in the economic national potential can lead to restrictions in the implementation of development programs, a decrease in defense capabilities during war, and undermine national security. A stable economy contributes to social stability and the avoidance of social conflicts. Negative economic trends, such as unemployment, inflation, or a decline in production, can lead to an exacerbation of social problems and threats to internal stability in addition to the problems created in war conditions. The main components of economic security that affect public life are macroeconomic, production, demographic, energy, foreign economic, investment and innovation, food, social, and financial security. Such indicators of macroeconomic security as the size of GDP, public debt, inflation rate, unemployment rate are important elements for effective management of the country's economy and contribute to systemic development, creating favorable conditions for sustainable economic growth and improving the living standards of the population. Despite military operations, foreign business continues to invest in Ukraine and open its own enterprises, attracted by the large market and population of the country. The main areas of interest to foreign investors are agriculture, alternative energy, information technologies, infrastructure and production.

In the modern world, a key factor in economic growth and an important element in ensuring economic security and sustainable development of the country is business activity. Business activity is understood as a set of economic actions and initiatives of business aimed at producing goods and services, making investments, creating jobs and ensuring economic growth. Business activity is an integral indicator that characterizes the efficiency and activity of an enterprise in its activities aimed at achieving planned goals. The components of the integral indicator of business activity are: production and sales volumes; level of profitability and profitability; concluded contracts and partnership agreements; innovation and implementation of new technologies; development of sales markets and expansion of sales geography; efficiency of resource management and optimization of business processes; growth of assets and investments in the development of the enterprise; level of customer and partner satisfaction; stability of financial condition and risk management; development of human resources potential and retention of personnel.

Developed entrepreneurship contributes to reducing unemployment, ensuring the stability of the socio-economic environment and making the economy more resilient to external influences. In addition, enterprises create new markets, develop innovative products and services, which contributes to increasing the country's competitiveness in the global market.

Entrepreneurship, based on the principles of sustainable development, contributes to economic growth, while ensuring the preservation of natural resources and reducing the negative impact on the environment. Thus, business activity, stimulating the development of entrepreneurship and business, not only contributes

to economic growth, but also ensures the stability and security of the country's economy. Despite the war, business development in Ukraine continues, and new investments and financing contribute to its support.

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A SEVEN-LEVEL, TWO-DIMENSION FRAMEWORK FOR ASSESSING THE ECONOMIC AND SDG IMPACT OF GENERATIVE AI

Roman Kolesnyk**,** *PhD Student,*
Sumy State University, Ukraine

Introduction. Generative artificial intelligence (GenAI) is changing how companies create value by automating knowledge work and generating new ideas. According to executive surveys (McKinsey & Company, 2023), GenAI is mainly associated with higher productivity and faster time−to-market. However, productivity gains without a reduction in environmental burden lead nowhere: any technology that ignores resource use and emissions risks becoming obsolete. Most studies discuss individual GenAI benefits, yet few provide managers with an integrated roadmap that considers both economic and ecological consequences for competitiveness. This study seeks to help close that gap by proposing a seven-level, two-dimension framework that also includes an assessment of environmental impact.

The aim is to show each business layer that is suitable for GenAI implementation and to evaluate the prospects of such deployment. Within this study we distinguish the following levels: (1) functional tasks; (2) business-model design; (3) production processes; (4) human resources; (5) sustainable-development practices; (6) investment policy; and (7) alliances or partnerships for joint GenAI solutions. Each layer is examined in two dimensions: the operational dimension, which tracks daily activities, and the strategic dimension, which links those activities to long-term market position. Together they form a matrix with fourteen cells that allows a company to assess its status and set clear targets.

Data and Methods. The method is a desk review of twenty-six industry and academic sources and a comparative scan of forty public GenAI use cases in manufacturing, retail, and IT services. Each use case was manually classified into one of the fourteen matrix cells using a predefined two-label coding scheme. The same cases were then mapped against the United Nations Sustainable Development Goals. Frequency counts indicate where projects are concentrated; the study is exploratory and does not claim causal proof.

Results. More than one-third of the forty public cases support clean-technology upgrade (SDG 9.4) and waste reduction (SDG 12.5) through predictive

maintenance. A smaller cluster advances responsible resource use (SDG 12.2) by redirecting revenue toward resource-efficient service models. Direct links to climate action (SDG 13) appear in only a few initiatives-mainly energy digital twins and pilot projects aiming for net-zero AI compute-while progress on strengthening global partnerships (SDG 17.16) emerges in joint AI laboratories that share data for circular supply chains. Conversely, several deployments, such as fintech fraud-detection copilots, meeting-summary tools, and subscription coding assistants, show little or no measurable benefit for SDGs and may even increase compute-related emissions. These neutral or negatively aligned cases confirm that adopting GenAI is not automatically "green" and highlight the need for clear carbon metrics to prevent rebound effects.

Conclusions. The seven-level, two-dimension matrix with an SDG overlay can serve a dual purpose. First, it works as a planning dashboard that helps managers quantify economic gains and locate blind spots at functional, production, and strategic levels when embedding GenAI in business processes. Second, by tagging SDGs it operates as an early sustainability filter that signals whether a proposed GenAI use case supports or undermines environmental goals. Applying these techniques produced an illustrative matrix that shows which data are required and how they can be aggregated; the next step is to build a full scoring tool capable of rating both the economic and ecological viability of GenAI projects. Future research will focus on broader data sets to examine and validate the emerging patterns identified here.

Academic Supervisor:
Dr., Assoc. Prof. Oleksandr Kubatko,
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DEVELOPMENT OF SMALL AND MEDIUM-SIZED ENTERPRISES IN UKRAINE FOR SUSTAINABILITY

Oleksandr Kubatko, *Dr. Sc., Prof.,*
Sumy State University, Ukraine
Vladyslav Piven, *researcher*
Sumy State University, Ukraine

Based on the fact that most of all businesses in market economic systems are owned by SMEs, they form a competitive environment and reduce the monopolization of markets. It is thanks to SMEs, regardless of their size, that market prices are equalized and equilibrium prices are established. When prices for certain goods or services are high, SMEs can easily enter the market (if there are no technological or other barriers) and saturate the market with their own products or products of other firms (thanks to trading SMEs). Opening your own business most often begins with SMEs, some of them eventually move into the group of large enterprises, but the majority remain in their market niche. Annual income from 2 to 50 million euros forms the social stratum of the middle class, which is the basis of the stability of the national economic system.

Small and medium-sized enterprises are easy to start and are usually not subject to additional regulation, which is why SMEs have the opportunity to contribute to employment, self-employment and reducing unemployment. According to data, it was thanks to small and medium-sized enterprises that in the early 2020s about 85% of all jobs were created and two thirds of total employment in the private sector in the EU were provided. Innovation of small and medium-sized enterprises, according to the work of Hervás-Oliver et al. (2021), relies on a variety of internal sources and external factors, and innovation policies built only on increasing investment in research and development may not produce the expected results in regions where the opportunities for SMEs to benefit from research and development are limited. Since cooperation and regional characteristics can play a greater role in determining SME innovation. As for the EU, small and medium-sized firms in more innovative regions of the EU benefit more from a combination of internal research and development, various types of external cooperation. Small and medium-sized firms in less innovative regions rely more on external sources and collaboration with other firms. Moreover, increased investment in public research and development does not always lead to improved regional innovation of SMEs.

As for Ukraine, the total number of employees in business entities in the group of individual entrepreneurs in 2022 is more than 649 thousand people, of which 53% of employees are employed in the wholesale and retail trade; repair of motor vehicles and motorcycles; 10.3% of all employees of individual entrepreneurs work in industry; 9% each in the fields of transport, warehousing, postal and courier activities, temporary accommodation and catering.

Due to their ability to quickly re-engineer at relatively low cost, SMEs contribute to the innovative development of the entire economic system. Small and medium-sized enterprises are able to track the latest technological developments and quickly adapt them to everyday business activities. Similarly, a firm's decision to invest in R&D has a positive impact on turnover and productivity growth, while the amount of investment in R&D also matters for the growth of the firm.

From a policy perspective, these results suggest the need for "soft support" and preparation of the firm itself for the adoption of R&D (in particular, education, training, software) in order to improve the potential of SMEs and maximize the benefits of increased investment in research and development. The empirical results that investment in training contributes to the growth of SMEs also provide arguments for further analysis on the development of appropriate training programs for SMEs [1].

The main consumers of SME products are ordinary consumers and therefore the key areas of activity of small and medium-sized enterprises are related to providing consumers with goods and services of everyday demand. Only a small part of SMEs is focused on large business or government orders. In view of this, the European Commission considers small and medium-sized enterprises to be key to ensuring long-term sustainable economic growth, developing innovative activities, creating new jobs and forming a social and solidarity economy in the EU. The paper [1] also emphasizes the potential role of economic policy aimed at creating favorable macroeconomic conditions, as well as export-oriented economic policy, which contributes to balanced and sustainable economic growth.

Small businesses are always easier to relocate, open in another location, restructure or re-profiling, while large enterprises are more rigid and cannot quickly relocate or change the trajectory of their activities. However, in Ukraine, SMEs more often face bureaucracy, excessive regulation and corruption on the part of public authorities, which hinders the development of their potential.

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FORMATION OF ENGLISH LEXICAL COMPETENCE USING THE "FLIPPED CLASSROOM" FOR GENERAL SECONDARY EDUCATION INSTITUTIONS UNDER MARTIAL LAW

***Oleksandra Kubatko**, student of group AM-5,*
Sumy State Pedagogical University
named after A. S. Makarenko, Ukraine

The war in Ukraine has negatively affected almost all aspects of public life. However, one of the most vulnerable sectors has become education, which has been trying to exist in the conditions of a global pandemic. Then educational institutions switched to remote working conditions, which contributed to the strengthening of EdTech – a set of technologies used to improve the learning and education process. These are not only online courses but also various digital tools and platforms that help in learning. Given modern challenges and threats, educational institutions are forced to adapt to new technologies and solve problems of ensuring the safety, reliability and accessibility of education for students. One of the EdTech tools is the "flipped classroom", which is considered an effective means of learning.

Thus, according to a study of the quality of the organization of the educational process in war conditions, conducted by the State Education Quality Service of Ukraine from December 2022 to January 2023, showed that about 800 thousand schoolchildren changed the form of education from full-time to distance learning (from 17,669 students in 2021 to 772,909 in 2022) and family (home) education (from 4,695 to 64,409 students, respectively). These changes most often affect the East and South of the country, from where about 40% and 30% of students, respectively, were forced to leave abroad or to other regions of the country.

Thus, online education has created opportunities to facilitate more inclusive and engaging learning experiences. Many educators have developed robust libraries of learning materials, such as learning modules, video lectures, assignments, and assessments, as well as a deeper understanding of online pedagogy and technology. Similarly, students have become increasingly comfortable interacting and learning through digital platforms. These resources and experiences can be used to enhance learning.

In the case of forming English-language lexical competence for students of secondary education institutions, using the "flipped classroom" technology is an effective and innovative approach. This technique allows for the most effective use of lesson time for practical work and discussions and more time to devote to communicative tasks and group work. Students study theoretical material independently at home by watching video lessons, reading texts or performing interactive exercises.

Using the "flipped classroom" methodology, we can distinguish the main directions of lexical competence formation: first, familiarization with new vocabulary through videos, audio materials or interactive platforms. The second

practical application involves performing exercises on using new words in context, creating dialogues, and writing texts. Third, consolidation involves project activities for deeper assimilation of the material, conducting interactive games, and testing.

The study results show that using the "flipped classroom" increases student motivation and the effectiveness of vocabulary acquisition. In addition, learning is individualized when students work on the material at their own pace. Those needing more time can watch the video or work through the material as often as necessary. Thus, gifted students can go further by studying additional material. Other advantages of the "flipped classroom" technology include the following:

Developing independence and responsibility allows students to take responsibility for their learning, organize their time, and search for information independently.

Effective use of class time allows more time to be devoted to speaking practice and interaction with other students. This contributes to the development of communicative competence.

Developing critical thinking allows you to memorize new words and apply them in different contexts.

Preparing for the challenges of the modern world promotes the development of self-study skills and digital tools, which is essential in the modern educational process.

In addition, it is worth noting the main challenges and obstacles to the implementation of the “flipped classroom” technology (Table 1).

Table 1 – Challenges and obstacles to implementing flipped classroom technology

Sign	Characteristic
Internet access and the presence of a gadget in	All students should have access to the necessary resources. It is possible to organize work at school (computer lab, library) for those who do not have access at home, but taking into account safety conditions.
Motivating students to learn independently	It is worth explaining to students the advantages of such an approach, using interesting and diverse materials and providing opportunities for feedback.
Monitoring the completion of homework (D/h)	For example, as a D/s, you can offer a short test at the beginning of the lesson, then a check on completed online tasks, or active observation by the teacher of students' participation in discussions.
Different pace of learning for students	“Flipped classroom” promotes individualization. Each student has different abilities and levels of development, so the teacher should be prepared because some students will need more help and attention during classwork.

So, summarizing the data in Table 1, it is worth noting that a significant challenge is access to the Internet and gadgets, especially since the situation was exacerbated in the absence of electricity. At the same time, in terms of distance synchronous and

asynchronous learning, 39% of teachers consider the challenge for the educational process in wartime to be that students are unable to learn independently.

Therefore, the world during wartime requires coordination and cooperation between all participants in the educational process to ensure maximum educational opportunities and protect children in learning conditions by strengthening and implementing new methods and technologies, in particular the "flipped classroom", which is promising for the formation of English-language lexical competence in students, as it shifts the emphasis from passive perception of information to active application of knowledge, develops independence and increases motivation to learn English.

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LEGAL ASPECTS OF DIGITAL TRANSFORMATION AND SUSTAINABLE DEVELOPMENT IN THE EUROPEAN UNION

Alona Bila, *Senior Lecturer,*
Department of Law,
HEI "Alfred Nobel University", Ukraine

Introduction. Digital transformation has emerged as a central component of the economic and social progress within the European Union (hereafter – EU), shaping the contours of modern industries such as Industry 4.0 and 5.0. These transformations revolve around the adoption of cutting-edge technologies such as automation, artificial intelligence (hereafter – AI), and interconnectivity, and raise significant legal and regulatory challenges. The need to create a legal framework that facilitates the integration of these technologies while ensuring alignment with the EU's sustainable development goals (SDGs) is critical. These goals include fostering an environmentally sustainable economy, ensuring social inclusion, and promoting innovation.

Besides, this paper delves into the legal aspects of digital transformation within the EU, with a specific focus on how these transformations align with sustainable development. It explores key EU regulations and their role in ensuring that digital innovations not only support economic growth but also promote environmental sustainability and societal well-being. The legal challenges arising from this transformation, such as data privacy, cybersecurity, and AI regulation, are also examined in depth.

Data and Methods. This study employs a qualitative legal analysis, reviewing EU legislation, directives, and policy documents related to digital transformation and sustainable development. Key documents and legal frameworks analyzed include: General Data Protection Regulation (GDPR) (the cornerstone of data privacy in the EU, which sets stringent requirements for data protection and creates a legal basis for data-driven innovation) (European Union, 2016); Regulation (EU) 2016/679 of the European Parliament and of the Council; Digital Services Act (DSA) and Digital Markets Act (DMA) (these acts address the regulatory landscape for digital services and platforms, promoting competition, fairness, and transparency in the digital economy) (European Union, 2020); Regulation (EU) 2020/1808 of the European Parliament and of the Council (European Union, 2020); Regulation (EU) 2020/1828 of the European Parliament and of the Council; European Green Deal (an overarching policy framework that outlines the EU's commitment to becoming climate-neutral by 2050, incorporating digital transformation as a key enabler) (European Commission, 2019); EU Digital Strategy (the EU's long-term vision for a digital economy, including initiatives such as the Digital Europe Programme, which aims to empower digital skills and support digital infrastructure) (European Commission, 2020).

Furthermore, the study also examines case law and legal precedents to assess how regulatory measures are adapting to the fast-paced technological landscape, ensuring that digital transformation aligns with EU values such as environmental protection and social equity.

Results. The findings from the legal analysis reveal several key insights into the intersection of digital transformation and sustainable development.

The GDPR stands as one of the most significant legal frameworks impacting digital transformation in the EU. While it is primarily concerned with data privacy and protection, it also creates a conducive environment for innovation by establishing clear guidelines on the lawful use of personal data. By empowering individuals with control over their data, the GDPR enhances trust in digital technologies, which is crucial for fostering long-term sustainability in digital services. For example, GDPR-compliant businesses can gain consumer confidence, essential for fostering a sustainable digital economy.

Moreover, the DSA and DMA address the dominance of large digital platforms such as Google, Amazon, and Facebook, ensuring that these platforms operate within a fair and transparent legal framework. These regulations aim to prevent monopolistic practices and foster competition, which can lead to more innovation

and consumer choice. By regulating the practices of digital platforms, the DSA and DMA contribute to a more ethical digital landscape. In terms of sustainable development, promoting fair competition helps smaller digital startups thrive, potentially contributing to more sustainable business practices and services.

Besides this, the EU's “Twin Transition” initiative exemplifies the integration of digital and green transformations. The Green Deal's ambitious targets for climate neutrality by 2050 cannot be achieved without embracing digital technologies that enhance energy efficiency, reduce carbon emissions, and promote the circular economy. For instance, smart grids, IoT-based environmental monitoring, and AI-driven waste management systems are key digital solutions that help realize these green goals. The EU’s policies on sustainable digital transformation, such as the EU Climate Law and the Digital Strategy, recognize that technological advancements can significantly contribute to achieving sustainability.

Despite the progress in digital regulation, several legal challenges remain. One of the primary concerns is the regulation of AI technologies. The rapid development of AI presents both opportunities and risks in terms of ethics, safety, and employment. The EU has taken steps to create a framework for AI regulation, with the draft AI Act aiming to ensure that AI systems are trustworthy and respect fundamental rights. However, significant gaps remain in terms of harmonized global standards for AI governance and cybersecurity.

Eventually, cybersecurity also remains a significant challenge as digitalization increases the vulnerability of critical infrastructure to cyber-attacks. The EU's Network and Information Security Directive (NIS2) aims to enhance the overall level of cybersecurity, but further coordination between member states and international partners is needed to create a robust legal framework that addresses the growing risks.

Conclusions. In summary, the EU’s legal framework governing digital transformation reflects a robust commitment to fostering a sustainable digital economy. However, challenges persist, particularly in harmonizing legal frameworks across different technologies such as AI and in ensuring comprehensive cybersecurity. The role of legal enforcement mechanisms is critical in holding digital players accountable, and there is a need for stronger international cooperation to address cross-border challenges.

Lastly, the intersection of digital transformation and sustainable development highlights the importance of forward-thinking legal frameworks that can balance innovation with environmental and social goals. To achieve a digitally advanced yet sustainable European economy, continuous adaptation and harmonization of laws will be required.

In addition, Ukraine is also undergoing a significant digital transformation, particularly in the wake of the ongoing conflict and its aspirations to align more closely with EU standards. Ukraine's efforts to implement the EU Association Agreement and its ambitions to integrate with EU digital policies reflect its commitment to adopting EU regulations, including those related to data privacy and

cybersecurity. Ukraine has introduced its own Data Protection Law and is working on aligning its legislation with the EU's GDPR. Moreover, Ukraine's national digital strategy is increasingly focusing on fostering innovation, supporting startups, and encouraging digital entrepreneurship, while also ensuring that these advancements contribute to a sustainable future. However, legal and institutional challenges remain, particularly in the areas of infrastructure, cybersecurity, and AI regulation.

Then, Future collaborations between the EU and Ukraine could provide valuable insights into harmonizing digital transformation with sustainable development in Eastern Europe, serving as a model for other countries transitioning towards digital economies.

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ALLOMETRIC APPROACH AS A TOOL FOR ENHANCING THE FLEXIBILITY OF SIGMOIDAL MODELS IN ECONOMIC MODELING

Halyna Tuluchenko, *Dr. Eng., Professor,*
National Technical University
"Kharkiv Polytechnic Institute", Ukraine

Introduction. In the field of information economics, sigmoidal curves serve as a crucial tool for modeling nonlinear processes exhibiting phases of acceleration, deceleration, and saturation. However, standard sigmoidal models, such as the logistic function, may demonstrate limited adaptability when modeling complex economic phenomena characterized by asymmetric behavior and a non-standard inflection point location. To enhance the adequacy of describing such processes, it is pertinent to expand the flexibility of model functions by introducing additional parameters (Yin et al., 2023).

This study investigates the potential of the allometric approach to improve the modeling of asymmetric economic processes and evaluates its advantage using information criteria.

Data and Methods. A promising approach in this context is the application of an allometric exponent, which provides an opportunity to more accurately reflect the asymmetry and variability of economic processes, thereby improving the quality of predictive models (Niklas et al., 1994). Unlike the standard logistic curve, which assumes symmetry around the point of maximum growth rate, real economic processes often exhibit asymmetric dynamics with a significant difference in the duration and intensity of growth and deceleration phases. The introduction of an allometric parameter into the logistic curve model allows for overcoming this limitation. The allometric parameter enables the regulation of the ratio between the duration and intensity of the growth and deceleration phases, as well as shifting the position of the inflection point – the moment of maximum growth rate – relative to the midpoint of the value range. This ensures a more accurate representation of the asymmetric dynamics characteristic of many economic phenomena, where the peak of growth does not necessarily coincide with the midpoint of the time interval.

Results. The relative quality of statistical models for a given dataset can be assessed using, for instance, the Akaike Information Criterion (AIC) (Burnham et al., 2004), the Bayesian Information Criterion (BIC) (Schwarz, 1978) among other similar criteria. Assuming that the model errors are normally distributed with constant variance, there is a fundamental relationship between the likelihood function and the Residual Sum of Squares (RSS): maximizing the likelihood of the model given the data is equivalent to minimizing the RSS. Consequently, if the data exhibit asymmetry or other features that are well captured by the introduction of an allometric parameter, the model incorporating this parameter should provide a significantly better fit compared to a standard sigmoidal model. This improved fit will manifest as a substantial reduction in the RSS and a corresponding increase in

the maximum value of the likelihood function. The Akaike Information Criterion (AIC) quantifies the trade-off between the goodness of fit and the complexity of the model. Adding a parameter to a model increases its complexity, which is penalized by the AIC. Therefore, for a more complex model (in this case, one with an allometric parameter) to be preferred over a simpler one, the improvement in fit must be large enough to outweigh this penalty. Specifically, if the increase in the likelihood function value upon transitioning to the model with the allometric parameter is such that the ratio of the likelihoods exceeds approximately $e \approx 2.718$, then the increase in the number of parameters by one is justified, and the more complex model is considered superior according to the AIC. This threshold implies that the enhanced ability of the model to explain the variance in the data, as reflected by a lower RSS and higher likelihood, must be sufficiently compelling.

The Bayesian Information Criterion (BIC) similarly evaluates the balance between model fit and complexity but imposes a more stringent penalty for each additional parameter, particularly as the size of the dataset grows. For the model incorporating the allometric index to be deemed superior by the BIC, the ratio of its maximum likelihood to that of the simpler model must exceed the square root of the sample size $\left(\sqrt{n}\right)$. This higher bar set by the BIC reflects a preference for more parsimonious models when dealing with larger amounts of data, requiring a more substantial improvement in fit to warrant the inclusion of an additional parameter like the allometric index. This highlights that while the AIC might favor a slightly more complex model if it provides a modest improvement in fit, the BIC will typically require a more significant improvement to justify the added complexity, especially with larger datasets common in economic modeling.

Conclusion. Therefore, the use of the allometric approach is an effective tool for increasing the flexibility of sigmoidal models in the information economy, which is confirmed by the analysis based on the information criteria AIC and BIC, which quantify the advantage of more complex models while adequately improving the quality of data description.

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THE ROLE OF ROAD TRANSPORT ENTERPRISES IN SUSTAINABLE LOGISTICS

Oksana Bilonoh, *PhD, As. Prof.*
Olha Sopotsko, *PhD, As. Prof.*
Volodymyr Fartuchnyi, *PhD student*
National Transport University, Ukraine

Introduction. Arranging and transferring resources, including machinery, food, liquids, inventories, materials, and people, from one location to the storage of the desired location is sometimes referred to as logistics. Logistics controls the movement of commodities from one point of origin to the point of consumption to satisfy client demands. The market is anticipated to grow gradually due to rising international commercial activity, particularly in emerging nations, and worldwide mass transit expansion. The road transport enterprises has shortened delivery times, reduced fulfillment costs, and given the retailer sector a greater chance to concentrate on customer service rather than delivery tasks.

Data and Methods. This research utilizes a mixed-method approach, including literature review, case study analysis. Data is collected from a diverse range of sources, including online articles, case studies, and secondary research reports.

The key players in the global logistics market include – MOLLER – MAERSK (Denmark), H. Robinson Worlwide Inc. (U.S.), DB SCHENKER (Deutsche Bahn Group (DB Group)) (Germany), Deutsche Post AG (DHL Group) (Germany), DVS (DVS Panalpina) (Denmark), FEDEX (U.S.), GEODIS (France), Kuehne+Nagel International AG (Germany), Nippon Express (Japan), United Parcel Service Inc. By 2030, the global logistics market will reach a value of $570.9 billion compared to $261.5 billion in 2022, according to Vantage Market Research (Logistics, 2022).

There are many steps to planning and building a sustainability strategy at the road transport enterprises. Business leaders must honestly assess their business practices and build bold, purposeful strategies to leave behind the unsustainable habits of the past for cleaner and greener logistics. For successful sustainable business, the road transport enterprises have to develop business practices according to sustainable goals.

The global logistics market will be dominated by the roadways segment during the forecast period. The highways market has expanded due to rising demand for roadway vehicles to move retail products over large distances, particular in domestic region. Retail business should use trucks and cargo with substantial carrying capabilities when choosing road transportation.

The logistics sector stands at a pivotal junction, facing a now-or-never moment. With rising sustainability pressures and radical technological shifts, businesses must transform operations to meet stringent emissions regulations and growing customer expectations around eco-friendly deliveries.

Logistics is under growing pressure to adopt sustainability measures. Key regulations are mandating reductions in transport emissions, notably in major markets such as the EU. Under the Paris Agreement, companies must cut carbon emissions by 55% by 2030 compared to 1990 levels to meet climate targets (Paris Agreement, 2015).

At the Era of Sustainable Logistics Global Summit, DHL brought stakeholders together to share their vision, best practices, and real-world experiences – to show that the current crisis is an opportunity to unlock new and better forms of business growth, economic development, and well-being for all. And that cleaner, greener logistics play an essential role. In a sense, the summit provided a cross-sector roadmap for businesses of all sizes to navigate the current challenges and progress toward their sustainability goals. This report reviews some of the event's main themes, starting with strategy and governance – the rethinking every business needs to build a solid foundation for sustainable operations. Chapter two dives into decarbonization and circularity – the challenges and opportunities to reduce emissions across supply chains, and enable a circular economy. Chapter three focuses on a vision for clean energy and mobility backed by digitalization that offers the hope of prosperity for all people. Transitioning to a circular economy running on cleaner, greener logistics is as urgent as it is unstoppable (The Era, 2024).

Results. The main role of logistics, key players in market and the role of road transport enterprises were determined. Also, recommendation for developing successful sustainable business for road transport enterprises was given. Road transport enterprises have to use and develop business practices according to sustainable goals.

Conclusions. Nearly 200 countries have joined the Paris Agreement, which provides a roadmap for governments to address the climate crisis. National governments are driving change through forward-looking legislation and policy. It means that businesses, civil society organizations, and local governments are embracing sustainable practices and building coalitions to accelerate the much-needed transition.

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FROM THE HISTORY OF THE DEVELOPMENT OF SANITARY AND ANTI-EPIDEMIC AFFAIRS IN KHARKIV: THE ROLE OF LOCAL MEDICAL JOURNALS OF THE SECOND HALF OF THE XIX – EARLY XX CENTURY

***Olena Bohdashyna**, D. sc, Prof.,*
H. S. Skovoroda Kharkiv National Pedagogical University, Ukraine
***Serhii Dorosh**, PhD Student,*
H. S. Skovoroda Kharkiv National Pedagogical University, Ukraine

Introduction. Modern Ukrainian researchers of medical periodicals of the XIX – early XX centuries (V. Plyushch, N. Kotsur. V. Sadovnichy and others) paid little attention to the importance of Kharkiv specialized journals in the development of sanitary and anti-epidemic affairs.

The purpose of our report is a detailed analysis of Kharkiv medical journals of the second half of the XIX – early XX centuries, namely articles on hygiene, epidemiology, veterinary medicine and the organization of sanitary affairs in Kharkiv.

Data and Methods. The source base of the research is articles on sanitary and epidemiological matters, which were published in the XIX – early XX centuries in the Kharkiv press. We used general scientific principles of historicism, objectivity, systematicity and special-historical methods: problem-historiographical, comparative-historical.

By the middle of the 19th century the prerequisites for the rapid development of epidemiological and hygienic sciences, the reform of sanitary and anti-epidemic affairs in the Russian Empire were created. It is no coincidence that it was in the second half of the XIX – early XX centuries that the largest number of medical journals was published during the imperial period and mainly in university cities. Many authors and editors of medical journals of that time were lecturers of universities and medical courses, who not only investigated scientific problems, but also made a great contribution to the popularization of sanitary and anti-epidemic knowledges.

Among the current medical topics hygiene, sanitation and epidemiology occupied a prominent place in specialized journals. The largest number of publications on this topic was published in various periodicals of the Kharkiv Medical Society, which was founded in 1861 and is still working fruitfully today.

In the published minutes of meetings («Протоколы заседаний Харьковского медицинского общества», 1862–1916) and annual reports of the Kharkiv Medical Society «Отчет о деятельности Харьковского медицинского общества за …. г.» and the Bacteriological station (Bacteriological Institute) attached to it («Отчет по Бактериологической станции Харьковского медицинского общества за …г.»,

«Отчет о деятельности Бактериологического института Харьковского медицинского общества за …г.», 1888–1915), reports of leading infectious disease specialists were regularly printed. They raised important theoretical and practical questions. So, for example, new methods of diagnosis and treatment of infectious diseases were proposed; method of vaccination against plague, diphtheria and other infections; preventive work to prevent the spread of known infections, etc. In 1889 head of the society, professor O. Kuznetsov made a report on a new epidemic disease of influenza (flu).

In 1884 Kharkiv Medical Society sent a special questionnaire to all doctors of Kharkiv province. The questionnaire included issues of registration of patients, their care, ways of infection, isolation, disinfection, etc.

In «Works of the Kharkiv Medical Society» («Труды Харьковского медицинского общества», 1888–1906) more than 20 thorough studies on various infectious diseases and methods of combating them were published. So, in 1902 V. Poznansky, referring to the experience of fighting the plague in Odessa, suggested that the authorities and the population more actively destroy rats by all means as carriers of infections.

Members of the Kharkiv Medical Society promoted world achievements in the field of epidemiology and bacteriology, reported on their participation in various international scientific events.

The doctor of the Bacteriological Institute S. Korshun described the latest methods of preparing serum for the treatment of scarlet fever, which he got acquainted with during a visit to the laboratories of Bern (Switzerland), Vienna (Austro-Hungarian Empire), Paris (France).

Another doctor of the Bacteriological Institute V. Nedrigailov, who trained at the Pasteur Institute (Paris), published an article on vaccination methods in «Works of the Kharkiv Medical Society» (Issue 2 for 1903) and proposed to the local authorities the forms of organizing mass vaccinations of Kharkiv residents.

In another edition of the Kharkiv Medical Society – in the «Kharkiv Medical Journal» («Харьковский медицинский журнал», 1906–1917) – the largest number of theoretical articles devoted to problems, in particular the pathogenicity of certain types of microbes, was published in comparison with other local periodicals of medical profile. The journal also published reports on the fight against epidemics of plague, typhus and cholera.

The editor of «Kharkiv Medical Journal» in 1906–1912 V. Favre emphasized to readers the need to prevent infectious diseases. Many of the professor's articles in this and other journals were devoted to Asian cholera, malaria, plague and the ways of their spread. The scientist even specially infected himself through a mosquito bite to prove the infectious nature of the disease.

Another well-known doctor K. Gamalia, in articles devoted to the epidemics of typhoid fever in 1909 and typhus in 1915–1916 in Kharkiv, summarized important statistical data in diagrams and tables. The scientist showed the ecological, socio-economic, demographic reasons for the spread of epidemics in the city, connecting

the epidemic of 1915–1916 with a large number of new residents, in particular refugees, as well as a lack of sanitary doctors.

A separate section of «Kharkiv medical journal» consisted of minutes of meetings of the Kharkiv Medical Society, reviews of its activities, articles about the work of various departments of the Medical Faculty of Kharkiv University, hospitals.

Each issue of the «Kharkiv medical journal» contained reviews of new medical literature, including from epidemiological affairs, hygiene. Special attention was paid to the study of infectious diseases of the region, the conditions for the spread of epidemics and the fight against them.

Sanitary doctor of Kharkiv P. Lashchenkov, and then privat-associate professor of Kharkiv University, head of the Sanitary Department of the Kharkiv city council V. Favr in 1901–1906 edited the periodical «Reports about the medical and sanitary organization and epidemic diseases of Kharkiv» («Сведения о врачебно-санитарной организации и эпидемических заболеваниях г. Харькова»). V. Favre described his predecessor as editor as «a talented, educated and tireless worker», who was the first to «take on the task of systematic comprehensive development of the sanitary organization and sanitary needs of the city» (Favr: 1905, 1).

The monthly «Reports about the medical and sanitary organization and epidemic diseases of Kharkiv» contained extremely important information, in particular static data on the number of patients, measures for the prevention and control of infectious diseases. The journal regularly published reports of the city council «Information on epidemic diseases» («Distribution of epidemic diseases in the city»). In the reports of the city council, reports of sanitary doctors of Kharkiv (P. Lashchenkov , V. Favr) and other well-known infectious diseases specialists published digital data (sometimes with details by districts and hospitals of Kharkiv) on patients with smallpox, influenza, diphtheria, measles, whooping cough, scarlet fever, relapsing typhus, typhoid fever, typhus, tuberculosis, cholera, plague. The number of patients with syphilis was also indicated as the main sexually transmitted disease of the study time.

In addition to the reports, the journal «Reports about the medical and sanitary organization and epidemic diseases of Kharkiv» contained regulations on conducting medical examinations in schools, colleges, colonies, and boarding houses that are mandatory for not only doctors, but all residents of Kharkiv. The journal published results of testing water quality, plans for anti-cholera, anti-plague or anti-diphtheria measures in Kharkiv.

The periodical «Reports about the medical and sanitary organization and epidemic diseases of Kharkiv» published survey data for keeping streets, markets, cemeteries, public toilets clean; assessments of the work of school and sanitary doctors, etc. The results of constant sanitary supervision of sellers of milk and meat in the markets; inspections of farms engaged in the production of milk and meat products were published.

It was constantly reported on the operation of the city disinfection chamber, the number of disinfections of public premises and private apartments.

For information support of measures aimed at prevention and control of epidemics and infectious diseases, the Kharkiv city council also published leaflets and brochures as appendices to the journal «Reports about the medical and sanitary organization and epidemic diseases of Kharkiv». For example in 1901 P. Lashchenkov published a brochure «Tephroid typhus in Kharkiv (1885–1900)»: a report to the Kharkiv branch of the Russian society for public health protection», in 1904 – a brochure «Hygiene detachments in the theater of military operations».

The Sanitary bureau of the provincial zemstvo council in 1897–1916 published the periodical «Medical chronicle of the Kharkiv province» («Врачебная хроника Харьковской губернии»), which also published various information about the disease of the population of the city and the province as a whole for infectious diseases.

Articles on the epidemic case were also published by other Kharkiv journals: «Bulletin of medicine» («Вестник медицины», 1896–1897), «Questions of the health of the city of Kharkov» («Вопросы оздоровления города Харькова», 1906–1907).

Zooveterinary periodicals in Kharkiv played a positive role in the prevention and treatment of infectious diseases not only of domestic animals, but also of people. «Veterinary bulletin» («Ветеринарный вестник» 1882–1895), which was published by professor of the Kharkiv veterinary institute P. Gordeev for 13 years. The journal has published more than 40 works devoted to the topic of anthrax in cattle and about 30 articles on tuberculosis of domestic animals. On the pages of the «Collection of works of the Kharkiv veterinary institute» («Сборник трудов Харьковского Ветеринарного института», 1887–1919), the largest number of publications on individual diseases was devoted to the problems of detection and treatment of anthrax and sapa in domestic animals. Each issue of both periodicals contained a variety of preventive advice for agricultural workers how to avoid diseases of the eyes, stomach and other human organs, injuries, etc., while caring for animals.

Local newspapers and magazines reported on various scientific and popularization activities. For example in 1881 an anti-diphtheria congress was held in Kharkiv. Regularly, especially during epidemics, Kharkiv newspapers published announcements about vaccinations and other sanitary-epidemic measures, reports on testing drinking water in water supply and open sources, problems of unsanitary conditions in places where people and animals gather.

Newspapers and magazines (including those of a non-medical profile) constantly gave sound advice on keeping the body and home clean, boiling water and milk, heat treatment of products, etc. Most of such sanitary and hygienic rules for citizens who planned to rest at resorts were contained in such Kharkiv journals as «Bulletin of balneology, climatology and physiotherapy» («Вестник бальнеологии, климатологии и физиотерапии», 1910–1911), «Bulletin of resorts and medical

institutions» («Вестник курортов и лечебных учреждений», 1908–1916) and «Healthy life» («Здоровая жизнь», 1909–1911).

For written citizens who had access to newspapers and magazines, following the rules of general hygiene sometimes saved lives. It is known that more affluent and educated residents of Kharkiv almost did not have dysentery.

Results. Kharkiv medical journals of the second half of the XIX – early XX centuries made a significant contribution to the development of various spheres of medical education and science. In addition, medical periodicals played a significant role in the dissemination of popular scientific knowledge, including hygiene, epidemiology, veterinary medicine. These periodicals contributed to the better organization of sanitary and epidemic affairs in Kharkiv, played a positive role in the prevention and treatment of infectious diseases of the city's residents.

Conclusions. A short analysis of the Kharkov periodicals of the second half of the XIX – early XX centuries shows the high scientific relevance of those topics and the need for further detailed research of specialized medical journals of that period in order to study the experience of the work of the sanitary-epidemiological service of the city of Kharkiv

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FROM THE TSARIST EMPIRE TO THE RUSSIAN-UKRAINIAN WAR: THE MANAGEMENT OF WATER IN DONBAS AND CRIMEA, AN ECONOMIC, SOCIAL AND POLITICAL ISSUE

***Dan Ziehli**, MA,*
University of Geneva, Switzerland

Introduction. The outbreak from 2014 of a post-Soviet territorial and then armed conflict between Russia and Ukraine has resulted from its outset in the use, targeting or damage of key water supply infrastructures, both after 2014 and after 2022. This is particularly the case in two regions that are disputed or in the grip of a local rebellion, namely the Crimean peninsula and part of the Seversky Donets river basin (the Donbas) – two regions that have historically had a water deficit and are supplied by former Soviet canals from the Dnieper river. We believe it is necessary to investigate past water management in these two regions and its consequences in order to assess its influence on the problems of independent Ukraine after 1991 and after 2014. In other words, can Tsarist and then Soviet water management in the Donbas and Crimea, and more broadly in the territory of present-day Ukraine during the 19th and 20th centuries, shed light on the economic, social and political issues faced by post-Soviet Ukraine after 1991, and on the recent use of water in times of

conflict since 2014 onwards? In particular, how do such contemporary issues manifest themselves on the basis of a post-Soviet legacy of infrastructures and water networks planned by Moscow when Ukraine and Russia did not yet have proper national borders?

Data and methods. The management and use of water resources in Crimea and Donbas throughout history and to the present remains a subject which has been little studied. Historical documents used in this research are a few articles of the soviet geo-engineering publication *Hydraulic Engineering* (*Gidrotekhnicheskoe Stroitel'stvo*) which were published between 1967 and 1975 and translated to English (Razin et al., 1967; Karpenko et al., 1975; Abroskin, 1975). Such documents deal with the state of water resources in Soviet Ukraine, the hydro-economic and environmental situation in Donbas and Crimea as well as features and projects of water supply canals in these two regions. Furthermore, available literature in French, English or German on these two regions' water resources is scarce and fragmentary, the issue being often treated in wider topics such as industrialisation and general history of these areas or of Ukraine within the Tsarist Empire and the Soviet Union. Nonetheless and among others, the researches of Theodore H. Friedgut and Hiroaki Kuromiya on the industrialisation and urbanisation of Donbas from the Tsarist era to the Soviet one are a precious literature (Friedgut, 1989; Kuromiya, 1998). On Crimea, the general history of the peninsula by Neil Kent is also a valuable reference on various events and datas, sometimes little known, for the whole timelapse of our research (Kent, 2016). More broadly, the wide and complete research of Paul R. Josephson et al. on the environmental history of the Russian Tsarist empire and the Soviet Union offers us an essential historical framework of the Tsarist and Socialist Soviet policies in the Ukraine, Crimea and Donbas of the 19th and 20th centuries (Josephson and al., 2013).

Results. It appears to us that the accelerated industrialisation, urbanisation and economic development of the Donbas and Crimea, under Tsarism and then Soviet socialism – in different key periods of post-war growth and reconstructions – have depleted and polluted the meagre water resources of these two regions and, in so doing, have given rise to frequent health and epidemic crises. At the same time, we are also seeing the transformation of the Dnieper as a necessary source of hydroelectricity for this industrial and agricultural development in the surrounding regions, including the Donbas and Crimea. The construction of Soviet water supply canals in the 1950's and 1970's to alleviate the water shortage in the Donbas and Crimea therefore appears to be a response contained within the borders of Soviet Ukraine, with two of these canals bringing water from the Dnieper to these two regions, and not from the River Don in the case of the Donbas.

When Ukraine became independent in 1991, in addition to the serious depletion of the waters of the Donbas and Crimea, the new state inherited a huge amount of industrial and urban pollution linked to the inadequacy of water-treatment systems, exacerbated by the economic depression that was then beginning. Nevertheless, cross-border cooperation with Russia began very quickly, from 1992, and led to

notable successes in managing the flow of rivers in the Seversky Donets basin in the 1990's, even though a territorial conflict between Kiev and Moscow was emerging around Crimea and the Sea of Azov. As a result, a political issue around the North Crimean Canal rapidly emerged after 1991, against a backdrop of Crimean separatism. The dilapidated water network in the heart of Donbas and the dramatic economic and health situation in Crimea up until the early 2010's then formed the backdrop to the conflict that began in these two regions in 2014.

The crisis in Crimea and its annexation by Russia in March 2014 were followed by Ukraine's blockade of the canal bringing water from the Dnieper, wiping out agriculture on the peninsula. As the Donbas slipped into the spiral of war, artillery shelling frequently hit the water infrastructures, cutting off access to water for an often large and dense population. The armed conflict therefore leads to the resurgence or aggravation of water-borne diseases, and also accentuates the problem of aquatic pollutants, some of which may also come from destroyed industries. In annexed Crimea from 2014, and then in the annexed part of Donbas from 2022, the construction of new water networks by Russia, alongside old Soviet ones, appears to be a major issue in Moscow's policy of annexing these territories, this by integrating their water and hydroelectric infrastructures into Russian territory. Russia's construction of a major pipeline to supply water to the annexed Donbas from the Don, which came into service in August 2023, is a case in point.

Conclusion. Given the significant influence of past water management on the affairs of Ukraine after 1991 and after 2014, we can hope that sufficient access to water for the populations will be an integral part of a peace process.

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RADIOACTIVE LEGACY: THE IMPACT OF CHERNOBYL ON GLOBAL ENVIRONMENTAL POLICY

Olha Honcharova, *PhD, As. Prof.,*
H. S. Skovoroda Kharkiv National
Pedagogical University, Ukraine

Introduction. The Chornobyl disaster on April 26, 1986, became one of the most significant man-made catastrophes in human history, the consequences of which are still felt today. This event affected millions of people's ecosystem and health and significantly changed the global attitude toward nuclear energy and environmental responsibility. In response to the disaster, international safety standards were established, new agreements were ratified, and cooperation mechanisms were introduced to prevent similar tragedies in the future. Chornobyl symbolized the need to account for ecological risks in political decision-making, which is especially important in contemporary challenges such as climate change, ecosystem degradation, and the energy crisis. The topic also allows for a rethinking of the lessons of the past. It contributes to the formation of effective global environmental policies focused on safety, cooperation, and the sustainable use of natural resources. Thus, the study of Chornobyl's impact on global environmental policy is a historical analysis and a significant contribution to understanding contemporary approaches to environmental responsibility, which is essential for ensuring sustainable development.

Data and Methods. Since the research is interdisciplinary, it requires various scientific research methods. First and foremost, a problem-chronological method was employed, which allowed for constructing problem-causal connections. Statistical methods were used to assess changes in public health (especially vulnerable groups, such as children) after the disaster and to study its impact on the environment. The comparative analysis method allowed for tracking political and legal changes in countries affected by the Chornobyl disaster and its influence on energy policies at the international level. This approach enables the creation of a comprehensive understanding of the impact of the Chornobyl accident on global environmental policy, including changes in regulatory and political approaches to nuclear energy, environmental safety, and sustainable development.

Results. The Chornobyl disaster affected the environment and the health of millions of people. As a result of the explosion at the 4th reactor, approximately 5% of the radioactive materials from the reactor's core were released into the atmosphere, including iodine-131, cesium-137, and strontium-90. The contamination spread across the territories of Ukraine, Belarus, Russia, and many European countries, including Scandinavia. In total, about 200,000 square kilometers were affected. In the 30-kilometer exclusion zone, radiation levels became so high that they became life-threatening. Over 350,000 people were evacuated from the most contaminated areas. The population that remained in the

contaminated regions experienced significant social and psychological stress due to the loss of homes, changes in their way of life, and stigmatization. Hundreds of thousands of people were exposed to elevated radiation doses, leading to an increase in cancer cases, particularly thyroid cancer, especially among children (Baranovska, 2011). The impact of radioactive contamination on the environment included the death of forests (the so-called "Red Forest"), changes in ecosystems, and long-term contamination of soils and water resources. Radioactive materials continue to affect the environment due to their long half-life, complicating the restoration of contaminated areas.

After the Chornobyl disaster, the world recognized the importance of enhancing safety standards for nuclear power plants to prevent similar catastrophes. The International Atomic Energy Agency (IAEA) had already developed safety recommendations for nuclear facilities before Chornobyl, but it was after the 1986 disaster that these safety standards were significantly revised. The IAEA initiated new international norms and guidelines for all countries using nuclear energy. Specifically, requirements were developed for 1) the reliability and safe operation of nuclear power plants (all countries were required to meet stricter standards for the construction, operation, and maintenance of nuclear plants, including regular safety checks and the introduction of new technologies to prevent catastrophic incidents); 2) international information exchange (the importance of data and experience sharing among countries operating nuclear power plants was emphasized, particularly regarding emergency situations) (Los, 2023). A key agreement was the "International Convention on Assistance in the Case of a Nuclear Accident," which facilitated the creation of a mechanism for international cooperation in cases of radiation hazards. This agreement allowed countries to provide mutual assistance in the event of nuclear accidents, including delivering specialized materials, technical support, and medical resources. After Chornobyl, many countries, particularly in Europe, initiated the strengthening of their national safety standards and developed new systems for disaster prevention. One of the most important measures was international cooperation and joint safety inspections, which involved the creation of a network of international inspectors and partnerships to oversee nuclear plant safety (Bilotskyi, 2016). This helped improve the monitoring of nuclear facilities.

The Chornobyl disaster not only led to devastating consequences for human health and the environment but also changed society's perception of nuclear energy on a global scale. Chornobyl became a catastrophic incident that forced many people worldwide to reassess their views on nuclear power. It became clear that nuclear accidents, even with the use of the most advanced technologies, had unpredictable and dangerous consequences for health, nature, and society. This raised doubts about its safety as an energy source and prompted a rethinking of state policies in the energy sector. Many countries abandoned nuclear energy or significantly reduced its use (e.g., Sweden and Austria). Energy policies shifted toward developing alternative and renewable energy sources like solar, wind, and hydropower. In

particular, Germany and Denmark became leaders in developing wind and solar energy technologies (Shulha, 2019).

Chornobyl also became a catalyst for the development of various anti-nuclear movements worldwide. One example is Germany, where a mass anti-nuclear movement emerged, opposing the use of nuclear energy. This movement led to the decision to gradually phase out nuclear power plants, known as the "Energy Transition" (Energiewende). In some countries, the construction of new nuclear power plants was halted due to public opposition and growing concerns about their safety (e.g., in the United States and Europe) (Lir, 2017).

Conclusions. The Chornobyl disaster exemplifies how a local environmental crisis can have global consequences. The catastrophe served as a reminder of the need to consider the long-term environmental impacts of any industrial or technological decisions. It laid the foundation for strengthening environmental safety standards at all levels. Just as with climate change, addressing the aftermath of Chornobyl required the involvement of many countries, highlighting the importance of global partnerships in solving environmental crises. This experience contributed to developing crisis prevention mechanisms and increased focus on renewable energy as a key component in the fight against climate change. The Chornobyl disaster became an essential signal for the world, reminding us of the need to align economic development with environmental safety and long-term sustainable development goals. It changed approaches to energy policy, integrated environmental considerations into global strategies, and served as a lesson in tackling other global environmental challenges.

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LOW–VALUE NON–CURRENT TANGIBLE ASSETS IN THE ACTIVITIES OF AN ENTREPRENEUR: RECOGNIZATION AND USE

Yuliia Hrybovska, *PhD, As. prof., As. Prof. of pedagogy, psychology and management Department, Bila Tserkva Institute of Continuous Professional Education, Ukraine*

Introduction. In the modern conditions of doing business in Ukraine, low-value non-current tangible assets play an important role in ensuring operational efficiency, especially for small enterprises. They allow to implement current functions without the need for significant capital investments (Butynskyi, 2020). Low-value non-current tangible assets include objects with a short or medium service life and relatively low cost – tools, furniture, inventory, office equipment, workwear, computers, measuring instruments, etc (Kuzmin et al, 2021).

Correct recognition and accounting of such assets directly affects financial reporting, depreciation deductions and the tax burden of the entrepreneur (Nazarenko, 2019). The lack of clear definitions of low-value non-current tangible assets in tax legislation creates legal uncertainty, which determines the relevance of this study (Verkhovna Rada of Ukraine, 2010).

Data and Methods. The following methods were used in the research process:

- analytical method – to study the norms of the Tax Code of Ukraine;
- logical-structural analysis – to identify classification features of fixed assets (Diakiv, 2022);
- comparative method – to distinguish fixed assets and low-value non-current tangible assets;
- systematic approach – to formulate practical recommendations on accounting.

Results. Low-value non-current tangible assets do not have a separate definition in the Tax Code of Ukraine, but in practice they are classified according to the following criteria:

- the presence of a material form;
- a period of use of more than 1 year (or operating cycle);
- the cost of a unit of the object up to 20,000 hryvnias (excluding VAT).

Low-value non-current tangible assets differ from low-value perishable items primarily in their service life. At the same time, for some objects this term is difficult to determine (for example, scissors or staplers can be used for less than or more than a year).

The features of some objects make it difficult to determine their service life, which creates uncertainties in tax accounting (Diakiv, 2022).

Methods of depreciation:

- Method «50/50»: 50% of the cost is charged upon commissioning, the rest upon write-off;

– Method «100%»: the full cost is charged in the first month of use (Nazarenko, 2019).

Table 1 – Comparative characteristics of the classification of objects

Name of the Object	Value excluding VAT (UAH)	Service Life	Classification
Canon printer	17,000	3 years	Low-value non-current tangible asset
Office chair	5,200	4 years	Low-value non-current tangible asset
Industrial printer	24,000	5 years	Fixed assets

Conclusions. Low-value non-current tangible assets are an important tool for optimizing small business costs. They:

– allow you to avoid excessive capital expenditures;
– reduce the tax burden;
– require streamlining accounting.

Given the lack of clear regulatory regulation, entrepreneurs need to:

– be guided by the criteria of service life and cost;
– maintain simplified accounting that reflects the commissioning of assets;
– apply recommended depreciation methods;
– the criterion of expenses up to 20,000 hryvnias (excluding VAT) is appropriate, but it should be revised in accordance with economic changes.

Given the lack of a regulatory classification of NMA, it is advisable to:

– develop unified methodological recommendations for entrepreneurs;
– periodically revise marginal costs taking into account inflation;
– ensure a unified approach to tax accounting at the level of the State Tax Service.

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ENVIRONMENTAL STRATEGY OF UKRAINIAN AVIATION ENTERPRISES IN THE CONDITIONS OF EUROPEAN INTEGRATION

***Ganna Kalashnyk**, Dr. Sc. (Geol.), Professor,*
***Mykola Belyaev**, Postgraduate student,*
Ukrainian State Flight Academy, Kropyvnytskiy, Ukraine

Introduction. The level of development of the transport system of Ukraine is one of the most important factors in the economic development of the national economy. When integrating into the European and world economies, the need for a highly developed environmentally safe transport system is increasingly increasing, it is becoming one of the fundamental principles of Ukraine's entry into the world community and occupying a worthy place in it, corresponding to the level of a modern highly developed state (Kalashnyk et al., 2024). The development of the domestic civil aviation sector was interrupted in Ukraine with the beginning of Russian aggression in February 2022. At the same time, the necessary starting conditions have been created in Ukraine for the integration of the domestic transport complex into the pan-European transport system. Today, Ukraine has a regulatory and legal mechanism that regulates the environmental aspects of civil aviation safety (Pro okhoronu navkolyshn′oho pryrodnoho seredovyshcha, 1991; Instruktsiya z ekspluatatsiyi aerodromiv derzhavnoyi aviatsiyi Ukrayiny, 2013). However, in the conditions of Ukraine's Eurointegration, it needs to be improved following international requirements and standards (ISO 14000; ISO 14001; ICAO, Doc. 10031, 2023; ICAO, Environmental protection, 2021; ICAO, Environmental Technical Manual, 2023).

Data and Methods. The analysis used international environmental standards of the ISO 14000 series, ICAO environmental standards, laws and regulatory documents of Ukraine that provide for the environmental safety of air transport. Methods used during the study: analysis methods, comparison and analogy method, generalization method**.**

Results. Modern global trends in the growth of environmental problems lead to more stringent environmental safety requirements for air transport enterprises. In the context of Ukraine's integration into the EU, especially after Ukraine's ratification of international environmental protection programs, additional incentives arise for domestic aviation enterprises to voluntarily implement international environmental standards of the ISO 14000 series, which is an important means of increasing their competitiveness. Environmental safety policies in accordance with the international environmental standards of the ISO 14000 series determine the relevance of research aimed at ensuring the greening of the aviation industry development strategy, as well as assessing the effectiveness of the selected environmental strategy, the implementation of which is a way to increase the competitiveness of aviation industry enterprises.

To form an effective environmental strategy at aviation enterprises in the conditions of Ukraine's European integration, it is necessary to consistently solve the following scientific and practical tasks:

- conducting an analysis of factors of the external and internal environment of the aviation enterprise (analysis, "value chain", analysis of data from the environmental passport of the aviation enterprise);
- determining the environmental goals and objectives of the aviation enterprise (environmentally oriented principles of activity, obtaining competitive advantages through environmental protection, certification according to ISO 14000);
- building an environmental strategy (determining the tools for its implementation; integrating the environmental factor into all functional areas) in accordance with current legislation;
- carrying out control, assessing the effectiveness of the introduction of the environmental strategy, and searching for reserves for its improvement.

These scientific and practical tasks must be solved based on both domestic and international experience in building an environmental strategy.

To form an optimal environmental strategy for aviation enterprises, we propose:

a) building an environmental management system taking into account: the possibilities of environmentally oriented reorganization of the organizational structure of the enterprise's management in the direction of integrating the environmental factor into functional units, forming an optimal investment portfolio based on environmentally oriented innovations, "joint implementation" projects (within the framework of the "flexible mechanisms" of the Kyoto Protocol (Kyoto Protocol, 2009);

b) selection and formation of an optimal environmentally oriented enterprise development strategy, assessment of the results of its implementation.

For a comprehensive assessment of the environmental strategy of aviation enterprises, it is proposed to use three areas of analysis: fulfilment of the environmental protection function, results of the development of the environmental protection function, effectiveness of the environmental protection function. The main criteria for a comprehensive assessment of the environmental strategy of an aviation enterprise by areas of analysis are as follows (ISO 14000; ISO 14001; ICAO, Doc. 10031, 2023; ICAO, Environmental protection, 2021; ICAO, Environmental Technical Manual, 2023):

A) For the analysis of the implementation of state environmental standards: 1) indicators of the implementation of the environmental protection function; 2) obtaining confirmation from all state regulatory organizations that the activities of the aviation enterprise comply with the requirements of environmental legislation; 3) the absence of excess discharges and emissions, the correctness of safe storage of waste at the industrial site; 4) the presence of all necessary documentation on the impact on the environment; 5) the presence of all the required licenses for integrated nature management, the presence of permits for the emission and discharge of pollutants; 6) the presence of payment certificates, developed and approved

documentation (standards for maximum permissible emissions and discharges, draft waste disposal limits); 7) the presence of an environmental passport of the enterprise.

B) For the analysis of the environmental management system of an aviation enterprise: 1) indicators of the effectiveness of the environmental protection function; 2) analysis of the environmental management system at the enterprise: the presence of an environmental policy that is communicated to the population and the public; the presence of environmental goals and objectives; environmental policy and planning of activities in the field of environmental management; 3) the presence of management and programs for the environmental management system; a clear division of personnel responsibilities, including their training; 4) introduction of a package of environmental documentation necessary for the implementation of the environmental management system; 5) organization of activities in the field of the environmental management system; evaluation of results and consistent improvement of activities in the field of environmental management; 6) conducting a preliminary audit to determine the environmental aspects of the enterprise's activities; conducting a systematic audit to confirm the operability of the environmental management system.

C) To assess the effectiveness of the environmental strategy of an aviation enterprise: 1) indicators of the result of the development of the environmental protection function; 2) implementation of the principles of environmental policy: combining environmental goals and objectives with the goals and objectives of the development of the enterprise as a whole; conscious adoption and active support of environmental policy and obligations by the management of the aviation enterprise; 3) conscious use of the foundations of modern environmental culture and environmental ethics; division of responsibility; contribution to sustainable development; civilized entrepreneurship; 4) voluntary expansion of the enterprise's environmental obligations; health protection and environmental safety of personnel and the population in the area of influence of the enterprise; assessment of the impact on the environment; 5) support for environmental scientific research and environmental education; development of voluntary eco-insurance; environmental charity; 6) implementation of the principles of eco-efficiency; achievement of economic efficiency of the environmental protection activities carried out, improvement of the quality of products and services through the development of environmental activities.

The proposed approach to implementing environmental strategies through an environmental management system allows identifying the main environmental problems of an airline and ways to solve them.

Conclusions. The environmental strategy in the conditions of Ukraine's European integration includes: the development of resource-saving, environmentally friendly technologies for the operation of air transport, the use of alternative fuels and energy, the introduction of improved methods for assessing its environmental safety, in particular, the proposed method for assessing the environmental friendliness of air transport according to a substantiated system of criteria; methods

for identifying the main environmental problems of the enterprise and finding ways to solve them; the implementation of an environmental control system; changes in the organizational structure; the formation of an environmental policy and its adaptation, changes and improvements; the introduction of environmental factors into all aspects of the enterprise's activities. Using the proposed environmental strategy will allow the development of justified management decisions to increase the environmental safety of air transport and at the same time the competitiveness of the aviation enterprise.

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ENVIRONMENTAL ASPECTS OF THE BUILDING OF THE CITY OF SUMY (UKRAINE)

Oleksandra Borysenko, *student,*
Yurii Zaika, *PhD student,*
Vitalii Horbulenko, *PhD student,*
Maksym Pokutnii, *PhD student,*
Sumy State University, Ukraine

Introduction. Most regional centres of Ukraine are characterised by a complex environmental situation, due to the significant concentration of their population, industry, and transport. Urban ecosystems are characterised by an increase in the share of harmful emissions into the air, deterioration of the ecological state of water bodies, changes in land cover, etc. Due to the rapid development of natural landscapes in urban areas are changing quite dynamically. Due to the continuous urbanisation processes of the city of Sumy (despite the declared decrease in population), there is a change in land cover in urban and suburban areas under the influence of rapid socio-economic development.

Methods.

1) Analysis and synthesis.

2) Remote sensing of the Earth (searching, visualisation, analysis of load and short circuit of the research area from the EO Browser resource).

3) Statistical methods.

4) Illustrative and cartographic methods (creation of appropriate carto schemes).

Results. The result of urbanisation is not the accumulation of structures, but the emergence of an urbosystem, which includes a complex of interrelated anthropogenic, natural-anthropogenic and natural objects preserved in the urban area (Klymchyk et al, 2016). These changes can be detected using remote sensing and GIS technologies.

Analysing the Landsat 4-5 space image of June 5, 1984 (Fig. 1), we can conclude that during the specified period, the coastal strip of the reservoirs was not built up. Thus, the distance from Lake Chekha to residential quarters measured using a ruler tool is from 100 to 413 m, to the Psel River around the Kharkiv Bridge – 189 m, to the 10th microdistrict – 578 m. On the map images around Lake Chekha, we can visualise the beginning of hydro-washing of sand for the creation of residential quarters, and active building of 10th – 12th microdistricts begins.

Already in the Sentinel-2 satellite image of May 6, 2022, true colour, (combination of channels B4, B3, B2), the development of the coastal strip of the Psel River, Lake Chekha, the Airport, and the settlements of Sad and Kosivshchyna, which form the suburban zone, is clearly visible (Fig. 2).

Fig. 1. Development of the city of Sumy in 1984 (Landsat 4-5 space image (combination of B5, B4, B3 channels) for June 05, 1984). Source: made by authors using EO-Browser (2025)

Fig. 2. Development of the city of Sumy in 2022 (Sentinel-2 space image for May 6, 2022 (false Colour Urban composite, combination of channels B12, B11, B04)). Source: created by authors using EO-Browser (2025)

The last years before the full-scale invasion of Russia in Ukraine were characterised by high rates of housing construction in the city of Sumy. As a result of the development of the city, a new ecological environment with a high concentration of anthropogenic factors was created. Intensive development affects the change in the microclimate of the territory, which can indirectly affect eutrophication and overgrowth of water bodies. Another negative consequence of the impact on the environment is the natural landfills, the dumping of contaminated or insufficiently

treated wastewater. Industrial enterprises of the city, particularly PJSC "Sumy Khimprom", pollute the atmospheric air with ammonia, superphosphates and apatites. Sumy CHP does not have the latest filtering devices, so its emissions are dangerous for residents of Shevchenko Avenue and adjacent streets.

Conclusions. In Sumy and suburban areas, the absolute and relative indicators of land occupied for residential construction are growing intensively. The main areas of development are located on the left bank of the Psel River and around Lake Chekha. If we talk about the ecological aspects of urbanisation, a large city changes almost all components of the environment: atmosphere, vegetation, soil, relief, groundwater and even climate.

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IMPLEMENTATION OF RENEWABLE ENERGY GUARANTEES OF ORIGIN: A TOOL FOR ACCELERATING THE POST-WAR ENERGY TRANSITION IN UKRAINE

Tetiana Kurbatova, *PhD in Economics, As. Prof.,*
Tetiana Perederii, *PhD student*
Sumy State University, Ukraine

Introduction. The expansion of renewable energy (RE) is essential for Ukraine's post-war recovery and integration into the European energy market, with Guarantees of Origin (GOs) – introduced under EU Directive 2018/2001 – emerging as a key instrument to support this transition.

Data and Methods. This analysis is based on a review of EU GO markets, historical pricing trends, Ukrainian legislative developments, and current integration efforts with ENTSO-E. Comparisons are drawn using market data from 2000–2023 and legal documents from Ukraine and the EU.

Results. GOs was introduced in the EU countries under the requirements of the European Directive No. 2018/2001 "On the promotion of the use of energy from renewable resources". Confirm that a certain 1MWh of renewable electricity. By purchasing GOs, companies can prove that their electricity is environmentally

friendly. GOs are an effective tool for decarbonizing the economy, calculating greenhouse gas emissions reduction, preparing corporate reporting on sustainable development, attracting green financing, etc. Thanks to the single European market and the Association of Issuing Bodies, which unifies the issue, sale, and cancellation of GOs, they can be traded in Europe outside their country of origin.

Although GOs are primarily designed for businesses and large energy consumers, households can also benefit from them. Many energy suppliers offer RE tariffs backed by GOs, allowing households to ensure that their electricity consumption is matched by an equivalent amount of renewable electricity in the grid. In some EU countries, households can purchase GOs directly to compensate for their electricity use, further promoting green energy adoption. Expanding consumer awareness and accessibility of GOs can enhance public participation in the RE transition and create additional incentives for investments in clean power generation.

It should be noted that GOs are particularly relevant for Ukraine given the integration of its energy system into ENTSO-E and the potential increase in green electricity exports to the EU post-war. Implementing this tool can generate additional income to support RE development through state mechanisms. GO prices are market-based and influenced by factors such as country of origin and type of RES. As renewable electricity generation grows, GO demand rises, leading to a general price decline. For instance, wind electricity in Germany dropped from EUR 5/MWh in 2000 to EUR 1/MWh in 2020; solar in the Netherlands fell from EUR 45 to EUR 5/MWh. Consequently, in 2020, GOs were traded at or below EUR 1/MWh on the European market (Future, 2022).

However, in recent years, a significant price increase for them has been observed in Europe. One of the main factors that influenced it was the shortage of hydropower generation, which affected the demand for GOs. Although the solar and wind energy markets are developing rapidly, hydropower still occupies the largest share of the EU renewable electricity mix. The share of issued hydropower GOs is 60-70% over the last 3-5 years of their total number. Other influencing factors were the growing demand for GOs from corporate buyers seeking to achieve targets for reducing emissions (Future, 2023). Thus, in the coming years, prices for GOs are expected to rise, which makes them a promising tool for promoting RE development.

Although the legislative foundations for adopting GOs were established in Ukraine in 2013, the first steps towards implementing this instrument began only in 2023, when the law “On Amendments to Certain Laws of Ukraine on the Restoration and Green Transformation of the Energy System of Ukraine”, was adopted (Law, 2023). However, the GOs has not yet been implemented. Currently, negotiations are underway to create a regional platform for their registration and support its functioning by developing appropriate software.

It is worth noting that currently, European legislation does not allow the circulation of Ukrainian GOs within the EU. Member states must not recognize GOs issued by a third country. An exception is the conclusion of an agreement between the EU and a third country on mutual recognition of GOs if there is a direct import

or export of electricity. Therefore, at present, the creation of a regional hub is the only possibility for exporting Ukrainian GOs. In the future, cooperation on making appropriate changes to EU legislation, which would open up the possibility of free circulation of Ukrainian GOs in Europe, is of utmost importance.

Conclusions. Implementing GOs presents a significant opportunity for Ukraine to accelerate its RE transition and strengthen its integration into the European energy market. As a proven mechanism for certifying renewable electricity, GOs can enhance transparency, attract green financing, and contribute to Ukraine's economic recovery, energy security, and sustainable development.

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DEVELOPING MEDIATION SKILLS OF FUTURE SOCIAL WORKERS DURING PRACTICAL TRAINING AS A FACTOR OF SUSTAINABLE DEVELOPMENT

Iryna Halchych, *PhD Student,*
Ukrainian State University named after
Mykhailo Drahomanov, Ukraine

Introduction. Sustainable development requires not only economic and environmental stability but also strong social cohesion. Social workers play a crucial role in maintaining societal well-being by assisting vulnerable populations, resolving conflicts, and promoting inclusion. One of the key skills that enhance their effectiveness is mediation—the ability to facilitate dialogue, prevent conflicts, and support peaceful resolutions.

Mediation is particularly important in today's world, where economic inequalities, migration, and social transformations lead to increased tensions. Social workers often work in crisis situations, helping individuals and communities

navigate conflicts. Therefore, equipping future professionals with mediation skills is essential for achieving long-term social stability and sustainable development.

The aim of this study is to analyze the importance of mediation skills for social workers and explore effective training methods during their practical education. The research also evaluates how mediation training contributes to sustainable development by fostering social harmony and reducing conflicts at various levels.

This paper examines the role of mediation skills in social work, explores best practices for integrating mediation training into practical education, and discusses the broader impact of these skills on societal sustainability.

Mediation is a structured process where a neutral third party helps conflicting parties reach a voluntary agreement. In social work, mediation plays a key role in:

– Reducing social conflicts – helping individuals and groups resolve disputes peacefully.

– Enhancing social inclusion – promoting communication between diverse social groups.

– Improving service efficiency – reducing administrative and legal burdens through non-judicial conflict resolution.

– Supporting vulnerable populations – assisting marginalized groups in defending their rights and accessing resources.

In the context of sustainable development, mediation contributes to long-term social stability by fostering cooperation and reducing the negative impact of unresolved conflicts. Countries with strong mediation practices report lower crime rates, better integration of minority groups, and increased trust in social institutions.

Integrating mediation training into social work education is essential for preparing future professionals. The following methods have proven effective:

1. Interactive Learning and Simulations. Role-playing and conflict simulations allow students to practice mediation in a controlled environment. By engaging in realistic case studies, they develop problem-solving skills and learn how to handle emotional tensions.

2. Field Practice in Social Institutions. Practical internships in social service agencies, community organizations, and NGOs expose students to real-life conflicts. Under supervision, they gain hands-on experience in mediation and conflict resolution.

3. Multidisciplinary Approach. Combining social work, psychology, and law helps students understand mediation from different perspectives. Knowledge of legal frameworks and psychological dynamics enhances their ability to mediate effectively.

4. Digital Mediation Training. With the rise of digital transformation, virtual mediation tools and online conflict resolution platforms have become valuable resources. Introducing students to digital mediation prepares them for future challenges in online communication and dispute resolution.

5. Collaboration with Experienced Mediators. Inviting professional mediators to workshops and guest lectures provides students with insights into best practices and ethical considerations. Learning from real-life cases helps students refine their skills.

The integration of mediation skills into social work training contributes to sustainable development in several ways:

Building Resilient Communities: effective mediation reduces long-term social conflicts, leading to greater societal resilience.

Reducing Legal and Economic Costs: mediation decreases the need for litigation and costly social interventions, saving public resources.

Enhancing Social Integration: mediators promote dialogue between diverse communities, supporting social cohesion.

Supporting Mental Well-being: resolving conflicts peacefully reduces stress and psychological trauma among individuals and families.

As Europe continues to pursue sustainable growth, investing in the professional training of social workers, including mediation competencies, should be a priority. Social harmony and conflict prevention directly contribute to achieving the United Nations Sustainable Development Goals (SDGs), particularly Goal 16 (Peace, Justice, and Strong Institutions).

Data and Methods. This study employs a mixed-methods approach, combining qualitative and quantitative data collection techniques. The following research methods were used:

Literature Review – Analysis of existing research on mediation in social work, sustainable development, and conflict resolution. Academic sources, policy documents, and reports from organizations such as the United Nations Development Programme (UNDP) were examined.

Survey of Social Work Students – A questionnaire was distributed among 150 social work students from universities in three European countries (Germany, Poland, and Ukraine). The survey focused on their knowledge of mediation, practical training experiences, and perceived effectiveness of mediation techniques.

Interviews with Social Workers and Educators – Semi-structured interviews were conducted with 20 social workers and 10 university educators to gather insights into the effectiveness of mediation training in professional practice.

Case Study Analysis – Real-life case studies from social institutions and community mediation programs were analyzed to assess the impact of mediation in preventing conflicts and promoting social inclusion.

The collected data was analyzed using thematic analysis for qualitative data and statistical analysis (mean, standard deviation, and correlation analysis) for quantitative data.

Results. The survey results indicated that 85% of social work students recognized mediation as a critical skill for their profession. However, only 40% reported receiving formal mediation training in their university curriculum. Interviews with practitioners confirmed that mediation skills significantly enhance the ability of social workers to manage conflicts and promote cooperation.

Among the students who participated in mediation training, the most effective methods were:

– Role-playing and simulations (78% effectiveness rate) – Students found interactive scenarios useful in developing conflict resolution strategies.

– Internships in social institutions (71% effectiveness rate) – Practical exposure helped students understand real-life conflict situations.

- Workshops with professional mediators (64% effectiveness rate) – Learning from experienced mediators provided valuable insights into practical applications.

The study found that mediation skills directly contribute to sustainable development by:

– Reducing social tensions – communities with active mediation programs reported fewer interpersonal and intergroup conflicts.

– Enhancing social inclusion – mediation facilitated dialogue between marginalized groups and mainstream society.

– Lowering legal costs – mediation prevented the escalation of disputes, reducing the burden on judicial systems.

Discussion. The findings suggest that while social work students recognize the importance of mediation, there is a gap in formal training programs. Universities should integrate mediation education into their curricula, emphasizing experiential learning. Additionally, collaboration between academic institutions, NGOs, and government agencies can enhance practical training opportunities.

Furthermore, the study highlights the need for digital mediation tools, as online conflict resolution is becoming increasingly relevant in the era of digital transformation. Future research should explore the role of artificial intelligence and virtual mediation platforms in social work practice.

Conclusion. Mediation skills are essential for future social workers to effectively contribute to sustainable social development. Practical training programs must incorporate conflict resolution techniques, interdisciplinary approaches, and digital mediation tools to prepare professionals for modern challenges. Well-trained social workers can play a pivotal role in fostering inclusive, stable, and cooperative societies, which are fundamental to Europe's long-term sustainability.

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RESTORATION AND REINTRODUCTION OF EXTINCT FISH SPECIES: SYNERGY OF SCIENCE, ECOLOGY, AND ECONOMY

Kostiantyn Fomenko, *postgraduate*
Andrii Khomenko, *PhD*
Maryna Petrushko, *D.Sc., Prof.*
Institute for Problems of Cryobiology and Cryomedicine of the National Academy of Sciences of Ukraine

Introduction. Various anthropogenic factors, including military aggression against Ukraine, lead to environmental pollution, threatening the loss of the gene pool of endangered species. Cryopreservation technologies enable the accumulation and long-term storage of reproductive cells and embryos of many animal species (Kopeika et al, 2019). The collection of fish reproductive cells in the Cryobank of the Institute for Problems of Cryobiology and Cryomedicine of the National Academy of Sciences of Ukraine, which holds the status of a National Heritage, contains more than 300 sperm samples of rare, endangered, and extinct fish species. The restoration of fish biodiversity is a priority for many countries that implement various programs and strategies adapted to their ecological conditions and challenges. Thanks to the innovative developments of the Institute for Problems of Cryobiology and Cryomedicine of the National Academy of Sciences of Ukraine, it is possible to restore and reintroduce species that are considered extinct. The aim of this study was to determine the pathways for implementing a program for the restoration of extinct fish species.

Materials and Methods. This study employed a comparative analysis of biodiversity restoration programs in different countries worldwide and combined the results with practical experience.

Results. In 2020, the European Commission adopted the new EU Biodiversity Strategy for 2030, which includes an action plan for nature conservation and ecosystem restoration. Different countries implement specific fish biodiversity restoration programs, considering their unique ecological conditions and challenges. Common elements include the restoration of natural habitats, the removal of migration barriers, and the breeding of endangered species. In 2020, 14 countries, including Australia, Canada, Japan, Mexico, Norway, and Portugal, signed agreements on biodiversity restoration. Most European countries pay significant attention to the conservation of genetic materials of rare fish species in low-temperature cryobanks (da Costa et al, 2024). Using genetic material from cryostorage enables practical results in species restoration, even when wild populations are critically low. Ukraine is actively working on adapting its national biodiversity conservation strategy to global goals. A project is currently being implemented to align Ukraine's strategy with global biodiversity objectives.

For successful species restoration, it is crucial to ensure the use of effective cryopreservation methods and sustainable low-temperature storage of fish

germplasm. The next step should involve the restoration of fish populations in controlled conditions. Before reintroducing the species into the wild, it is essential to select an optimal release site, considering ecological requirements. Monitoring the survival, reproduction, and interactions of the restored species with other species is also vital (Rivers et al, 2020).

Conclusions. The conservation of genetic resources through cryopreservation is a crucial tool for maintaining biodiversity and enables the future restoration of fish species that are considered extinct.

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VIRTUAL EXCHANGE AS A TOOL FOR INTERCULTURAL LEARNING AND EUROPEAN IDENTITY BUILDING[1]

Inna Koblianska, *PhD, As. Prof.,*
Sumy State University, Ukraine

Introduction. Virtual exchange (VE) today serves as a valuable supplement to traditional offline learning, offering opportunities for collaboration with peers from other countries. VE opens a world of intercultural teamwork to those who face social, geographical, or economic barriers to participating in traditional mobility and learning activities. In some cases—such as in Ukraine—virtual exchange may be the only available opportunity to gain experience in teamwork and intercultural communication. In certain contexts, the role of VE becomes even more significant due to geopolitical challenges and the threats posed by disinformation and propaganda. This research aims to demonstrate the relevance and importance of VE

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in the context of the ongoing russian-Ukrainian war and its impact on the European area, democratic movements, and shared values.

Data and methods. This research draws on available analytical data to illustrate social trends in Eastern European countries and the threats to the European trajectory posed by disinformation and propaganda, as well as the barriers to accessing international knowledge caused by social, economic, and geographical constraints. Through qualitative analysis of existing analytical and research data, the paper highlights the need to promote and implement virtual exchanges as a means to overcome these barriers, foster intercultural knowledge and skills, and strengthen European identity.

Results. One of the most influential analyses of labor market trends – the World Economic Forum's Future of Jobs Report 2025 [1] – highlights three transformative forces shaping tomorrow's workforce: technological advancement and digital innovation accelerating the need for digital literacy and proficiency in tech-related fields; climate change and sustainability concerns elevating environmental responsibility to the list of the top ten fastest-growing skills; demographic shifts pushing organizations to rethink talent acquisition and retention.

In response to these challenges, virtual exchanges have emerged as a dynamic approach to preparing young people for evolving job markets. In the U.S., a 2024 survey by the Stevens Initiative revealed a 39% growth in VE programs and a 23% increase in student participation since 2021. Collaborative Online International Learning (COIL) formats now make up 43% of these programs, often combining real-time and self-paced interactions. Interestingly, the landscape is becoming more international, with half of VE providers now based outside the United States [2].

Virtual exchange initiatives contribute to a broad range of educational outcomes, including: strengthening intercultural awareness and communication; advancing technological proficiency; enhancing creativity and critical thinking; deepening disciplinary knowledge; improving collaborative and teamwork abilities; supporting green skill development, especially when tied to sustainability-related content; promoting soft skills, such as leadership, adaptability, and time management.

Moreover, virtual exchange sometimes represent the only accessible international opportunity for learners affected by political restrictions, economic hardship, or geographic isolation. In a world marked by instability and uncertainty, VEs offer a flexible and inclusive path to global learning and understanding.

In Ukraine the war has deeply disrupted academic mobility, especially for male students, who are largely unable to travel abroad due to martial law restrictions. From January to April 2024, only 561 students (a mere 0.3% of new bachelor's entrants) were able to participate in mobility programs abroad [3-4]. These trends pose risks to the internationalization agenda and efforts to instil shared European values. Although public support for EU membership remains high (84%) and 60% of Ukrainians trust the EU, over half (53%) still do not identify themselves as Europeans. While the EU is associated with opportunities, it is not strongly linked to leadership in education, science, or innovation [5].

Georgia's trajectory toward European integration is complicated by political turbulence and social polarization. Public support for the EU has declined, with just 54% of citizens holding a favorable view as of the latest data. Only 30% believe that Europeans see Georgians positively, and nearly one-fifth of the population feels uninformed about the EU perceptions. Awareness of the EU–Georgia Association Agreement has dropped to a record low of 41% [6].

In terms of student mobility, Georgian youth face multiple hurdles: high travel costs, limited scholarship options, complex visa requirements, lack of credit recognition, and disparities between urban and rural institutions. Institutional support is often weak, and many universities rely heavily on Erasmus+ as their sole mobility channel. Nevertheless, 79% of young people in Georgia still view the EU positively [6], and mobility programs have helped maintain this support.

Many Moldovan students—especially those from rural or economically disadvantaged backgrounds – face significant obstacles to participating in international learning. Around 15% of the population lives below the poverty line, and nearly 50% are at risk of poverty [7], making traditional mobility programs financially inaccessible for many. While Moldova has fewer political restrictions than some neighbouring countries, equitable access to global education remains limited.

In Moldova public attitudes toward the EU are also sharply divided. Although a 2024 constitutional referendum narrowly supported EU integration (50.38%), pro-European aspirations coexist with persistent scepticism, often stoked by disinformation. russian-backed narratives targeting social and economic fears – such as threats to tradition, farming, and national security – amplify mistrust [7]. In this context, virtual exchange programs offer a crucial platform for Moldovan youth to engage directly with their EU peers, counter misinformation, and build mutual understanding rooted in shared democratic and European values.

Conclusions. Finally, in the context of the challenges currently facing Eastern European countries, the role of facilitating virtual exchanges (VEs) with European partners cannot be underestimated. By integrating partners from EU countries and Eastern Partnership nations—each facing distinct, yet interconnected challenges related to mobility, inclusion, and global engagement—VEs can serve as a powerful tool to strengthen EU identity and values.

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ECONOMIC MECHANISMS FOR STIMULATING VOLUNTEER ACTIVITIES IN THE CONTEXT OF COMMUNITY SUSTAINABLE DEVELOPMENT

***Tetiana Kuchmiiova**, PhD, As. Prof.,*
Mykolaiv National Agrarian University, Ukraine
***Victoriia Bilous**, Bachelor student*
Mykolaiv National Agrarian University, Ukraine

Introduction. Volunteer activity plays a key role in the socio-economic development of communities, especially in the face of the modern challenges that Ukraine has faced since 2022. Its transformational impact contributes to strengthening social cohesion, economic resilience, and expanding community opportunities by engaging the population in active participation in social processes. According to a study by the Democratic Initiatives Foundation, over 60% of Ukrainians are involved in volunteer activities, demonstrating a high level of civic engagement (Democratic, 2023). In this context, the question of economic mechanisms to stimulate volunteering becomes relevant, as effective support for this sector can significantly enhance its contribution to the sustainable development of the country.

Data and Methods. The aim of the study is to conduct a comprehensive analysis of the economic mechanisms for stimulating volunteer activity and their impact on the sustainable development of communities in Ukraine. The research focuses on assessing the effectiveness of various incentive mechanisms, considering both monetary and non-monetary approaches to enhance volunteer engagement.

The research methods are based on a mixed approach that includes both quantitative and qualitative analysis. Primary data sources encompass statistical information from the State Statistics Service of Ukraine and analytical reports from the National Institute for Strategic Studies, which provide a comprehensive dataset on volunteer engagement models and their economic consequences (National, 2023). The

Pro Bono Club Ukraine report indicates that volunteer activity spans several sectors, from social and humanitarian assistance to environmental initiatives and digital transformation projects (Pro Bono, 2023). Quantitative analysis allows for the assessment of the scale and economic effectiveness of volunteering, while qualitative analysis aims to identify the most effective stimulation mechanisms across various areas of civic activity.

Results. Volunteer activity plays a crucial role in community development, fostering social cohesion and economic resilience. Effective stimulation of volunteering requires actionable economic mechanisms, including tax incentives, municipal grants, and public-private partnerships. The results underscore the importance of integrating volunteering into local development strategies and forming systematic approaches to its support. The methodology for stimulating volunteering includes a complex cost-benefit analysis (CBA) system to assess the economic effectiveness of various support mechanisms for volunteers. This approach is complemented by econometric modeling using the USAID Civil Society Sustainability Index methodology, which provides standardized metrics for evaluating the development of the volunteer sector (USAID, 2023).

To reflect the dynamics of the volunteer sector's development in Ukraine from 2022 to 2024, key quantitative indicators have been summarized, illustrating the scale of volunteer engagement, the volume of financial support for initiatives, and the level of institutional support from the state. The consolidated data is presented in Table 1.

Table 1 – Key Indicators of the Development of the Volunteer Sector in Ukraine (2022–2024)

Indicator	2022	2023	Q1 2024
Number of registered volunteer organizations	2650	4452	4850
Number of active volunteers (million people)	5,3	8,4	8,9
Economic equivalent of volunteer activity (% of GDP)	4,7	5,2	5,4
Percentage of organizations with tax incentives (%)	21	35	47
Volume of funds raised through volunteer initiatives (billion UAH)	15,8	23,4	6,7
Number of implemented volunteer projects	4250	6870	1950

Source: compiled based on data (Ukrainian Philanthropists Forum, 2023; Ministry of Social Policy of Ukraine; State Tax Service of Ukraine, 2024).

The study revealed significant insights into the effectiveness of economic mechanisms for stimulating volunteer activity. According to the Ministry of Social Policy of Ukraine, communities that implemented comprehensive volunteer support programs demonstrated a 42% higher index of social cohesion and a 35% increase in economic resilience indicators (Ministry, 2023). Three key economic mechanisms were identified as particularly effective in enhancing volunteer engagement and optimizing resource utilization. Firstly, the system of tax incentives emerged as a powerful tool for encouraging corporate involvement in volunteer initiatives.

Research indicates that communities introducing comprehensive tax relief measures for businesses supporting volunteer activities experienced a 35% increase in corporate volunteer engagement. This finding underscores the effectiveness of fiscal stimuli in mobilizing private sector resources for community development. Secondly, the implementation of municipal grant programs has proven to be a critical factor in ensuring project sustainability. Communities that established structured grant support systems reported a 40% higher level of project resilience compared to those relying on ad hoc financing approaches, highlighting the importance of systematic financial support mechanisms. Thirdly, the integration of public-private partnership (PPP) models into the implementation of volunteer projects has shown remarkable outcomes, demonstrating a 45% improvement in resource mobilization efficiency. This result emphasizes the value of collaborative approaches that leverage the capacities of both public and private sectors to support volunteer initiatives.

An assessment by UNDP in Ukraine indicates that communities integrating volunteer activity into their local economic development strategies achieved a 30% improvement in resource allocation efficiency and a 25% enhancement in service delivery effectiveness (UNDP, 2023). These outcomes reflect a strong correlation between structured economic support for volunteering and improved community development results.

The research highlights the critical importance of developing systemic economic mechanisms for supporting and incentivizing volunteer activity as part of sustainable community development. Drawing on best practices documented by the Association of Ukrainian Cities (Association, 2023) and international experience analyzed by UNDP (UNDP, 2023), the study proposes a comprehensive framework for optimizing volunteer support systems.

Based on the identified trends and the evaluation of existing economic incentive mechanisms, the study formulates a set of practical recommendations for local governments, public authorities, and non-governmental organizations, including:

– the establishment of dedicated municipal funds for volunteer support with transparent allocation mechanisms;

– the development of standardized tax incentive programs for businesses engaged in volunteer initiatives;

– the creation of sustainable financing mechanisms for volunteer organizations through public-private partnerships;

– the integration of volunteer impact assessment indicators into community development planning.

The study's limitations include the variability of regional data and the relatively short observation period under post-2022 conditions. Future research should focus on the long-term impact assessment and the development of standardized methodologies to evaluate the economic contribution of volunteer activity to community development.

Conclusions. Economic mechanisms for stimulating volunteer activity represent a vital tool for sustainable community development, with the most effective approaches combining tax incentives, municipal grants, and public-private partnerships. Integrating volunteering into local development strategies requires systemic approaches, as its economic dimension enhances resource allocation and service efficiency, positioning it as a powerful instrument for community transformation in the face of contemporary challenges. The proposed measures—including the establishment of support funds, tax incentive programs, and financing mechanisms—are aimed at strengthening the institutional capacity of the volunteer sector. A promising area for future work remains the development of methodologies for assessing the economic contribution of volunteering and its long-term impact on community development.

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ANALYSIS OF EXTERNAL AND INTERNAL FACTORS OF ENTREPRENEURSHIP'S DEVELOPMENT IN UKRAINE

Andriy Kovalenko, *BA student*
Inna Koblianska, *PhD, As. Prof., scientific supervisor*
Sumy State University, Ukraine

Introduction. Globalization, pandemics, geopolitical conflicts, changes in legislation, currency fluctuations, inflationary processes and other external factors constantly create new challenges and opportunities for business. Systems analysis

helps enterprises identify these factors, assess their potential impact and develop adequate adaptation strategies. Additionally, market saturation and the emergence of new players, especially using innovative technologies, are intensifying competition. A prerequisite for building competitive advantages is a deep understanding of both external competitive forces (according to Porter's model) and one's own internal strengths and weaknesses. In this context, modern business requires constant innovation to maintain competitiveness. A systematic analysis of external opportunities (e.g., new technologies, changes in consumer preferences) and internal opportunities (e.g., research and development potential, staff creativity) helps to identify promising areas of innovative development. This research aims to conduct a systematic analysis of external and internal factors that influence the entrepreneurship's development.

Data and methods. This study is based on a review of academic literature, official statistics, and current media reports related to business development in Ukraine. Data on the closure of individual entrepreneurs and investment support mechanisms were examined to understand the impact of wartime conditions on business resilience and adaptation. A qualitative content analysis was used to assess how these factors affect business sustainability and investor interest.

Results. The famous scientist F. Kotler believes that the external environment (macroenvironment) consists of six main factors: demographic, economic, natural, scientific and technical, political and cultural factors (Gorelov et al., 2010). Each of these factors has a huge impact on the enterprise. The business entity, in turn, cannot influence them in any way and can only adapt, unlike internal factors. Internal factors can be divided into three groups, namely:

1. Factors of resource provision of production, which represent everything without which it is unthinkable to produce products and provide services in the quantity and quality required by the market.
2. Factors that ensure the desired level of economic and technical development of the enterprise
3. Factors that ensure the commercial efficiency of the enterprise's production and economic activities.

Of the listed internal and external factors, the russian-Ukrainian war had the greatest impact on business development in Ukraine. In January 2025 alone, about 60,000 individual entrepreneurs ceased operations, according to state registers. This is a record for the entire period of the full-scale war, but the negative trend has been noticeable throughout the past year (Golich, 2025). Businesses in frontline regions, including Sumy, are suffering the most. In addition, taxes have increased, making them simply unaffordable for young entrepreneurs. In addition, under the pressure of taxes and military actions, it is very difficult for small businesses to adapt and implement new technologies without significant start-up capital.

Currently, Ukrainian business is largely saved by investments. On April 7, 2024, the European Union launched the Ukraine Investment Framework under the Ukraine Facility program, aiming to attract up to €40 billion in public and private investment

into the Ukrainian economy. The UIF provides guarantees of €7.8 billion to partially cover investment risks, particularly security risks, and €1.5 billion in grants, blending and technical assistance. It is expected that successful EU-funded projects will serve as role models for private businesses, stimulating further investment once security risks have been reduced (Shabelnikov, 2025).

Internal factors directly determine the capabilities and effectiveness of business entities. Organizational structure, available resources (financial, material, human, information), technological level, efficiency of business processes, corporate culture and quality of management – all this forms the internal potential of the enterprise. Strong internal factors create competitive advantages, provide flexibility and adaptability to change, while weak ones can inhibit development, lead to inefficiency and reduce competitiveness. Effective management of internal factors is the key to the success of any business entity.

Conclusions. Although Ukrainian business is currently operating under the strong influence of external factors, it nevertheless remains attractive to Western investment and has strong potential for growth, especially after the Ukrainian victory.

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LABOR MARKET IN THE ERA OF DIGITAL TRANSFORMATION: GLOBAL TRENDS AND CHALLENGES

Andrii Konoplenko, *PhD student,*
Sumy State University, Ukraine

Introduction. The global labor market is undergoing profound transformations driven by digitalization, automation, and socio-economic upheavals. The rapid development of technologies related to Industry 4.0 and 5.0, such as artificial intelligence, big data, and remote work platforms, is changing the structure of employment, driving a shift from industrial and agricultural employment to service- and knowledge-based sectors.

The COVID-19 pandemic has acted as a catalyst and reinforcing trends towards flexible work. These shifts have significantly altered the organization of the workforce, skill requirements, and business processes (Lazarova et al., 2023). As economies adapt to new work patterns, it is essential to understand how digital transformation impacts employment structures, labor distribution, and inequality. This study examines the dominant trends and challenges in the global labor market shaped by digital transformation.

Data and Methods. This study combines decomposition, statistical analysis, logical synthesis and graphical modeling. The study uses secondary data from the International Labor Organization (ILO) and Statista. Key indicators include labor force size, employment rate, unemployment dynamics and sectoral employment distribution.

Results. Recent data indicate a significant transformation in the structure of global employment. The sectoral distribution of employment in 2022 was as follows: services – 51%, agriculture – 27%, industry – 22%. This confirms the dominance of the service economy in the labor market and reflects global urbanization and the growing demand for knowledge-intensive labor. At the same time, the global labor force is growing steadily and is projected to reach 3.74 billion people by 2025. However, the share of the employed population decreased from 60.2% in 2000 to 55.3% in 2020 and has since stabilized at around 57% (ILO, 2024).

The acceleration of digital transformation, especially within Industry 4.0, has changed job roles, work processes and required competencies. Remote work technologies, AI-based automation and cloud platforms ensured business continuity during the COVID-19 pandemic and have since become part of standard work practices.

The shift towards Industry 5.0 emphasizes human-centric innovation and collaboration between humans and intelligent machines. As a result, the demand for soft skills has increased dramatically (Poláková et al., 2023).

The pandemic has led to the reconfiguration of work. The COVID-19 crisis reduced total working hours by 8.8%. Sectors such as tourism, retail and hospitality have been hit hardest. However, the pandemic has also fostered the emergence of

new employment models: hybrid working, remote collaboration and task-based outsourcing.

Thus, the main trends in digital work were identified:

- Digitalization and automation. AI and machine learning are displacing low-skilled jobs, prompting the need for lifelong learning strategies (Zarifhonarvar, 2024).
- Hybrid employment. It increased flexibility but requires infrastructure and cultural adaptation.
- Work-Life Balance. Flexible work raises wellbeing concerns and requires institutional safeguards (Vyas, 2022).
- Outsourcing. IT outsourcing is projected to reach $812.7B by 2029 (Statista, 2024).
- Soft skills. There is increasing demand for analytical thinking, creativity, and communication, which complement digital competencies.

The main challenges to labour market resilience have been:

- Job displacement by artificial intelligence: approximately one-third of occupations worldwide may face the risk of full or partial automation (Zarifhonarvar, 2024).
- Demographic aging: the population aged 65 and over will increase from 9% in 2020 to 16% by 2050, reducing the active labor force.
- Socio-economic inequality: gaps in education, gender participation, and access to income are widening. Informal employment and the lack of social protection increase vulnerability in developing economies.
- Geopolitical instability: the war in Ukraine, climate change, and the recovery from the pandemic continue to change labor demand worldwide.

Conclusions. The labor market is becoming more digitized, flexible, and globalized. At the same time, the risks of technological unemployment, demographic imbalances, and social exclusion are growing. Addressing these issues requires coordinated action between the government, business, and educational institutions.

Academic Supervisor:
PhD, Assoc. Prof. Bohdan Kovalov,
Sumy State University.

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THE SMART CITY CONCEPT AS A FACTOR FOR THE SUCCESSFUL DEVELOPMENT OF LOCAL TOURISM

Yevhen Kozlovskyi**,** *PhD, As. Prof.,*
International European University, Kyiv

Introduction. According to UN forecasts, by 2050, more than 70% of the Earth's population will live in cities. This means that the traditional model of urban space functioning will be less effective in the near future: the population of cities is growing, and at the same time the load on urban services and infrastructure is increasing, the volume of exhaust gas and wastewater emissions is increasing, resource consumption is increasing, and the negative impact on the environment is intensifying. That is why the concept of a "smart city" is gaining increasing popularity in the modern world, because it is the tools of the smart model that allow optimizing resource consumption processes through competent management of the urban environment, improving the lives of local residents, and making individual facilities and services more accessible.

Data and Methods. The study of scientific publications and analytical reviews on this issue shows that there is currently no unified understanding and definition of a "smart city". Some countries and authorities consider it exclusively as a set of solutions for optimizing management processes, in some cases all intelligence is reduced to creating a single digital platform for most city services, but most often a "smart city" is considered as a tool for sustainable development, rational use of nature and reducing anthropogenic load on ecosystems.

Results. A smart city is a concept that involves the use of modern technologies and innovative approaches to managing urban infrastructure, increasing efficiency and improving the quality of life of citizens (transport management, energy consumption, water supply, waste, public order and security).

A smart tourist destination is the use of technologies to optimize and improve the experience of travelers (the use of mobile applications and online platforms for planning and organizing trips, the use of carriers and sensors to monitor the health and safety of travelers, the use of autonomous vehicles and robots to move around the city or between cities, the creation of digital platforms for the exchange of experience and knowledge between travelers).

Both concepts use modern technologies to improve people's lives, but they belong to different areas: a smart city is focused on managing urban infrastructure, and a smart tourist destination is focused on travelers, their comfort and impressions, on the attractiveness and competitiveness of the territory as a tourist destination.

The concept of a "smart city" includes a number of subsystems that are intended for the local population, but are no less important for the tourist:

1. Traffic and navigation – tourists, like the local population, move around the territory and are interested in a transparent system of navigation and understanding of routes, various places, etc. At the same time, the local population also visits recreation areas and attractions on weekends and holidays, which equates them to tourists and they also want to know the occupancy of routes and places of tourist attraction;

2. Public safety – important for both the local population and tourists. Moreover, nowadays tourists are very interested in safety when choosing places to travel, this is an important factor in the attractiveness of any tourist destination;

3. Energy efficiency – of course, this is more important for the local population, since they live in this territory permanently, but comfort, sustainability, environmental friendliness, clean water, energy-saving lighting sources are also important for the traveler;

4. Health care – it should be said that for a traveler to receive quality medical care in case of an unforeseen situation is very important, in addition, one should not forget about medical tourism;

5. Public utilities – this is not the main thing, but also important. Cleanliness and order, good water supply, heating – this is also a significant factor in the attractiveness of the territory.

So, a "smart destination", within which smart tourism exists, is a subsystem of a "smart city". It is built into a general system, which requires not the development of separate systems in one territory, but the addition of the smart city system with additional functions.

It should be noted that measures to develop tourism in smart cities largely boil down to the creation of a city information portal of services, which includes the ability to plan a tourist route, book hotels, excursions, hold festive events, provide a QR navigation system at cultural heritage sites, audio guides and augmented reality mechanisms, and provide information on interactive and cultural and exhibition events.

In the context of global practice of urban tourism in smart cities, the presence of only an information system is an insufficient condition. Therefore, the analysis of cities that occupy leading positions in the ratings of "smart cities" allowed us to group smart solutions into the following groups with relevant examples.

1. Solutions created for the sustainable development of urban space (rational use of natural resources, resource conservation, waste disposal). For example, in Singapore, this is the use of solar energy and rainfall to support urban ecosystems, in New York, clean water leak detection systems, LED indoor agricultural lights and

advanced air quality monitoring systems are used. As a result, a comfortable environment for tourists to stay and live, minimizing the load on urban infrastructure due to tourism, and the formation of new attractions.

2. Solutions aimed at sustainable development of the transport system (reducing emissions, increasing accessibility of facilities, improving navigation and tracking of vehicles on the route). For example, in New York, car-sharing solutions help reduce emissions in the city and its surroundings, as well as cope with traffic jams. In Copenhagen, a system has been implemented that monitors air quality, energy consumption, traffic and waste disposal, and also connects parking systems, traffic lights, buildings, smart meters and electric vehicle charging systems to manage traffic in real time. As a result, the formation of a more favorable environment, comfortable transportation and movement around the city allows tourists to see more in the city, and as a result, arouses the desire to return to it.

3. Measures to improve urban infrastructure (arrangement of bicycle paths and sidewalks, formation of pedestrian zones, squares, playgrounds). For example, in many cities of Northern Europe, a pedestrian zone is being developed in the center, navigation programs and lighting systems are being created for this purpose. Thus, a comfortable urban environment demonstrates the level of care of the authorities for the population and forms a positive image of the city, creates conditions for tourists to stay in it.

4. Solutions in the field of improving the quality of communication and Internet coverage, free Wi-Fi, the availability of charging points for gadgets. For example, in New York, a program has been implemented to replace telephone booths with Wi-Fi-enabled charging stations. In Auckland (New Zealand), the development of the 5G network of the SPARK company in the city center is a demonstration of what the future of the city's central business district could look like. The presence of coverage, chargers and free Wi-Fi creates a comfortable environment, allows you to share your impressions online here and now, and therefore works not only as a tool for increasing comfort during a trip, but also as a way to promote the destination.

5. Solutions aimed at optimizing the time of citizens (stimulating service aggregators, delivery services and digital marketplaces, systems based on biometric indicators). For example, in many smart cities, service aggregators and digital marketplaces are actively developing and are in demand. This approach makes tourist offers more accessible, improves the quality of a tourist's stay in the city.

6. Digital platforms and tools to enhance security (video surveillance systems and cameras for tracking violators, smart sensors and analytical systems for studying and preventing crimes). For example, the New York Police Department tested web software that, based on data on committed crimes, allows you to predict possible violations of the law and respond to them. Safety is a key factor influencing the choice of a vacation spot. Many methods for assessing the safety of destinations are calculated taking into account the ratio of crimes per capita. The safer the destination, the more popular it is with tourists.

7. Measures to reduce the negative impact of the environment on residents (formation of artificial shade, irrigation). For example, in Saudi Arabia and the UAE, there are districts with artificial irrigation, which is turned on using digital services. This approach allows you to create a comfortable environment, in particular for tourists, while rationally using resources. Such solutions are an additional factor of attractiveness for tourists.

As we can see from the examples given, solutions for implementing the concept of smart cities can significantly improve the comfort of the environment, create additional factors of attractiveness for tourists, and make individual objects more accessible.

Conclusions. The formation of smart cities is a prerequisite for the development of a modern urban environment, because it is smart solutions that allow cities to develop optimally, and their individual components and services to function effectively.

Smart cities are more attractive to tourists for various reasons: these are additional attractive qualities, awareness of their sustainability as a destination, which corresponds to the trends in demand for eco-friendly forms of tourism, the comfort of the city environment, which meets the needs of the modern digital traveler. In addition, working conditions are formed in a smart city for employees of the tourism industry, which contribute to more efficient work, and therefore, the quality of service provision and the creation of new creative tourist and excursion products based on digital services and devices.

So, we can distinguish the key features of a smart city – these are active processes of digitalization of all spheres, aimed at improving the quality of life of the population by creating conditions for intensive and effective communication between all city services and residents, through the formation of a comfortable urban environment and rational use of resources, as well as by optimizing the lives of city residents and increasing the share of their leisure time. Depending on the approaches to studying a smart city, one or another of these aspects is brought to the fore. In the context of tourism, the basis of the concept of a "smart city" is the urban community and the tourist, who becomes a part of it for a short period of time in a specific destination.

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APPLYING CLUSTERS TO IMPROVE THE RELIABILITY OF WATER SUPPLY AND WASTEWATER SYSTEMS IN UKRAINE

***Oleksandr Kravchuk**, PhD, As. Prof.,*
***Kateryna Lavrukhina**, PhD, As. Prof.,*
Kyiv National University of Construction and Architecture, Ukraine

Introduction. Water supply and wastewater systems are critically important for the functioning of both urban agglomerations and rural areas. They are essential components of the housing and utility sector. And the comfort and health of the population, as well as the ecological state of the surrounding area, directly depend on the smooth operation of these systems. However, water supply and wastewater systems often face significant challenges, including high infrastructure wear and tear, inefficient energy consumption, and management issues (Potapenko et al., 2024; Kravchuk et. al., 2024).

One modern approach to enhancing the reliability of water supply and wastewater systems is the concept of clustering within the housing and communal sector (Bezus, 2022). Clusters integrate multiple system components into a unified network, improving efficiency, reducing the load on individual elements, and minimizing the risk of operational failures (Lavrukhina et al., 2024). This issue is particularly relevant in the context of the increasing demand for high-quality water supply, the urgent need for modernization of existing systems, and efforts to mitigate the consequences of military actions in Ukraine.

Data and Methods. The study utilized open data from publications and reports by the European Union, international organizations, and national institutions specializing in water resources and water supply, as well as scientific articles on the implementation of cluster technologies.

The research methodology included a comparative analysis of cluster implementation experiences in various EU countries and modeling, which enabled an assessment of the efficiency of clustered systems compared to traditional management schemes.

Results. Clustering is the process of combining certain objects or systems into groups (clusters) based on similar characteristics or operating conditions (Lavrukhina et. al., 2018). In the context of water supply and wastewater systems, clustering refers to the integration of various infrastructure elements (water intake facilities, pumping stations, treatment plants, reservoirs, pipelines, etc.) into a unified network. This approach ensures more efficient management, reduces the load on individual components, and enhances system reliability and continuity of operation.

The research results highlighted several key aspects of using clusters in the housing and utility sector to enhance the reliability of water supply and wastewater systems:

- ***Ensuring reservation and reducing accident risks*.** Clusters enable the creation of reservation capacity for critical infrastructure elements. If one of the pumping stations or treatment facilities fails, other network components can take on the load, ensuring continuous water supply and wastewater management. This reduces the probability of accidents and improves the reliability of the system.

- ***Optimization of energy consumption*.** Implementing clusters allows for centralized management of energy consumption, which promotes more efficient use of energy resources. Clusters provide flexible distribution of energy loads between pumping stations and other system components depending on current demand, which helps reduce overall energy consumption and lower electricity costs.

- ***Improved monitoring and management*.** Centralized monitoring, facilitated by clustering, allows for real-time tracking of the condition of all components in the water supply and wastewater systems. This enables quick responses to potential issues, early detection of failures, and their resolution before they lead to serious consequences. Real-time management allows adjustments to the system's operation, reducing response time to unforeseen situations.

- ***Increased resilience to external impacts*.** Clusters allow the system to maintain functionality even under changing external factors such as weather variations, fluctuations in water demand, or failures in individual subsystems. Distributed components within the cluster can adapt to changing conditions, enhancing the overall resilience of the systems to external impacts.

- ***Integration of renewable energy sources*.** Clustering allows the integration of renewable energy sources such as solar panels or wind turbines into the water supply system. This helps reduce dependence on traditional energy sources, lower electricity costs, and has a positive environmental impact.

- ***System flexibility and scalability*.** The network can be adapted to changes in water demand or increased load by adding new components to the existing infrastructure. This allows the system to easily respond to changing conditions and expanded service areas without the need for major capital overhauls or large investments.

- ***Reduction in maintenance and operating costs*.** Through centralized management, clustering reduces maintenance and operating costs for water supply and wastewater systems. Since monitoring and control are performed from a single center, the need for manual intervention is reduced, and maintenance efficiency is increased. Clustering also helps lower repair and modernization costs, as it allows for more accurate identification of wear and system issues.

Participation in a cluster provides advantages in the implementation of repair technologies, operation, resource conservation, development of new service offerings, dispatching and automation, through access to information, new strategies, franchising of best practices, monitoring trends in the solvency demand of various consumer categories, specialization, and modular training for specialists and workers.

Conclusions. The use of clusters in the housing and utility sector, particularly in water supply and wastewater systems, offers significant potential to enhance their reliability, efficiency, and resilience to external challenges. Integrating various infrastructure elements into a unified system ensures the stable operation of all components and improves the quality of services provided to the population.

However, there are certain limitations, including the high cost of implementing cluster solutions, especially for outdated infrastructure that requires modernization. Moreover, the effective application of such technologies requires a high level of automation and the integration of data from various system components.

Prospective research should focus on developing more efficient and flexible solutions for small and medium-sized cities, addressing modern challenges such as economic instability, outdated infrastructure, and growing resource demand.

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INTEGRATION OF ECOLOGICAL PRINCIPLES INTO THE STRATEGIC MANAGEMENT OF AGRICULTURAL ENTERPRISES

***Volodymyr Kushnir**, PhD, doctoral student of the*
Department of Economics, Entrepreneurship,
Trade and Exchange Activities,
Higher Educational Institution «Podillia State University», Ukraine

Introduction. Climate change, resource depletion, and increasing demands for environmental sustainability present agricultural enterprises with the need to incorporate ecological aspects into their development strategy. The integration of ecological principles into the strategic management of agricultural enterprises is a crucial element that allows not only for the preservation of ecological balance but also for achieving long-term economic efficiency. Sustainable development involves the combination of economic, social, and environmental aspects within the framework of strategic management, enabling enterprises to reduce their environmental impact, optimize resource usage, and achieve sustainability in their operations.

Methods and Data. For this study, data from over 50 agricultural enterprises of varying scales were used, which implement eco-innovations and environmentally responsible practices in strategic planning. The research methodology included comparing the efficiency of enterprises that actively integrate ecological principles with those that do not apply sustainable development strategies. Interviews were also conducted with managers of enterprises certified by international environmental standards.

Results. Enterprises that actively integrate ecological principles into their development strategy show notable improvements in resource efficiency. For example, agricultural companies using precision farming technologies reduce their water and fertilizer costs by 20-30%, which not only positively impacts economic results but also improves soil and water resources. These practices allow for cost reduction by 10-15% compared to traditional farming methods, particularly through more accurate use of agrochemicals, which also helps reduce the environmental burden on land and water resources [1].

In large agricultural enterprises, the implementation of ecological innovations and monitoring systems allows for better results in managing water resources and preserving biodiversity. For example, some enterprises using organic farming and reverse water treatment technologies report significant reductions in soil contamination by pesticides and chemical fertilizers. This helps maintain ecological stability over the long term, improving the company's reputation and attracting new customers willing to pay a premium for products certified as environmentally clean [2].

With the adoption of ecological technologies, enterprises also receive economic benefits through increased demand for organic products and enhanced market competition. Enterprises with certification according to international environmental management standards, such as ISO 14001, have competitive advantages in terms of higher consumer trust and access to international markets. According to research data, 75% of consumers are willing to pay more for products that have ecological certification, which enables companies to increase their profits and strengthen brand loyalty [3].

Access to green investments is an important aspect of ensuring sustainable development for agricultural enterprises. Large agricultural enterprises typically have easier access to financing, including through green bonds and subsidies for eco-technologies. However, for small and medium-sized agricultural enterprises, this remains a challenge, as they often lack the necessary resources to implement expensive eco-innovations without additional funding. Enterprises integrating ecological principles can attract green capital, which in turn allows them to implement new technologies that reduce costs and environmental footprints [2].

Conclusions. The integration of ecological principles into the strategic management of agricultural enterprises significantly improves resource management efficiency, reduces costs, enhances brand reputation, and ensures access to financial resources. Sustainable development in the agricultural sector contributes to environmental preservation, improved operational efficiency, and reduced ecological risks. Enterprises that actively include ecological principles in their strategy not only achieve economic benefits but also gain competitive advantages in the market. However, to facilitate broader implementation of sustainable development, support from the state, financial institutions, and educational organizations is necessary, as well as expanded access to green investments and environmental certification.

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CIRCULAR ECONOMY AS A RESPONSE TO SYSTEMIC CHALLENGES OF SUSTAINABLE DEVELOPMENT

Maria Kucheriava, *PhD, Senior Researcher*
State Educational-Scientific Establishment
"The Academy of Financial Management", Ukraine

Introduction. The modern world is under the influence of a set of systemic risks that threaten, among other things, the achievement of the Sustainable Development Goals (SDGs). These risks include: environmental risks associated with climate change, ecosystem degradation, resource depletion, increased waste and environmental pollution; economic risks (inefficient use of resources, fragmentation of financing for sustainable development initiatives); social risks (inequality, labor market vulnerability, healthcare restrictions, etc.); institutional risks (low level of trust in government institutions). Taken together, these and other risks form a polycrisis reality that requires a transition from the linear to the circular model of economic management.

The central categories of the concept of sustainable development are the rational use of resources and responsible consumption, which also form the basis for the formation of institutional support for the integration of circular economy principles into the economic life of society.

Achieving sustainable development, especially SDG 16 "Peace, Justice and Strong Institutions," requires using economic instruments and attracting a significant amount of financial and other material resources. At the same time, the ratio of military spending to Official Development Assistance (ODA), as exemplified by OECD member states since adopting the SDGs, is disappointing. Figure 1 shows that, on average, the official development assistance of OECD countries in 2015–2023 amounted to 12.23% of the expenditures on military needs of OECD countries in 2015-2023.

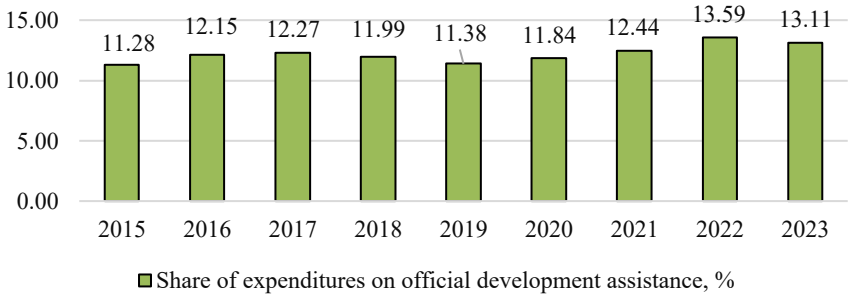

Fig. 1. Dynamics of the share of spending on official development assistance in relation to spending on military needs of OECD countries in 2015-2023.
Source: calculated by the author according to (Sachs et al., 2024).

The above points to the expediency of finding and implementing new conceptual approaches to achieving sustainable development through the rational use of resources and counteracting the effects of climate change, considering the need to ensure global, regional and national economic security. The principles of the circular economy are aimed at solving these problems. Ensuring the country's economic security through developing new reserves and resources is particularly important in the context of uncertainty caused by military operations.

Data and Methods. The research methods include comparative analysis, synthesis and generalization of the data obtained, and graphical methods (to ensure the clarity of the data presentation).

Regulations and program documents on implementing the principles of the circular economy and green transformation and scientific publications provide information support for the study.

Results. The circular economy as "a model of production and consumption that involves the exchange, rental, reuse, repair, recovery and recycling of existing materials and goods for as long as possible" (European Parliament, 2024) is a tool for achieving the SDGs. For example, the introduction of circular economy principles contributes to the implementation of SDG 12 "Responsible Consumption and Production" by reducing the use of primary resources, introducing environmentally friendly technologies, and managing waste. The implementation of this economic concept is also directly related to SDG 13 "Climate Action" as the transition to circular models reduces greenhouse gas emissions by reducing dependence on primary materials and energy-intensive production.

Other aspects of sustainable development, such as achieving SDG 8 "Decent Work and Economic Growth", are realized by developing new jobs in the recycling, service and innovation sectors.

The main idea of the new economy is to introduce economic models and principles that consider environmental, social, and ethical aspects along with financial indicators. This means that economic growth is not the only indicator of state development; improving the welfare of the population, environmental sustainability, and fair and rational distribution of resources are also important.

Conclusions. The circular economy is not only a means of implementing individual SDGs, but also an integrated approach that supports systemic change on the path to sustainable development. Implementing the principles of the circular economy requires cooperation between governments, businesses and civil society, as well as innovative solutions that ensure environmental, social and economic balance. Achieving sustainable development necessitates a scientific rethinking of traditional economic models to ensure sustainability.

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INTEGRATION OF SUSTAINABLE DEVELOPMENT PRINCIPLES INTO FINANCIAL AND MANAGERIAL ACCOUNTING OF ENTERPRISES

***Ljudmila Kushnir**, PhD, Assoc. Prof.,*
Educational and Rehabilitation Institution of Higher Education «Kamianets-Podilskyi State Institute», Ukraine

***Tetiana Kushnir**, lecturer of the cycle of fundamental subjects*
Separate structural subdivision Kamianets-Podilskyi professional college of ERIHE "Kamianets-Podilskyi state institute", Ukraine

Introduction. Sustainable development has become a crucial aspect of modern business, influencing financial and managerial decision-making processes. Companies worldwide are increasingly integrating sustainability principles into their accounting systems to enhance transparency, social responsibility, and environmental consciousness. The importance of sustainability in accounting arises from the need to evaluate not only economic performance but also social and environmental impacts. This study explores the integration of sustainable development principles into financial and managerial accounting, addressing the key challenges and benefits of this approach. The research question focuses on how sustainability-oriented accounting practices contribute to improved corporate responsibility and long-term financial stability.

Data and Methods. The study relies on secondary data from international reports, academic research, and case studies of companies that have implemented sustainability-oriented accounting. Data sources include the Global Reporting Initiative (GRI) standards, corporate sustainability reports, and regulatory frameworks. The methodological approach involves a qualitative analysis of accounting practices integrating sustainability principles. The research also utilizes comparative analysis to evaluate different strategies for incorporating sustainability in financial and managerial accounting.

Results. The principles of sustainable development cover three main areas: economic, social, and environmental. In the context of an enterprise, this means that its financial activities should also include aspects that ensure social responsibility and environmental preservation. Integrating these principles into accounting systems requires changes in approaches to financial performance evaluation, cost planning and analysis, and reporting. Financial accounting is focused on reflecting enterprise activities for external stakeholders such as investors, creditors, and government agencies. Integrating sustainable development principles into financial accounting

allows companies to be more transparent regarding their social and environmental commitments. This can be achieved through: 1. Recognition of sustainability-related expenses**:** Costs associated with environmental projects, social initiatives, or investments in energy efficiency should be recorded in financial statements [1]. 2. Environmental reporting**:** Financial statements, such as profit and loss reports and balance sheets, may include expenses related to environmental conservation measures, such as CO_2 emission reductions or waste management [2]. 3. Corporate social responsibility (CSR) reporting**:** Information on social projects, community support, and cooperation with NGOs can be integrated into standard financial reports [1].

Managerial accounting focuses on internal users, such as company management, and supports decision-making processes. Integrating sustainability principles into managerial accounting enables executives to engage in long-term planning and make decisions that consider not only economic benefits but also social and environmental factors. This can be implemented through: 1. Economic feasibility assessment of social and environmental investments**:** Using tools like cost-benefit analysis to evaluate the efficiency of environmental and social projects [3]. 2. Sustainability cost management**:** Implementing a system for accounting and controlling expenses aimed at reducing environmental impact, such as energy conservation or waste reduction [2]. 3. Monitoring social and environmental initiatives**:** Establishing key performance indicators (KPIs) that reflect the success of sustainability initiatives, such as emission reductions or improved working conditions [3].

The following table illustrates the main aspects of integrating sustainability principles into accounting:

Table 1. Integration of Sustainability Principles into Financial and Managerial Accounting

Sustainability Aspects	**Financial Accounting**	**Managerial Accounting**
Environmental Costs	Recording expenses for environmental initiatives in financial statements	Evaluating the efficiency of environmental projects through cost-benefit analysis
Corporate Social Responsibility (CSR)	Including social program costs in financial statements	Assessing the impact of social investments, monitoring KPIs
Cost Management	Accounting for energy efficiency and waste reduction expenses	Controlling and monitoring sustainability-related costs
Sustainability Investments	Reporting investments in environmental and social projects	Developing long-term sustainability investment strategies

Source: Summarized by the author based on [1, 2, 3].

For successful integration of sustainability principles into enterprise accounting systems, appropriate methodologies and standards must be implemented. Key

practical steps include: 1) utilizing international standards**:** For example, the Global Reporting Initiative (GRI) standard provides guidelines for sustainability reporting, covering environmental, social, and governance aspects [1]; investing in accounting software for sustainability reporting: Automating data collection and processing on environmental and social costs ensures accuracy and transparency in reporting [3]; **t**raining accountants and managers**:** Enhancing employees' expertise in sustainability, including an understanding of corporate social responsibility and environmental standards, facilitates the adaptation of accounting systems to new requirements [2].

The integration of sustainability principles into enterprise accounting systems poses several challenges. Firstly, adapting existing accounting standards to new requirements can be complex and require significant time and resources. Secondly, the development of standardized approaches to assessing social and environmental costs is hindered by the lack of uniform regulations in this area.

However, despite these challenges, implementing sustainability principles in accounting creates significant opportunities for businesses. It not only enhances transparency and accountability but also improves the company's reputation among consumers, investors, and regulatory bodies. Ultimately, this contributes to long-term business stability and success.

Conclusions. The integration of sustainable development principles into financial and managerial accounting is a crucial step in building a more responsible and sustainable business. This approach not only improves cost management efficiency but also fosters the creation of socially and environmentally responsible business models that address global sustainability challenges. It is vital for enterprises to go beyond traditional economic standards and actively incorporate social and environmental aspects into their activities, laying the foundation for future success.

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POSSIBILITIES OF REDUCING HARMFUL EMISSIONS BY ROLLING STOCK OF ROAD TRANSPORT

Volodymyr Sakhno, *D.Sc., Prof.,*
Svitlana Sharai, *PhD, As. Prof.,*
Victor Poliakov, *PhD, As. Prof.,*
National Transport University, Kyiv, Ukraine

Introduction. When carrying out the process of transportation by rolling stock of road transport, sufficiently large volumes of harmful emissions fall into the environment, which adversely affects the livelihood and quality of life of the population. Considering that the basis of sustainable development is the economic and ecological components of society, the condition of sustainable development of society is the safety of people and the environment, and the goals of sustainable development include increasing the level of productivity and the use of technological innovations that will contribute to economic growth, the issue of the possibility of reducing harmful emissions by the rolling stock of road transport with the increase of the volume of freight road transportation due to the using of such motor vehicles as multi-link road trains are relevant.

Reducing the number of harmful emissions into the environment and increasing the productivity of motor vehicles can be facilitated by the use of multi-link road trains instead of single cars in the transportation of goods in intercity traffic. Reducing the number of motor vehicles when using multi-link road trains on the road network will significantly improve the situation with accidents and the amount of harmful emissions into the environment. It should be taken into account that the use of multi-link road trains should not create problems for other types of transport on highways, that is, their traction, speed and braking properties, which ensure safe use, must comply with current standards.

Data and Methods. The purpose of the research is a comparative analysis of tractor trucks in multi-link road trains with modern tractor trucks by indicators of traction and speed properties.

The data for conducting research are the technical characteristics of tractor trucks and trailers which are included in the compositionof of road trains for various purposes. Analytical methods are used to study the traction and speed properties of multi-link road trains.

Results. Traction and speed properties are important in the operation of motor vehicles, as they are directly related to average speed and productivity. Improving traction and speed properties means increasing the potential average speed and reducing the time spent on transporting of goods, as well as increasing the productivity of the motor vehicle [1]. These properties determine the acceleration dynamics of a motor vehicle, the ability to develop its maximum speed, and reduce the time required for it to accelerate to a certain speed. Improving traction and speed properties is one of the main trends in the development of the automotive industry,

as evidenced by higher maximum speed and acceleration values of each new generation of motor vehicles. This also applies to buses, including articulated ones, which can be hybrid, electric, as well as with diesel engines.

The average speed of a road train is one of the criteria by which its productivity is assessed. However, as its speed increases, fuel consumption increases too, which leads to an increase in the number of harmful emissions into the environment. When choosing a road train for cargo transportation, it is advisable to analyze this indicator. EU Directive 92/6/EEC [2] establishes requirements for the construction of motor vehicles that relate to maximum speed. Ukraine has joined UN Regulation No. 89 [2] on limiting the maximum speed of motor vehicles.

The calculation of the indicators of traction and speed properties that determine the average speed of a road train is based on the characteristics of tractor trucks and trailers, as well as their operating conditions. The differential equation used in the theory of the car was used to simulate the movement of road trains on a computer to determine the main estimated indicators of traction and speed properties [3]. The calculations of the average speed of a road train consisting of MAN, Iveco, Scania, DAF, Volvo tractor trucks, the power of which varies within 10-16%, with a Krone semi-trailer in given road conditions determined that the average speeds of road trains differ little from each other. The maximum deviation of the average speed does not exceed 8.5% [4].

However, it should be noted that the use of multi-link road trains instead of single vehicles has its advantages in terms of reducing harmful emissions, and the cost of transportation one ton of cargo will be lower, which entails a reduction in the costs of carrying out the transportation process.

Conclusions. The calculations of the average speed of a road train consisting of different tractor trucks have shown that this indicator has a small discrepancy, despite the fact that the engine power of different tractor trucks may differ from each other within 10-16%. Therefore, it can be concluded that the selection of a tractor truck unit for a road train should be carried out according to other criteria, which may be the direction of further researches.

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POPULATION AGING AS A GLOBAL RISK FOR HUMANITY

Svitlana Luchyk, *Doctor of Economics, Professor*
Kharkiv National University of Internal Affairs

Introduction. The World Economic Forum (WEF) in Davos presented the Global Risks Report 2025, which analyzes the most important threats facing the world community in the coming years. World experts say that state armed conflicts, such as the war in Ukraine, are the biggest threat in 2025, which emphasizes the growing geopolitical tensions. Climate change, economic inequality, and technological challenges are also recognized as global problems of humanity.

A scientific study published in Science Advances has revealed a dangerous link between climate change and accelerated human biological aging. Scientists say that constant exposure to extreme heat can lead to aging, particularly in older people. The main reason for accelerated aging is the combination of high temperatures and humidity, which disrupts the body's ability to cool itself normally, especially in older people whose sweating decreases with age [1].

Data and Methods. The researchers assessed the impact of heat in the previous six years on people's aging by their blood tests. They determined the level of DNA methylation, which is the inactivation of genes by attaching methyl groups to DNA. A higher level of methylation means a faster rate of aging. As the scientists found out, the level of DNA methylation was higher in those people who had spent more than 200 days at temperatures of 32 degrees and above over the past six years. That's about 33 extremely hot days a year [2]. Heat can have a negative impact on the body even in a comfortable environment, and therefore it is important not only to stay in cooler rooms, but also to take measures to adapt to climate change.

Results. In general, population aging around the world is caused by a decline in birth rates and an increase in life expectancy, which leads to a steady increase in the share of elderly people in the population.

Today, there are many countries in the world where the elderly (65+ years old) make up about a third of the population. Among them: Japan -30%, Italy – 23%, Germany 21%; Asia – China, South Korea (in China, more than 30% of its population (approximately 44 million) will be over 60 by 2040); Africa – Kenya, Nigeria and South Africa (South Africa's elderly population will grow from 8% in 2022 to 15% by 2050); Latin America – Argentina, Brazil and Mexico (the share of Brazil's elderly population will grow from 13% in 2022 to 29% by 2050). While the average age of the EU-27 increased from 35.4 years in 1991 to 41.2 years by 2011, by 2060 the average age of the EU-27 population is projected to rise to 47.6 years,

about 7 years higher than in 2011. The total population of the EU-27 over 65 is expected to increase from 17.5% in 2011 to 29.5% by 2060 [3].

Even before the full-scale war, the demographic situation in Ukraine was in crisis. The war unleashed by the aggressor only accelerated this process. Before the war began, about 25% of the population in Ukraine was aged 60 and older, while only 15% were under the age of 15. After three years of war, Ukraine's population now stands at 34 million people. Of these, 29 million live in the government-controlled territories of Ukraine, while the rest have fled the country because of the war. After the massive migration of young people and able-bodied people abroad, the population structure was further deformed. According to Eurostat, 62% of Ukrainians in the European Union are of working age, and 32% are children under 18. This change in the demographic picture leads to further aging of the nation, which has already become a problem for social and economic structures.

In addition to the large-scale migration of young Ukrainians abroad, the country's birth rate has fallen significantly. In Ukraine, before the full-scale invasion, it was 1.16, and at the beginning of 2025 it was 0.9. The international reproduction rate is 2.2 children per woman of childbearing age. The average for EU countries is 1.5. These are EU countries with a difficult demographic situation. The lowest total fertility rate was recorded in Korea – 0.7, as well as in Italy and Spain – 1.2 children per woman. The highest rate was recorded in Israel – 2.9, followed by Mexico and France – 1.8. According to the OECD, if we compare women born in 1935 and 1975, the percentage of childless women doubled in Estonia, Italy, Japan, Lithuania, Poland, Portugal and Spain [4].

Population aging causes significant changes in society. For example, from an economic perspective, population aging can affect labor markets, pension systems, and fiscal policy. As the number of retirees increases, the burden on social security systems and pension funds increases, potentially leading to financial stress if not managed effectively. By 2050, almost one in five people in low- and middle-income countries will be over 60 years old. The situation with such a rapid increase in the share of pensioners has no precedent in world history. Countries have to raise the retirement age and change the entire system. Otherwise, there is a risk of falling into a debt hole. According to the OCED, if pension systems are not reformed, the public debt of developed and emerging countries will increase by 180% and 130%, respectively, by 2050 [5]. Most EU countries continue reforms to raise the retirement age, including 10 countries – Denmark, Estonia, Greece, Italy, Cyprus, the Netherlands, Portugal, Slovakia, Finland, Sweden, and the United Kingdom – that have linked the increase in retirement age to the dynamics of life expectancy. Instead of the traditional retirement age of 60-65, the limit is increasingly being set at 67 or even 70. All European countries, except Poland, have a retirement age of 65-67 years, with a steady increase in some of them. The pensionable service period varies from 5 years in Germany to 43 years in France [6].

The increasing number of retirees in society is putting significant strain on the healthcare system. Older people tend to need medical care, long-term care, and

specialized services, which increases healthcare costs and requires more healthcare professionals trained in geriatric care. In Ukraine, healthcare expenditures in 2024 will total UAH 239 billion, which is 31 billion more than in 2023. The largest item of expenditure is the implementation of the State Healthcare Guarantee Program (SHG). Funding for this item of expenditure is to increase by 10.6% to UAH 175.5 billion compared to the current year. These funds will finance the provision of primary healthcare, emergency medical care, specialized medical care in outpatient and inpatient settings, taking into account priority services and conditions, psychological support and psychiatric care, transplantation of organs and other anatomical materials, palliative care and medical rehabilitation, infertility treatment using assisted reproductive technologies, as well as reimbursement of the cost of medicines and medical devices. One of the best solutions is active longevity. 75 years of activity as an average should become part of the state vision, which includes education, responsibility, prevention, a healthy lifestyle, and a total change in the health care system.

In social terms, Ukraine was among the countries least prepared for the challenges posed by population aging, ranking 79th out of 143 countries. This was shown by an analysis of the productivity and engagement of the older population, well-being, equality, cohesion, and security for older people in countries around the world. Switzerland had the best indicators, while Rwanda had the worst. As the world is experiencing a trend toward an increase in the average and maximum age of the population, this ranking emphasizes the need to improve the living standards of older people, who make up a significant portion of the population, especially in developed countries [7]. According to a survey conducted by the National Institute for Strategic Studies, 64% of Ukrainians aged 40+ have faced age discrimination when looking for a job. This indicates a deep structural bias in the labor market, which only exacerbates the problem of staff shortages [8].

Conclusion. Thus, today the aging process is characteristic of many nations. Ukraine is among the leaders in terms of the number of pensioners in the population structure. The country is already facing a shortage of personnel caused by the war, a sharp decline in birth rates, high mortality, and large-scale migration. Therefore, older people can become the main resource for post-war recovery economies. And employers should change the way they look at the age of an employee, engage older people in active working life by investing in their development and experience.

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THE ROLE OF DIGITAL TWINS IN ACHIEVING SUSTAINABLE DEVELOPMENT IN INDUSTRY 4.0 AND 5.0

***Oleksandr Pashchenko**, Cand. Tech. Sc., As. Prof.,*
Dnipro University of Technology, Ukraine
***Volodymyr Khomenko**, Cand. Tech. Sc., As. Prof.,*
Dnipro University of Technology, Ukraine

Introduction. The rapid advancement of digital technologies has led to the emergence of Industry 4.0 and, more recently, Industry 5.0. These industrial paradigms emphasize the integration of cyber-physical systems, the Internet of Things (IoT), artificial intelligence (AI), and human-centered approaches to production and sustainability. One of the most transformative technologies in this landscape is the digital twin, a virtual replica of physical assets, processes, or systems that enables real-time monitoring, simulation, and optimization. Digital twins hold immense potential in achieving sustainable development by enhancing resource efficiency, reducing waste, and improving decision-making processes (Kritzinger et al., 2018; Grieves et al., 2017; Tao et al., 2019).

This article explores how digital twins contribute to sustainability in the context of Industry 4.0 and 5.0. Specifically, it examines their role in energy efficiency,

predictive maintenance, supply chain optimization, and human-machine collaboration. The research question guiding this study is: How do digital twins facilitate sustainable development in advanced industrial environments?

Data and Methods. To analyze the impact of digital twins on sustainable development, this study utilizes a combination of literature review, case studies, and data-driven analysis. The dataset includes reports from industrial sectors implementing digital twins, sustainability assessments from organizations such as the World Economic Forum and the United Nations, and empirical studies from academic journals (Boschert et al., 2016; Qi et al., 2019; Xu et al., 2018).

The methodology follows a mixed-methods approach:

Qualitative Analysis: a systematic review of academic literature, industry reports, and best practices provides insights into the theoretical and practical applications of digital twins in sustainability efforts.

Quantitative Analysis: a data-driven approach assesses sustainability metrics, including energy consumption, emissions reduction, and operational efficiency improvements from industries utilizing digital twins.

Simulation & Modeling: advanced simulation tools and digital twin platforms are employed to model real-world scenarios, demonstrating their effectiveness in sustainable industrial processes.

Comparative Case Studies: examining real-world implementations of digital twins across different industries helps identify common challenges, success factors, and potential scalability.

Results. The findings reveal that digital twins play a significant role in advancing sustainable development across various dimensions:

Energy Efficiency: Digital twins enable real-time monitoring and optimization of energy consumption in industrial settings. Smart grids utilizing digital twins can predict and balance energy loads, reducing unnecessary consumption and minimizing carbon footprints. Manufacturing plants integrating digital twins with AI-driven analytics have achieved up to 20% reductions in energy costs.

Predictive Maintenance: By continuously monitoring equipment performance through IoT-enabled sensors, digital twins help in early detection of faults, reducing downtime and minimizing waste associated with unexpected failures. This proactive approach leads to cost savings, enhanced safety, and sustainability by extending the lifespan of machinery and reducing material consumption.

Supply Chain Optimization: Digital twins provide end-to-end visibility into supply chain operations, allowing companies to identify inefficiencies and reduce material waste. For example, logistics firms use digital twins to optimize delivery routes, reducing fuel consumption and emissions by as much as 15%. Additionally, warehouse operations benefit from demand forecasting models that minimize overproduction and excess inventory.

Human-Machine Collaboration: In Industry 5.0, digital twins enhance collaboration between humans and intelligent machines, fostering safer and more sustainable work environments. Augmented reality (AR) applications powered by

digital twins allow workers to interact with real-time data, improving operational accuracy and efficiency while minimizing material waste.

Carbon Footprint Reduction: By enabling accurate tracking and reporting of emissions, digital twins assist companies in meeting sustainability targets and regulatory compliance. Advanced carbon accounting models help industries assess their environmental impact and implement strategies for decarbonization.

Conclusions The study underscores the transformative role of digital twins in achieving sustainable development within Industry 4.0 and 5.0. By enabling energy efficiency, predictive maintenance, supply chain optimization, and human-centric industrial processes, digital twins contribute to reducing environmental impact while enhancing economic productivity. However, challenges such as high implementation costs, data security concerns, and interoperability issues must be addressed to maximize their benefits.

Future research should focus on developing standardized frameworks for assessing the sustainability impact of digital twins, exploring their applications in emerging industries, and integrating them with circular economy principles. Additionally, advancements in AI-driven automation, 5G connectivity, and blockchain for secure data transactions will further enhance the potential of digital twins in sustainable industrial transformation. As industries move towards more intelligent and sustainable operations, digital twins will continue to be a cornerstone of innovation and efficiency.

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THE ROLE OF HUMAN-AI COLLABORATION IN INDUSTRY 5.0 FOR SUSTAINABLE INNOVATION

Vira Kudlai, *PhD in Economics, As. Prof.,*
National University "Kyiv Aviation Institute"
Bohdan Mitiushkin, *Undergraduate Student,*
National University "Kyiv Aviation Institute"

Introduction. Industry 5.0 represents a shift from automation-driven production to a human-centric model, emphasizing collaboration between humans and AI for more sustainable and inclusive innovation. As global industries face mounting environmental and social challenges, the integration of AI with human creativity offers new pathways for achieving sustainable development goals. This is particularly relevant as companies seek to balance technological progress with ethical responsibility and resource efficiency. The growing interest in human-AI synergy reflects the need to reimagine industrial systems that are not only smart but also socially and environmentally aware. This paper investigates the question: How can human-AI collaboration in Industry 5.0 contribute to sustainable innovation, and what are its benefits and limitations?

Data and Methods. This research is based on a structured literature review using sources from databases such as ResearchGate, Scopus, and Google Scholar. Keywords like "human-centric AI," "Industry 5.0," and "sustainable innovation" were used to identify relevant academic articles, conference papers, and industry reports. The selected literature was analyzed to explore current trends, recurring themes, and knowledge gaps related to human-AI collaboration in sustainable industrial contexts. The goal was to synthesize current insights, highlight key themes, and identify gaps in existing research. This approach provides a broad understanding of the conceptual foundations and practical implications of the topic.

Results. The reviewed literature reveals a diverse range of perspectives on the integration of human-AI collaboration within industrial contexts, particularly in relation to sustainability. Rather than offering a single, unified view, existing studies highlight both the transformative potential and the practical challenges of implementing such systems. To better understand this duality, the findings have been organized into advantages and limitations, reflecting the most frequently discussed themes in the current discourse. This structure allows for a balanced examination of how human-AI collaboration is shaping – and being shaped by – sustainability goals in Industry 5.0.

The integration of AI with human creativity and judgment offers unprecedented opportunities for sustainable development (Figure 1). When humans and AI work together, they can enhance innovation by combining the computational power and pattern recognition abilities of AI with human intuition, ethical reasoning, and contextual understanding. This complementary relationship enables more informed and creative solutions to complex sustainability challenges, such as reducing

emissions, improving resource efficiency, and designing eco-friendly products. Human-AI collaboration also contributes to better resource optimization. AI systems can analyze real-time data on energy consumption, raw material usage, and environmental impact. When paired with human oversight, these insights can lead to timely, responsible decisions that minimize waste and promote circular economy principles. Furthermore, this approach supports more inclusive and resilient work environments by encouraging the upskilling of workers and enabling them to co-create value alongside intelligent machines. Such environments foster meaningful employment and promote social sustainability by aligning technological change with human well-being. Additionally, collaborative human-AI systems can enhance agility in decision-making, particularly in scenarios involving high complexity and uncertainty. For instance, in climate-sensitive manufacturing or supply chain disruptions, the combined strength of human experience and AI analytics allows for rapid, adaptable responses that are both data-driven and ethically grounded (Kamalabai et al., 2025; Martini et al., 2024; Rane et al., 2024).

However, the implementation of human-AI collaboration in Industry 5.0 also presents significant challenges (Figure 1).

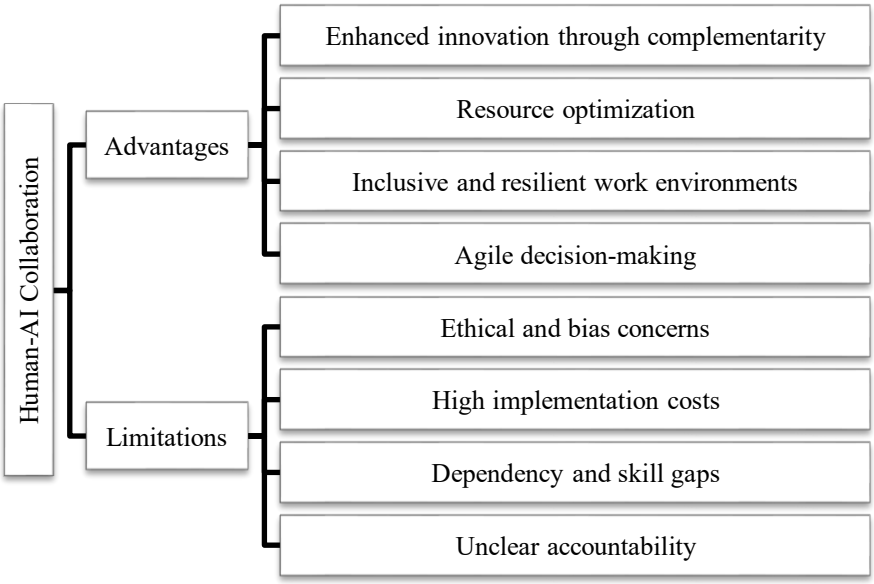

Fig. 1. Advantages and limitations of Human-Ai Collaboration in Industry 5.0 for Sustainable Innovation (based on Anang et al., 2024; Kamalabai et al., 2025; Martini et al., 2024; Rane et al., 2024).

Ethical concerns, such as algorithmic bias and lack of transparency, can undermine the social legitimacy of AI-assisted decision-making. Without careful oversight, AI systems may inadvertently reinforce existing inequalities or make unsustainable choices. Moreover, the costs associated with deploying such systems – both in terms of infrastructure and human training – can be prohibitive, particularly for small and medium enterprises. There is also the risk of creating dependency on AI systems, potentially eroding critical human skills while simultaneously requiring new competencies that are not yet widespread in the workforce. Addressing this skill gap is essential for ensuring that collaboration is genuine and empowering, rather than merely a transfer of agency to machines. Furthermore, the issue of accountability becomes complex in human-AI teams, especially when decisions have long-term ecological or societal consequences. Clearly defined responsibilities and governance frameworks are needed to ensure that both technological and human actors are held accountable (Anang et al., 2024; Kamalabai et al., 2025; Rane et al., 2024).

Conclusions. Human-AI collaboration in Industry 5.0 shows strong potential to drive sustainable innovation by combining the strengths of data-driven systems with human judgment and creativity. It enables smarter resource use, faster decision-making, and more inclusive industrial practices. However, challenges such as ethical concerns, high implementation costs, and skill gaps remain significant barriers. Addressing these issues is crucial to fully realize the benefits of this collaboration. Future research should focus on empirical validation and the development of inclusive frameworks for responsible AI integration.

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MOBILE LEARNING – A VIEW THROUGH THE EYES OF AN ATHLETE (SPORTS COACH)

Illia Shutieiev, *postgraduate student,*
Andrii Yefremenko, *PhD, As. Prof.,*
Svitlana Piatysotska, *PhD, As. Prof.,*
Kharkiv state academy of physical culture, Ukraine

Introduction. Mobile learning is firmly gaining its own niche among modern educational technologies. Its simplicity and convenience, accessibility and efficiency of mobile create advantages that are not available in the traditional face-to-face learning format (Criollo et al., 2021). Mobile learning is evolving, and its principles are shaped by researchers rather than practitioners (Johnson et al., 2021). Nevertheless, a practical perspective is quite important for understanding the essence of mobile learning. Mobile learning has a rather vague definition. In general, it is associated with interaction with learning content through the use of mobile technologies. It is often seen as a structural component of distance learning (Gumantan et al., 2022).

Practical disciplines are the most difficult to scale in the mobile learning format. For example, the field of physical education and sports is highly dependent on the practical skills of a specialist. This is due to the need to perform motor activities of a different nature. Movement training using mobile applications, videos, and electronic educational resources is only gaining popularity (González-Calvo et al., 2022). Programs are becoming more detailed, involve individualization and collaboration of participants, and the combined use of various mobile technologies (Killian et al., 2021). It seems attractive to take advantage of mobile learning on the way to modernizing the educational process in higher education.

The research problem is focused on generalizing the idea of the requirements for the organization of mobile learning in the study of athletics in the framework of higher education for future sports coaches.

Aim. The goal is to establish requirements for the organization of mobile learning in athletics.

Data and Methods. The analytical research method and pedagogical modeling were used as the main methods to achieve this goal.

Results. An understanding of the requirements for bundling different mobile technologies for athletics education is needed. Establishing this is related to two groups of factors that: 1) are a prerequisite for the potentially successful implementation of mobile technologies in the educational process; 2) determine the choice of mobile tools (Fig. 1).

The study of the accessibility of mobile learning organization involves conducting a survey on the participants' understanding of the educational process using mobile technologies. This will indirectly establish the preliminary level of

proficiency in learning tools. As a result, the feasibility of preliminary instruction of participants on the features of mobile learning will be determined.

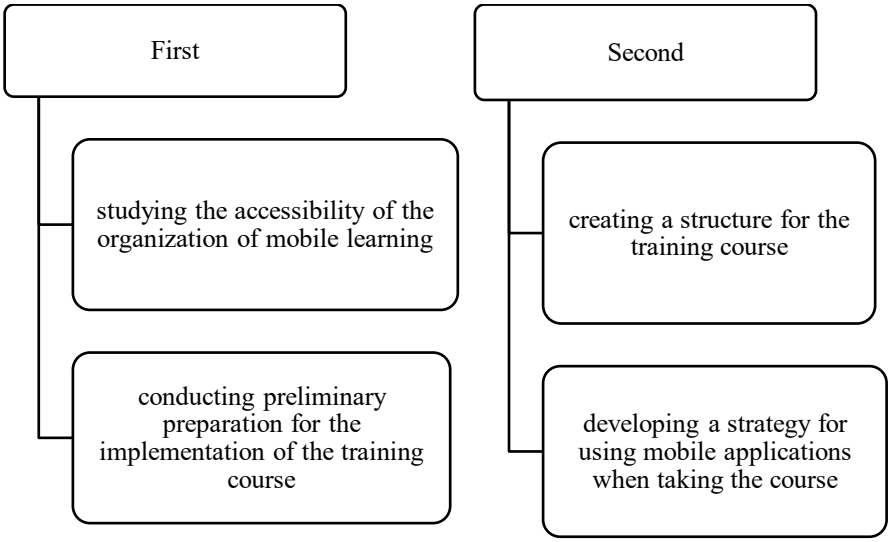

Fig. 1. Factors in the development of mobile learning in athletics

The next step is to identify the main means of implementing mobile learning – personal communication tools and work with electronic educational resources (EER). The third stage is variable – familiarization with the basis of the training course and a survey on the preliminary perception of mobile learning. This stage is important if, in addition to assessing the learning outcomes of the course, it is planned to reflect on the perception of the course by the participants. The fourth stage involves determining students' prior knowledge of athletics and motivation to learn using mobile technologies.

Preliminary preparation for the implementation of the training course involves analyzing the results obtained in solving the first task. This will allow you to: 1) understand the need to simplify / complicate the course; 2) provide for the possibility of individual learning / collaboration; 3) determine the need to correct student motivation; 4) outline the structure of using various mobile tools in the structure of the training course; 5) determine the most appropriate format for interaction and feedback with students, specifically in the process of tutoring.

Creating a course structure involves defining: 1) course goals and objectives; 2) competencies to be acquired by students; 3) program learning outcomes. This allows you to outline the course format and the possibilities of using mobile learning technologies. Course development focuses on addressing the following issues: 1) the feasibility of developing special tools; 2) the complexity of scaling educational content in an electronic format; 3) the scope of training in a mobile format, taking

into account practical and independent classes. Gradually, from module topics to individual lessons/tasks, the range of mobile learning tools available to all participants in the process is determined. Develop step-by-step recommendations for using the training course and its tools. This allows you to create a matrix of mobile tools, determine the parameters of their use and ways to complete the course. Also, at this stage, the selection or development of educational content in the E-Learning format is EER.

Developing a strategy for using mobile applications in a course is a key aspect of successful learning. Creating an environment that is understandable to participants and establishing sustainable feedback will minimize obstacles and help keep students motivated to learn. The key issues are: 1) ensuring the interaction of participants when using various mobile technologies; 2) prompt collection and processing of educational information obtained from various mobile tools; 3) maintaining high motivation for self-study. The solution of these issues allows to ensure the integrity of the course in athletics in a mobile format. This will contribute to its «comprehensibility» and increase expectations for achieving the goal of the discipline.

An important element of monitoring the completion of a mobile learning course in athletics is to determine the self-efficacy of participants. This allows to indirectly and integrally assess the impact of the mobile learning environment on the effectiveness of the educational process.

Thus, the development of a course in athletics in a mobile format is a rather painstaking process. Its success largely depends on the establishment of initial characteristics related to the expected learning effectiveness, as well as a strategy for the integrated use of mobile technologies.

Conclusions. The conducted research allowed us to focus on the key requirements of the organization of mobile training in athletics. The key factors of building a training course, taking into account accessibility and establishing the initial readiness of participants, have been identified. The process of developing mobile learning in athletics is characterized. The proposed approach creates the basis for the technologizing of teaching athletics, taking into account the peculiarities of training future coaches.

Prospects for further research are in the plane of testing the methodology for building a training course in athletics using mobile technologies.

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POSSIBILITIES OF APPLYING INNOVATIVE HEAT PUMP TECHNOLOGIES IN UKRAINE: ENVIRONMENTAL ASPECTS FOR IMPLEMENTING A SUSTAINABLE DEVELOPMENT PROGRAM

Olha Ostapenko, *PhD, As. Prof.,*
Vinnytsia National Technical University, Ukraine

Introduction. The introduction of heat pump technologies in Ukraine has significant potential in terms of environmental sustainability and energy efficiency. Heat pumps are energy-efficient equipment that allows: to reduce greenhouse gas emissions by 50-80% compared to traditional heating systems, to use renewable energy sources (heat from the ground, water, air) and to significantly reduce fossil fuel consumption.

Ukraine has favorable conditions for the introduction of heat pump technologies. These include, in particular, the significant potential of low-potential heat sources (soil, groundwater, water bodies), the need to modernize the outdated heat supply system, obligations to reduce CO_2 emissions in accordance with international agreements, the course towards energy independence and decarbonization (Ostapenko et al., 2020; Ostapenko, 2021; Ostapenko et al., 2022; Ostapenko et al., 2023).

The implementation of heat pump technologies directly corresponds to several UN Sustainable Development Goals: Goal 7 “Affordable and Clean Energy”, Goal 11 “Sustainable Urban and Community Development”, Goal 12 “Responsible Consumption”, and Goal 13 “Combating Climate Change” (UNDP, “Transforming our world: the 2030 Agenda for Sustainable Development”, 2018; UN, “Support Sustainable Development and Climate Action”, 2018).

Data and Methods. The study used methodological and statistical data from the databases of the International Energy Agency (IEA), of the International Renewable Energy Agency (IRENA), the World Bank, the United Nations Statistical Department (UNSD) and others. Our study used systemic, structural, statistical, factor, and comparative analyses.

Results. Large-scale implementation of heat pump technologies can become an important element of Ukraine's green recovery and its integration into the European energy space, taking into account the requirements of the European Green Deal (EC, "A European Green Deal. Striving to be the first climate-neutral continent", 2019; IEA, "Net Zero by 2050", 2021).

Heat pumps provide significant environmental benefits for Ukraine, especially in the context of modern environmental challenges and energy transition.

The introduction of heat pumps will ensure a reduction in direct CO_2 emissions by 50-80% compared to gas boilers and by 70-90% compared to coal-fired thermal power plants; will contribute to the reduction of methane emissions associated with the extraction and transportation of natural gas; will ensure a reduction in the overall carbon footprint of the heating and hot water supply system.

The introduction of heat pumps will also ensure a reduction in local air pollutants, namely: the absence of direct emissions of nitrogen oxides (NOx), sulfur oxides (SOx), carbon monoxide (CO) and particulate matter characteristic of fossil fuel combustion; improving air quality in cities, especially during the heating season; reducing the risks of respiratory diseases associated with air pollution.

The introduction of heat pumps in Ukraine will contribute to the conservation of natural resources. The consumption of non-renewable fossil resources (gas, coal, oil) will be reduced, energy will be used efficiently in heat pumps and the load on the power grid will be reduced due to high energy efficiency.

The synergy of heat pumps with renewable energy sources will be ensured. The following will be provided: the possibility of working in conjunction with solar power plants, wind generators; increasing the share of "green" energy in the energy balance of Ukraine, promoting the decarbonization of the heat sector through the use of electricity from renewable sources.

The introduction of heat pumps will reduce heat pollution: no direct discharge of hot water into water bodies (unlike some CHPs and industrial facilities), reducing the heat load on urbanized areas. Water resources will also be conserved, namely: reducing the consumption of water required for cooling traditional generating capacities; preventing pollution of water bodies with wastewater associated with the extraction and processing of fossil fuels.

In the foreseeable future, replacing 40% of gas boilers with heat pumps in Ukraine could reduce CO_2 emissions by 10-15 million tons annually, and reduce natural gas consumption by 5-7 billion m^3 per year. These actual figures demonstrate the significant potential of heat pumps as an environmentally friendly alternative to traditional heating systems, especially in the context of the goals of decarbonization and improving the state of the environment in Ukraine.

Conclusions. As a result of the widespread introduction of heat pumps in Ukraine, long-term environmental effects will be ensured – contributing to the achievement of Ukraine's climate goals in accordance with the Paris Agreement, supporting the goals of the European Green Deal in the context of European

integration; preserving ecosystems that suffer from the consequences of fossil fuel extraction (mines, gas extraction).

In the conditions of Ukraine, the introduction of heat pumps is of particular importance for ensuring environmentally sustainable restoration of infrastructure and modernization of the energy sector, which will contribute to the overall improvement of the environment and public health.

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APPRECIATIVE INQUIRY (AI) METHOD IN THE STUDY OF SUSTAINABLE DEVELOPMENT

***Iryna Melnyk**, PhD, As. Prof.*
Borys Grinchenko Kyiv Metropolitan University, Ukraine

Introduction. The approach developed by Dr. David Cooperrider and Dr. Suresh Srivastava in the 1980s aims to improve the quality and sustainability of educational practices through the collaboration of all stakeholders (Cooperrider, 1990). This approach is known as the 5-D model – Definition, Discovery, Dream, Design, and Destiny – which helps to identify strengths, co-create effective strategies, and develop a culture of positivity and collaboration (Srivastava et al.,1999). Nowadays, university education prioritizes sustainable development as an opportunity to align educational practices with broader global goals. Appreciative Inquiry is based on several core principles that guide its application in organizational development and change management. These principles emphasize a strengths-based approach and foster constructive stakeholder engagement, promoting a positive collaborative environment for sustainable change.

Data and Methods. The 5-D model is a structured framework for implementing an assessment study consisting of five stages: Definition, Discovery, Dream, Design, and Destiny. Each stage builds on the previous one, including identifying strengths, anticipating future opportunities, co-creating effective strategies, and committing to continuous learning and adaptation. This model promotes effective change management and strengthens stakeholder cooperation and collective action, ultimately improving education quality.

The study of using the Positive Inquiry method has become a transformative methodology in education, particularly in improving the quality and sustainability of educational practices. This strengths-based approach enables educators and students to co-create a vision for improvement by focusing on academic institutions' strengths and potential. Involving all stakeholders in the educational process helps create a collaborative environment conducive to meaningful change. Applying the Positive Inquiry Method in the academic context is intended to promote transformational change. In the present study, the method was used to explore the perspectives of first-year students to come together to solve common problems and find ways to improve pedagogical practices tailored to their needs. In the first month of studying at the university, a student actively gets acquainted with all the processes of the university community through the discipline “University Studies,” which allows the student to express their thoughts and impressions, gain new knowledge about the future specialty and unite students into an academic group with their views, observations, and preferences. During these first introductory classes, the Appreciative Inquiry (AI) method of positive-oriented research is used (Word of Work Project, 2024). Collaborative work in groups of students begins with the correct formulation of generative questions. How do you see it? How can we do this

best together? Perhaps if we…Discussing such questions together stimulates creativity and innovation in acquiring new knowledge, deepens connections, and improves relationships between students and the teacher and students in the group. As a result of such collaboration, new ways of solving complex problems and compelling images for collective ideas emerge. In a student group, trust in each other is necessary, positive energy is generated, and the community of students moves further in the direction of mutual trust and understanding. The first topic used in the positive research method was "How do you see your future at this university?" The first phase of the research (Discovery) is the discovery of the best of what is, during which students explore the historical past of the university where they will study and find fundamental knowledge helpful in shaping their future. While researching the phenomenon of visioning the future, students focus on their vision and learn the basic principles they use in their research. In the second stage of the cycle, the dreaming phase, students explore the question: How should it be?

Results. They imagine themselves in three years…model what situation is desirable and what their environment looks like, and move on to the third stage of research (Design) (What should be?). At this stage, the vision of the future is transformed in the first-year students' minds. The fourth and final research stage (Destiny) is developing an action plan to translate all the ideas into tangible actions. The joint passage of all four phases of the cycle of the positive research method leads to the rapprochement of students and the organization of a new, friendly group. The research resulted in works created with the help of data visualization services – infographics, drawings, digital narratives, and other forms of self-expression-allowing students to formulate their dreams and emphasizing the importance of their involvement in decision-making related to their education.

The use of the Appreciative Inquiry (AI) method of positive-oriented research when working with first-year students who are just starting their way in the university community is based on the fundamental principles: constructivism (creating social reality – you should always be open to new knowledge), predictability (you need to move in the direction of thoughts, see and hear the expected results), positivity (many ways of open communication provide endless possibilities in understanding a person, object, phenomenon, action).

Students are actively involved in the initial stages of the 5D cycle – "Discovery" and "Dream" – where they identify the key ideas that shaped their educational experience. Their findings emphasized the importance of enjoyable learning, relevant life experiences, collaborative learning environments, and family metaphors in the learning environment. These findings have important implications for sustainable development to create a supportive and effective learning environment. Discovery, Dream, Design, and Destiny phases focus on identifying what is already working well and envisioning an improved future.

Research using the Appreciative Inquiry (AI) method of positive-oriented research plays a crucial role in promoting transformational change in educational institutions, which is a prerequisite for achieving sustainable development.

Sustainable development requires a fundamental transformation in the way education systems operate, moving from traditional incremental approaches that prioritize efficiency to focusing on developing new, impactful processes.

Conclusions. The use of this method in education emphasizes its importance in preparing future leaders to address complex global issues, equipping people with the knowledge, skills, and attitudes necessary to contribute to a sustainable future. In this context, this approach serves as a pedagogical tool that emphasizes the strengths and potential of educational systems, promoting the collaborative search for innovative solutions to pressing problems. This shift from traditional problem-solving to generative approaches is in line with the broader goals of sustainable development. Transformational changes in the educational environment are closely related to the use of various innovative methods, the introduction of modern digital tools, and the involvement of various forms of formative assessment of classes. All these aspects are closely interconnected and stimulate the adoption of the main idea: learning is an opportunity that needs to be supported, as students say, "embraced". Such a positive focus not only creates motivation among the participants of the educational process but also promotes a culture of cooperation and engagement, which is vital for the implementation of sustainable practices in education. By creating an environment in which stakeholders are encouraged to explore and build on their strengths, the Appreciative Inquiry (AI) cultivates the conditions necessary for sustainable transformation.

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DECARBONIZATION AFTER DESTRUCTION: COST-OPTIMAL STRATEGIES FOR UKRAINE'S ELECTRICITY SECTOR TRANSITION

***Iryna Sotnyk**, D.Sc. (Econ.), Prof.,*
***Jan-Philipp Sasse**, Ph.D.,*
***Evelina Trutnevyte**, Ph.D., Prof.,*
University of Geneva, Switzerland

The Russian full-scale aggression in Ukraine has caused unprecedented challenges for the country's electricity infrastructure. By December 2024, over 50% of electricity capacities were destroyed or severely damaged due to Russian attacks, with the occupied and frontline territories suffering the most significant losses (World Bank, 2025). Key installations, including large solar photovoltaic (PV), wind, hydroelectric, and thermal power plants, faced mass destruction. Ukraine hence necessitates post-war reconstruction based on the "building back better" principle. The war revealed critical vulnerabilities in Ukraine's electricity sector, such as the excessive concentration of electricity capacities, outdated technologies, and policy distortions. However, the destruction also presents opportunities to rebuild the system with innovative technologies and sustainable policies. Ukraine's commitment to the European Green Deal and carbon neutrality by 2050 (United Nations, 2023; Verkhovna Rada of Ukraine, 2024) highlights the importance of transitioning to green energy and decentralizing infrastructures.

To support effective reconstruction, this study modeled Ukraine's electricity sector for 2035 in line with the National Energy and Climate Plan until 2030 (Cabinet of Ministers of Ukraine, 2024) and the Updated Nationally Determined Contribution of Ukraine to the Paris Agreement (United Nations, 2023). Unlike previous research relying on macro models such as TIMES-UKRAINE or DESTINEE (Chepeliev et al., 2023, 2023a; Tröndle et al., 2024), we adopted a regionalized focus, offering higher resolution cost-optimal scenarios for sustainable electricity sector development across Ukraine. The study further evaluated associated sustainability impacts, including those on PM_{10} air pollution, land use, employment, total system cost and marginal electricity prices.

The UKRAINE-EXPANSE model (Sotnyk et al., 2025) used in the study was a spatially-explicit, cost-optimization electricity sector model (Sasse & Trutnevyte, 2020, 2023) adapted to Ukraine and designed to plan electricity generation, storage and transmission for 2035 while integrating 17 power generation, three storage, and two transmission technologies across the country's regions. The model evaluated social, environmental, and economic impacts of electricity processes at regional and nodal levels, including export-import flows. It covered 24 Ukrainian administrative regions, connected through 11 domestic nodes. Regions under Russian occupation since 2014 (Crimea and parts of Luhansk and Donetsk oblasts) were excluded from the analysis due to unreliable statistics. Additionally, five neighboring countries

(Romania, Poland, Slovakia, Hungary, and Moldova) were incorporated as unified nodes connected by transmission lines.

Baseline regional electricity sector data (2018–2020) were used and adjusted to Y2021 conditions. Due to restricted access to recent energy data, destruction assessments as of December 2024, sourced from national and international reports, news agencies, and databases, were incorporated. Regional power plant capacities were adjusted to reflect destruction: fully destroyed plants were excluded from scenario modeling for the future, and regional capacities were reduced based on proximity to the frontline, ranging from 20% (western regions) to 90% (eastern regions).

The model then generated four cost-optimal scenarios using three constraints aligned with decarbonization and renewable energy targets (Cabinet of Ministers of Ukraine, 2024; United Nations, 2023; Verkhovna Rada of Ukraine, 2024). These scenarios quantified installed capacities, electricity generation volumes by technologies, and regional impacts. Social, economic, and environmental effects were assessed alongside annual average marginal electricity prices. Total system costs were calculated, as were capital investments in new capacities. Changes in electricity export-import flows were also evaluated. Policy recommendations were formulated to guide sustainable regional electricity sector development, emphasizing decarbonization, resilience, and regional equity.

Our findings showed that Ukraine could meet its 2035 electricity demand (181 TWh/year) without increasing pre-war nuclear capacities or rebuilding destroyed hard coal facilities. Hard coal could be replaced by environmentally friendly electricity sources such as wind power, biomass and pumped hydropower storage. The largest capacity growth would be needed in war-affected eastern and northern regions (Donetsk, Luhansk, Zaporizhzhya, Zhytomyr, Chernihiv, and Kyiv) and southern areas (Odesa and Mykolayiv). Nuclear power would remain dominant in regions with existing plants, providing affordable electricity nationwide. In zero coal scenarios, hard coal capacity would be initially supplanted by gas facilities. However, without the zero-coal constraint, hard coal would still be critical in some regions, like Ivano-Frankivsk, Volyn, and Ternopil. Conversely, regions such as Zakarpattya, Kirovohrad, Odesa, and Kherson could transition entirely to green electricity generation. Wind power capacity would be expected to grow significantly in eastern, southern, and north-central areas based on favorable natural conditions. Solar capacity growth would be slower, reflecting a pre-war solar boom. To eliminate hard coal, biomass power plants would expand notably in Donetsk, Luhansk, Zhytomyr, Chernihiv, Kyiv, Odesa, Sumy, and Kharkiv regions.

Green reconstruction would require a 10-13-fold increase in storage capacity by 2035 to balance the electricity mix, given the rise in renewable generation and a large share of nuclear generation. Due to high costs, technologies like batteries and power-to-hydrogen would still play a limited role in 2035. Transmission infrastructure would expand to facilitate interregional flows, with enhanced links to Slovakia, Romania, and Hungary to support export-import needs.

Environmental benefits of scenarios would include reduced CO_2 and PM_{10} emissions, with Dnipropetrovsk and Kyiv remaining the most polluted areas, though far less than pre-war levels. Donetsk and Luhansk could see minimal pollution due to the adoption of renewable technologies. Job growth would accompany green electricity expansion, particularly in eastern and southern regions, though increased direct land use for facilities would be required. Average marginal electricity prices were projected at 55–72 EUR/MWh, with higher costs in green power-focused regions, like Luhansk and Kyiv. Investments in wind, solar, and nuclear power would drive costs, with total system cost differences of up to 10% across scenarios. This modest variation could encourage policymakers to adopt greener solutions.

Overall, based on the modeling results, the reconstruction strategies for Ukraine must balance regional equity, environmental sustainability, energy security, and economic efficiency, as a 10% increase in total system costs for green reconstruction underscores the need for broader criteria. Nuclear power policy should evaluate the possibility of extending operational lifespans with attention to safety, regional needs, and electricity transport costs. Prosumerism for solar PV should be encouraged through net billing and investment in micro-installations, alongside green auctions for business projects. Wind power should receive priority investments in high-potential regions, supported by economic incentives. Biomass requires feed-in tariffs and pricing reforms, while pumped hydropower storage expansion must undergo thorough environmental and economic evaluations. Transmission infrastructure expansion is crucial for interregional electricity flow within the country and with its neighbors. Overall, a balanced, multifaceted policy framework is vital for achieving decarbonization targets and fostering a resilient, equitable electricity sector future for Ukraine's regions.

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THE EU'S DIGITAL TRANSFORMATION: IMPERATIVES OF ECONOMIC AND ENVIRONMENTAL SUSTAINABILITY

Yuliia Kaliuzhna, *PhD in Political Science, As. Prof.,*
H. S. Skovoroda Kharkiv National Pedagogical University, Ukraine

Introduction. In the context of the global transformations characterizing the early 21st century, the European Union ambitiously positions itself not only as a leader in the digital revolution but also as a pioneer in the integration of technological progress with the imperatives of ecological sustainability. Having articulated three pivotal vectors for digital transformation – technology for people, a fair and competitive economy, and an open, democratic, and sustainable society – the EU demonstrates a strategic comprehension of the interconnectedness between digital advancement and the future of the planet (EC, 2010; EC, 2020a). The adoption of the strategic document "Digital Compass 2030: the European way for the Digital Decade," with its central tenet of "Joining forces: a digital transformation for Europe's sustainability," underscores the pressing need for an integrated approach

to addressing contemporary civilizational challenges (EC, 2021; EC, -b; EP & Council of EU, 2022).

At a time when escalating geopolitical instability, economic disparities, and environmental threats are becoming defining features of the global landscape, the EU's trajectory towards a human-centric, resilient, and prosperous digital future assumes particular salience. Leveraging its inherent strengths – a robust single market, a progressive regulatory environment, a commitment to European values, an active role in international trade, a developed industrial base, a highly skilled workforce, and a mature civil society – the EU endeavors to harness the potential of digitalization as a catalyst for positive change (EC, 2024; EC, -a; EC, -b; EP & Council of EU, 2022).

Indeed, digital technologies unlock unprecedented opportunities for stimulating economic growth, fostering entrepreneurial initiatives, expanding markets, and attracting investment, while simultaneously generating new employment avenues amidst growing concerns regarding economic security and environmental integrity. Of particular significance is the potential of digital innovations in the context of achieving the ambitious objectives of the European Green Deal. The deployment of digital solutions and the effective analysis of data constitute crucial instruments for the transition towards a climate-neutral, circular, and more sustainable economy. Ranging from the substitution of traditional business travel with videoconferencing to the optimization of ecologically sound processes in agriculture, energy, construction, industry, and urban governance, digital technologies are critically important for realizing the EU's stated goal of reducing greenhouse gas emissions by at least 55% by 2030 and improving the state of the environment. Furthermore, initiatives such as the development of a pan-European digital identity wallet and the implementation of the Once-Only Technical System, which ensures the secure exchange of official documents and data between EU public authorities upon the requests of citizens and businesses in cross-border administrative procedures, not only streamline interactions but also contribute to the reduction of paper-based processes and their associated environmental costs (EC, 2024; EP & Council of EU, 2022). Concurrently, acknowledging the significant environmental impact of digital infrastructure, the EU aims to render digital technologies themselves more sustainable, energy-efficient, and resource-effective. The encouragement of innovation and the implementation of stringent environmental standards are key elements of a strategy directed at minimizing the ecological footprint of the digital transformation.

Data and Methods. The analysis of the relationship between digital transformation and environmental sustainability of the European Union was based on an integrated qualitative and quantitative approach. The qualitative analysis focused on EU legislative acts and strategic documents obtained from official sources (European Commission, European Parliament, Council of the European Union). Systematic elaboration of EU directives, regulations, and strategies enabled the identification of regulatory frameworks, political instruments, and strategic

vectors in the areas of digital and environmental policy. Furthermore, the quantitative analysis was based on Eurostat statistics (DESI index, environmental indicators, data on the UN SDGs, innovation activity), with the aim of identifying statistical correlations between digital transformation and environmental sustainability.

Results. Acknowledging the planetary boundaries of ecological sustainability, the European Union considers digital transformation not merely as a discrete technological trend but as a fundamental instrument for a qualitative leap towards a new paradigm of environmental responsibility. The strategic alignment of the ambitious digital policy, embodied in the "Digital Compass 2030," with the far-sighted objectives of the European Green Deal represents a unique endeavor to converge technological progress and the ecological imperative. This symbiosis transcends the simple transposition of existing processes into the digital sphere, instead envisioning a profound re-evaluation of socio-economic models wherein digital innovations become pivotal in addressing complex environmental challenges, guided by human-centric values as an ethical compass (EC, 2021; EC, 2024).

The essence of this approach lies in leveraging the pervasive capabilities of digital technologies to cultivate ecosystems of sustainable development. From smart energy grids that optimize consumption and integrate renewable sources to precision agriculture that minimizes resource and chemical utilization, digital solutions are becoming the architects of more efficient and environmentally benign processes. Big data and artificial intelligence unlock opportunities for in-depth analysis of ecological trends, crisis forecasting, and the development of proactive measures. Concurrently, the expansion of digital capabilities for citizens and businesses fosters a culture of environmental awareness, empowering each participant in economic relations with the tools to make more sustainable decisions (EC, 2024).

However, the trajectory towards digital ecological sustainability is not without its impediments. Bridging the digital divide, ensuring the cybersecurity of critical infrastructure, minimizing the environmental footprint of the digital industry itself, and the ethical deployment of artificial intelligence constitute significant challenges. The European Union demonstrates a commitment to addressing these through active regulation, the stimulation of innovation, and the promotion of international cooperation. The four strategic directions of the "Digital Compass 2030" – digital skills, sustainable digital infrastructures, digital transformation of businesses, and digitalisation of public services – are not merely discrete goals but interconnected elements of a comprehensive strategy where ecological sustainability serves as a cross-cutting priority. Thus, Europe's digital evolution emerges not as a technological end in itself but as a conscious choice in favor of a sustainable, human-centric, and environmentally responsible future, where technology serves as a potent instrument for achieving ambitious ecological objectives. The strategic fusion of digital transformation and environmental policy is a key imperative for ensuring the long-term resilience of the European Union in the context of global change.

Conclusions. The European Union perceives digital transformation not merely as a technological upgrade, but t as a strategic imperative for achieving the fundamental objective of economic and ecological resilience amidst the increasing turbulence of the global landscape. The synchronization of the ambitions of the "Digital Compass 2030" with the forward-looking vision of the European Green Deal attests to the EU's mature understanding of the necessity for a holistic approach, wherein technological progress becomes an indispensable component of environmental responsibility, guided by human-centric values. This study corroborates that the EU's strategic digital initiatives possess significant potential for a qualitative transformation of the paradigm of resource utilisation and the minimisation of the ecological footprint. Ranging from the intellectualisation of energy systems to the optimisation of the agricultural sector and the development of a circular economy, digital technologies emerge as a pivotal instrument in the attainment of the Union's ambitious environmental goals. Enhancing the digital competence of citizens and supporting the digital maturity of businesses are critically important elements of this comprehensive strategy.

However, the realisation of this dual imperative – digital and ecological sustainability – is not a trivial undertaking. This article highlights critical barriers, among which addressing digital inequality, ensuring robust cybersecurity for critical infrastructure, minimising the intrinsic environmental impact of the digital sector, and implementing ethical frameworks for novel technologies warrant particular attention. The success of this ambitious integration will necessitate not only consistent regulatory policies and the stimulation of innovation but also active international cooperation for the exchange of best practices and the harmonisation of global standards. In conclusion, the European Union demonstrates strategic foresight in considering digital transformation as a catalyst for forging not only an economically prosperous but also an ecologically sustainable future. Future scholarly inquiries should focus on the empirical evaluation of the effectiveness of implemented initiatives, the identification of optimal models of synergy between the digital and environmental agendas of the EU, and the development of practical recommendations for maximising the interplay of these two key imperatives.

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A MODEL FOR SUSTAINABLE ECONOMIC RECOVERY OF UKRAINE: ENVIRONMENTAL DIMENSION IN THE CONTEXT OF EUROPEAN INTEGRATION

Lidiya Shergina, *PhD in Econ., As Prof,*
Kyiv National Economic University named after Vadym Hetman, Kyiv
Alla Zhemba, *PhD in Econ., As.Prof.,*
National University of Water and Environmental Engineering, Rivne

Introduction. In the context of the deep socio-economic transformation caused by the war, Ukraine faces the need not only for rapid economic recovery, but also for the integration of sustainable development principles that are in line with the European course. In this regard, it is important to develop a model of sustainable economic recovery that combines economic growth, environmental safety and integration into the EU.

The European Green Deal has become not only an environmental initiative, but also an economic strategy focused on modernising production, developing human capital, and energy efficiency. For Ukraine, it is important not only to adapt to these requirements but also to use them as an opportunity for a qualitative economic upgrade.

Data and Methods. Accordingly, the creation of a sustainable economic recovery model for Ukraine is essential – one that integrates economic growth, social inclusion, and environmental safety, all aligned with the context of European integration.

A comprehensive multi-level methodology combining quantitative and qualitative approaches is employed in researching sustainable economic recovery

and justifying the recovery model. The methodological foundation includes analysis of Ukraine's and the EU's legal and regulatory frameworks, particularly: the Association Agreement [1], the European Green Deal roadmap [2], and World Bank reports [3].

To compare Ukrainian and European environmental-economic policies, the study assesses the compliance of Ukrainian environmental indicators and strategies with the requirements of the European Green Deal. This includes comparative analysis of GDP, greenhouse gas emissions, and employment structure in the green economy sectors.

In 2022, Ukraine's CO_2 emissions per unit of GDP amounted to 0.62 kg/USD, while the EU average was 0.21 kg/USD [4]. The share of renewable energy in total energy consumption was 12.4% in Ukraine compared to 22.5% in the EU.

To identify the potential for sustainable recovery in the ecological dimension and European integration context, a SWOT analysis of the recovery model based on sustainable development is used. This reveals the key factors influencing the development of sustainable recovery within European environmental standards and requirements:

1. Strengths: compliance with European environmental standards; investments in sustainable development; support for innovation in green technologies; public demand for environmental responsibility.

2. Weaknesses: low adaptation to EU environmental regulations; inadequate waste processing infrastructure; low environmental education levels; limited access to ecological innovations.

3. Opportunities: attracting European grants and investments; implementing the green economy; strengthening EU integration through environmental initiatives; expanding markets for sustainable products and services.

Threats: political uncertainty; economic dependence on traditional industries; changes in EU environmental regulations; infrastructure gaps; weak institutional control mechanisms.

The following methods were also applied: inductive-deductive method; expert evaluation; scenario modeling method; content analysis of strategic documents; case analysis of successful environmental transformations in Central and Eastern European countries.

Using scenario modeling, two basic recovery scenarios were developed:

Industry-oriented scenario – focuses on traditional production without prioritizing sustainability.

Sustainable/green scenario – integrates ESG principles, energy efficiency, and circularity.

Scenario analysis based on UNIDO [5] data showed that the green scenario can increase GDP by 5–7% in the long term through energy savings, reduced dependence on imported energy resources, and improved investment attractiveness.

The case study expansion under the ecological dimension and EU integration context involves examining specific examples of how countries or organizations

adapt to EU environmental standards and implement sustainable development in line with European integration principles.

When conducting case analysis, key focus areas include: adaptation to EU environmental standards; attracting investment in sustainable development; innovations in ecological projects; circular economy and waste management; environmental education and public awareness.

Key challenges in implementing sustainable development principles in line with EU integration include: additional work on implementing legislative initiatives; raising public and business awareness of new environmental standards; outdated infrastructure requiring modernization; high costs of developing and implementing innovative technologies; need for harmonizing waste processing infrastructure with EU standards; necessity of long-term educational initiatives.

Results. Sustainable development is a concept that ensures the harmonious combination of economic growth, social responsibility, and environmental stability aimed at securing the long-term viability of society. This approach acknowledges that economic development must account for not only financial indicators but also social and environmental aspects to preserve natural resources for future generations [6].

Among sustainable development models at the enterprise level are: linear economy; circular economy; triple bottom line; green business models; closed-loop economy; socially responsible business; innovative environmental technologies [6]. Green business models involve strategies aimed at using environmentally friendly technologies and minimizing negative environmental impacts.

In Ukraine, environmental factors are increasingly seen not as obstacles to growth, but as tools for modernization. Implementing green economy principles generates a multiplier effect – stimulating innovation, green sector employment, and foreign investment [7].

The development of green technologies and sustainable practices requires substantial financial investments. It is important to utilize funding opportunities through European funds and investment programs.

The EU financially supports projects focused on meeting environmental standards, granting access to funds such as Horizon Europe, LIFE, and EU4Environment. Adoption of a national decarbonization and climate change adaptation strategy is a key prerequisite for this. Raising environmental awareness among citizens and businesses is also a crucial step for effective adaptation to EU environmental standards.

A sustainable economic recovery model for Ukraine must integrate the environmental dimension as an inseparable part of the development strategy. In the context of European integration, this model may include:

Implementation of the EU Green Deal principles;

Institutional integration of environmental policy into economic planning;

Human capital development through environmental education and specialist training;

Use of EU funds for green reconstruction financing;

Circular economy as a strategic priority at the regional and community levels.

Key instruments for implementing the sustainable recovery model: integration of environmental components into national reconstruction programs; creation of green industrial parks; support for clean technology startups; educational and informational campaigns for citizens and businesses [8].

Conclusions. The period of economic recovery presents a window of opportunity for Ukraine to achieve a qualitative transformation of its economy based on sustainable development principles. Integrating the environmental dimension will not only align Ukraine with European requirements but also ensure competitiveness, energy security, innovation, and resilience to future challenges.

Implementing a sustainable recovery model aligned with the EU's environmental benchmarks will promote harmonization with the European economic space and ensure a sustainable future for the country. Focusing on sustainable development will enable Ukraine not only to meet European integration demands but also to build long-term resilience to future risks and challenges.

Sustainable development in the context of European integration should become the cornerstone of Ukraine's new economic model – one that is resilient, innovative, and environmentally oriented.

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DECENTRALIZED ENERGY FOR NATIONAL RESILIENCE: BUSINESS MODELS AND DIGITAL SOLUTIONS FOR UKRAINE'S BUSINESS

***Iryna Sotnyk**, D.Sc. (Econ.), Prof.,*
***Yu Yang**, Master student,*
***Chen Yingyou**, Master student,*
Sumy State University, Ukraine

Decentralized Renewable Energy Systems (DRES) support energy security, economic resilience, and environmental goals by allowing businesses to generate and manage energy independently from centralized grids. These systems include solar photovoltaic, wind turbines, bioenergy, geothermal and other renewable sources, as well as energy storage technologies. DRES are especially valuable in contexts with disrupted or unreliable energy supplies – such as remote areas, aging infrastructure, or wartime conditions.

The ongoing Russian aggression in Ukraine has caused unprecedented damage to energy infrastructure, underscoring the need for decentralized, resilient energy solutions. DRES offer a path toward continuous energy supply, reduced reliance on fossil fuels, and greater national energy autonomy (Sotnyk et al., 2024a). However, their successful deployment depends on implementing robust business models that facilitate investment, scalability, and operational efficiency. The most widespread business models are presented in Table 1.

To effectively implement DRES, Ukraine must adopt innovative business models mentioned in Table 1 and integrate digital technologies aligned with the principles of Industry 4.0 and Industry 5.0. These industrial paradigms provide a framework for transforming traditional energy systems into smart, flexible, and human-centered ecosystems. Industry 4.0 emphasizes the digitization and automation of processes through the Internet of Things (IoT), artificial intelligence (AI), big data, and cyber-physical systems. In contrast, Industry 5.0 builds on this foundation by integrating human creativity, ethical considerations, and social responsibility into the technological evolution. Together, these approaches offer powerful tools for rebuilding and modernizing Ukraine's energy landscape during and after the war.

Table 1 – Business models for implementing DRES (Arowana, 2024; Leal-Arcas et al., 2020; Piterou, & Coles, 2020; Sotnyk et al., 2024)

Business model	Key features	Benefits

Community-owned energy models	Local stakeholders co-invest in and manage renewable systems like solar or wind, sharing the generated energy.	Promote energy democracy and local development.
Pay-as-you-go (PAYG) models	Minimal upfront cost; users pay for the consumed energy incrementally using smart meters to monitor usage and manage payments.	Expand access for small and medium-sized enterprises and low-income communities.
Peer-to-peer (P2P) energy trading	Decentralized energy trading via blockchain or smart grids. Producers can sell surplus electricity, and consumers purchase locally generated green power at competitive rates.	Reduces energy costs and promotes local power generation.
Virtual power plants (VPPs)	Aggregate distributed energy sources into a unified, digitally-managed system.	Enhance grid reliability and revenue generation, and optimize resource utilization.
Corporate power purchase agreements (PPAs)	Long-term contracts between producers and businesses, which enable purchasing renewable energy directly from producers at predetermined rates.	Ensure cost stability and support green targets, reducing carbon footprints.

One of the most promising developments in the energy sector, fully aligned with both Industry 4.0 and 5.0, is the Energy-as-a-Service (EaaS) model. This model shifts the traditional energy paradigm from product ownership to service subscription (GridX, 2025). Businesses subscribe to a comprehensive package that may include green energy generation, real-time monitoring, predictive maintenance, and performance optimization, which is delivered by specialized providers who retain ownership of the infrastructure. In wartime Ukraine, where capital investment is risky and uncertain, the EaaS model offers flexibility, scalability, and reduced financial barriers (Table 2).

Furthermore, Public-Private Partnerships (PPPs) can play a crucial role in financing and expanding DRES (Table 3). These collaborations between government institutions and private enterprises are particularly effective in post-crisis recovery contexts, as they allow for shared investment, risk management, and knowledge transfer (Investopedia, 2025). In Ukraine, PPPs could be structured around concession agreements, build-operate-transfer models, or joint ventures – each enabling rapid development of renewable energy systems, particularly in critical infrastructure such as hospitals, communication networks, and military facilities.

Table 2 – Characteristics of the EaaS model for adopting DRES (Enel X, 2025; (GridX, 2025); Malani & Sehjpal, 2024)

Main features	Benefits	Driving factors
subscription-based pricing; outcome-oriented approach;	providers leverage advanced technologies and expertise to optimize power generation and consumption;	technological advancements (integration of IoT devices, AI, and blockchain technology);

third-party ownership (the service provider retains ownership of the infrastructure, reducing capital expenditure for businesses).	reduced financial barriers (eliminating the need for significant upfront investment); operational efficiency and scalability.	decarbonization goals (the model provides a viable pathway to transition to renewable energy sources); regulatory incentives (governmental incentives for adopting energy-efficient and green power solutions).

Table 3 – Characteristics of the PPPs model for adopting DRES (Investopedia, 2025)

Main elements	Benefits
concession agreements (government grants private entities the right to develop and operate energy infrastructure for a specified period); build-operate-transfer models (private entities finance, construct, and operate DRES projects before transferring ownership to the public sector); joint ventures (private and public sectors share ownership and operation responsibilities for green power projects).	access to expertise (businesses benefit from the technical expertise of public institutions and the operational efficiency of private entities); market expansion (businesses can penetrate new markets by leveraging public sector networks and support); regulatory support (public sector involvement ensures compliance with regulatory frameworks and facilitates permitting processes).

The integration of DRES in Ukraine must also consider broader national policy goals. Regulatory frameworks should be adapted to encourage innovation, streamline permitting processes, and provide financial incentives for digitalized energy solutions. Encouraging local manufacturing of renewable technologies, supported by digital twins and smart manufacturing tools from Industry 4.0, can further stimulate economic recovery and create new jobs. In the Ukrainian context, the application of technologies of Industry 5.0 can help in designing energy systems not only for efficiency but also for resilience, community empowerment, and social equity. DRES can reduce energy poverty, improve the quality of life in affected regions, and support national efforts toward decarbonization, fostering technological sovereignty in a time of geopolitical instability.

To sum up, DRES are more than just a technical solution as they are a strategic necessity for Ukraine in the face of war. By implementing considered business models into practice, and by embedding digital innovations inspired by Industry 4.0 and 5.0, Ukraine can build an energy system that is not only resilient to current challenges but also future-ready. The integration of digital technologies, human-centered design, and sustainable values will be critical in ensuring that Ukraine's green energy transition is robust, inclusive, and aligned with its long-term national interests.

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DETERMINATION OF THE PROPERTIES WELDED SEAM IN THE MANUFACTURE OF LATHE BED

***Pavlo Havrysh**, Dr. Sc., Full Prof.,*
***Vadim Yusifov**, Postgraduate,*
***Vitalia Segin**, Postgraduate,*
Donbas State Engineering Academy, Kramatorsk, Ukraine

Introduction. Modern machines for processing heavy parts of power engineering, metallurgical equipment, equipment for the nuclear industry, etc., require strong lathe beds with high performance properties of vibration resistance, fatigue load, bending moments, etc. However, traditional cast lathe beds have less load resistance and nevertheless have huge dimensions and mass [1–3]. Welded lathe beds are 30-40% more economical than cast lathe beds and have a number of advantages. A special advantage is that welded lathe beds are much less harmful to the environment compared to casting technology.

In the manufacture of welded lathe beds, it is necessary to determine which metals during welding will have the highest resistance to fatigue, cyclic loads.

Data and Methods. If we consider from the position of strength, the resulting weld affects the structure formation and performance of the lathe bed structure. Therefore, the analysis of the microstructure of the weld and HAZ (Heat Afected Zone) is very important. When welding steels, physical and chemical processes occur that affect the condition and composition of the weld and the whitish zone. Liquid and solid solutions are formed, crystallization and recrystallization are compatible, and the base metal is not exposed to welding heat [4, 5].

Preparation and microstructural analysis of the obtained weld samples were performed in accordance with the requirements of the regulatory documentation. The microstructure was studied using a MIM 8 microscope.

Microstructure examination of samples. Steel samples were welded A570-36 ASTM + Gr1J3502 ASTM; A570-36 ASTM A10 ASTM; 1045 ASTM + Gr1J3502 ASTM. Report presents only microstructure analysis of samples A570-36 ASTM + Gr1J3502 ASTM. The choice of low-carbon steel of ordinary quality is A570-36 due to the fact that such steel is used for the manufacture of the main elements of crane metal structures (main and final beams), it has sufficient strength and plasticity.

The (Fig.1) shows the microstructure of the Gr1J3502 sufficient strength and plasticity. The microstructure of the base metal Gr1J3502 (Fig.1) is a ferrite-pearlite mixture it is characteristic of pre-eutectoid low-carbon steels. However, there is a orientation en bandes, the direction of the "bands" of pearlite grains coincides with the direction of metal flow during metal processing by pressure.

Pearlite grains are heterogeneous in size, there are small and large crystals, and clusters in the form of large formations are characteristic of small grains. Perlite is large-lamellar and its structure is easily differentiated under a microscope, even at moderate magnifications. According to the degree of development of acupuncture

of ferrite, the microstructure can be estimated 1-2 points of scale 3 DSTU 8974:2019 (National standard of Ukraine). The microstructure is characterized by a weak manifestation of needle and only in certain zones there is a more developed needle of ferrite at the grain boundaries.

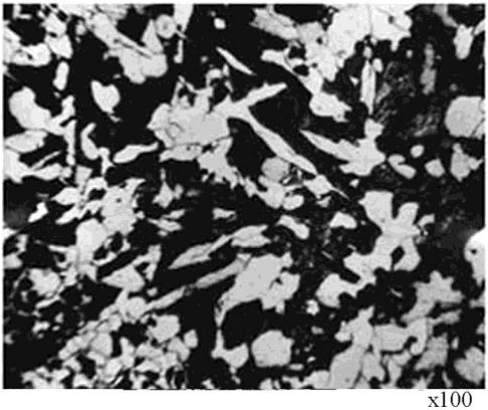

Fig. 1 Microstructure of the Gr1J3502

The number of non-metallic inclusions on non-etched sections does not exceed the norms established by the relevant standards. Microcracks, gas pores and other microscopic defects are not detected. However, in the root of the seam there are separate non-welding with a plane of 2–3 mm^2. Between the layers of surfacing – no evaporation was detected. The deposited metal has a well-defined columnar structure. Each of the columnar crystals consists of separate groups of dendrites. Ferrite grains are strongly elongated due to columnar crystallization and have a needle structure. On the microstructure there is a needle-like arrangement of the ferrite along the grain boundaries and to a strong extent in the middle of the grain, which corresponds to the widmandstet structure estimated at 3 points of the standard microstructure reference scale. The transition from the microstructure of the base metal (A570-36) to the deposited one is smooth, the amount of perlite gradually increases, and the grains are shallow, the clusters adjoin the striped pearlite grains of low-carbon steel, the orientation is initially preserved and further deep into the surfacing, the predominant orientation of the pearlite grains disappears.

The transition from the microstructure from the deposited metal to the base metal (Gr1J3502) is also initially smooth: at first the amount of perlite increases, but gradually as it approaches the fusion boundary – the sizes of the pearlite grains increase, the ferrite acquires a predominant arrangement around the pearlite grains. From the deposited metal to the main one – ferrite is located in the form of narrow strips (bands) oriented perpendicular to the fusion boundary. Near the fusion zone, ferrite is crushed and then closer to the thermal impact zone, becomes large in size, in separate areas it is located in the form of separate clusters.

The transition zone to metal casting (Gr1J3502) is characterized by significant carburization to a purely pearlite structure. The carburization zone has different widths along the seam length. The outline of the zones corresponds to the configuration of the welding boundary corresponding to the heat flows. Closer to the root of the weld, the width of the carburization zone increases. The specified unevenness of structures is due to: on the one hand – the technological features of welding, for example: vibrations of the liquid bath, drop-like flows of filler metal, variable speed of electrode movement during welding, etc., which creates layers of different composition; on the other hand – with uneven heating of steel, components and impurities diffuse in the direction from less heated to more heated areas, as a result of which the carbon content increases at the fusion limit compared to the base metal. In the fusion zone with (Gr1J3502), the carbon concentration is higher than in the fusion zone with steel (A570-36), this is obviously due to the different carbon content in both steels.

The marked structural heterogeneity of the weld and the whitish zone causes mechanical heterogeneity of the material. This is clearly detected by the results of measurements of hardness along the seam with an exit from the deposited metal to the main one. Nevertheless, the removal of the final stresses, as a result of heating to temperatures below critical ones, slightly reduces the overall unevenness of properties, that is, the anisotropy of properties – this can be detected by the results of determining the hardness.

Discussions. The change in the microstructure during welding occurs due to additional heat deposition and the influence of additive metal. But the impact of microstructure changes can be reduced by post-welding metal working techniques. In general, the reduction of the negative impact of the technology of manufacturing the metal structure of the frame in comparison with the technology of casting the frame is very significant [6,7].

Conclusions. The production of heavy machine lathe beds by welding has many advantages over casting.

Reducing the negative impact of the technology of making lathe beds on the environment.

Analysis of the welds of the microstructures of steels for the manufacture of machine tools showed that homogeneous steels have the greatest resistance to fatigue loads.

It is recommended to use low-carbon steels for the manufacture of beds with post-welded machining methods.

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ANTHROPOLOGICAL FACTORS OF KAZENNY TORETS RIVER POLLUTION

***Natalia Gorban**, Teacher 1 categories,*
***Yaroslava Havrysh**, Student,*
***Vladyslava Havrysh**, Student,*
Pedagogical Lyceum, Slaviansk, Ukraine

Introduction. Today, Ukraine faces significant consequences from the military action. The fighting led not only to direct destruction and economic losses, but also affected the state of the environment, causing significant man-made pollution of air, water, and land. The full-scale invasion and military operations in the Donetsk region caused further damage to the environment, including the Kazenny Torets River. At the time of our work, water from the Kazenny Torets River is prohibited for use for technical needs, domestic needs, fishing and swimming. Our work is aimed at a comprehensive study of the ecological state of the Kazenny Torets River in terms of the development of environmental measures in the biomonitoring system of Donbass reservoirs in combat conditions.

Data and Methods. A systematic comprehensive study of the organoleptic parameters of the Kazenny Torets River was conducted, and the degree of pollution

of the aquatic ecosystem by substances of anthropogenic origin was determined by the biomonitoring approach according to chemical indicators.

Results. Sampling was carried out systematically, once a month, using a special sampler or directly into laboratory vessels to minimize the risk of infection, with a container of 0.5–3 liters at a depth of at least 25 cm. One of the goals of our study was to determine the mass measurement of ammonium-ion concentration in surface, underground and return waters of the river [1, 2]. Monitoring the content of ammonium nitrate in surface waters is important for assessing the ecological state of the aquatic ecosystem.

The optical density of the color solution was measured by the photocolorimetric method using cuvettes with a working length of 10 mm at a light wavelength of 425 nm. The volume of the initial and blank water samples for the study was 40 cm^3. The calculated concentration of ammonium ions in the output water sample was determined using the calculation method according to the measurement using the photocalorimetric method with Nesler's reagent (MBB № 081/12 – 0106 – 03).

The results of measuring the mass concentration of ammonium-ions shown in (Fig.1).

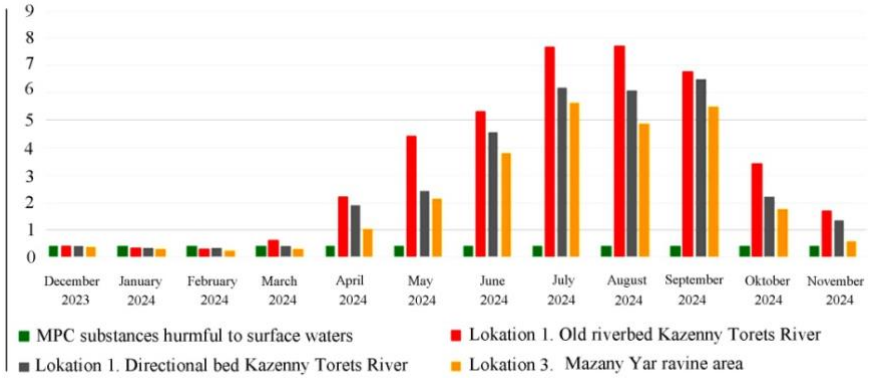

Fig. 1. The content of ammonium nitrate in the surface waters of the Kazenny Torets River

Results of analysis of water samples at location 1 exceeded the standard during the year the highest indicators were 7.68–7.71 mg/dm^3. This ammonium-ions concentration is associated with the pattern of high temperature and low precipitation during this period. But the main reason is anthropogenic impact: household waste, food [3], chemical compound resulting from the explosion of rockets and artillery shells. Water sample results at location 2 confirmed the seasonal dynamics of changes in ammonium nitrogen content the highest values obtained in September – 6.48 mg/dm^3 and July – 6.19 mg/dm^3 exceeded the permissible concentrations.

Ammonium nitrogen content of on-site samples at location 3 ranged from 0.26 mg/dm^3 to 5.65 mg/dm^3.

Discussions. Thus, the concentration of mass ammonium nitrogen in water samples from the Kazenny Torets River fluctuated depending on the time of year: decreased in winter, which is associated with the low temperature regime and the amount of precipitation, which affect the processes of decomposition of organic matter and the activity of aquatic organisms. The content of mass concentrations of ammonium-ions increased in the warm season, which is explained as a natural process of decomposition of organic substances, "blooming" of water, and a high content of nitrate acid salts in surface waters due to anthropogenic activities and chemical compound resulting from the explosion of rockets and artillery shells.

Conclusions. Based on instrumental measurements and detailed theoretical analysis surface water quality indicators Kazenny Torets River taking into account the mass concentrations of ammonium and sulfate ions, the following conclusions were made:

Seasonal fluctuations in the mass concentration of ammonium-ions from the Kazenny Torets River were studied.

A slight decrease in the concentration of ammonium-ions in winter is explained by the low temperature and precipitation. At the same time, the activity of decomposition processes of organic matter and hydrobionts decreases. The increase in the mass concentration of ammonium-ions during warm periods is explained by the natural process of decomposition of organic matter, the “blooming” of water, as well as a significant content of nitrate acid, which is associated with anthropogenic human activity. A special role in increasing the mass concentration of ammonium-ions is played by substances formed after explosions of various types of military missiles and shells.

3. The research results can be used as a basis for developing recommendations for improving the sanitary and biological state of the region’s rivers in the environmental monitoring system.

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CONCEPTUAL MODEL FOR MANAGING ENTERPRISE DIGITAL TRANSFORMATION AS A TOOL FOR SUSTAINABLE REGIONAL DEVELOPMENT

Kostiantyn Zavrazhnyi, *PhD (Econ.), Senior researcher,*
Iryna Sotnyk*, D.Sc. (Econ.), Prof.,*
Anzhelika Kulyk, *PhD student,*
Sumy State University, Ukraine

Introduction. In the context of global challenges such as geopolitical instability, climate change, and socio-economic inequality, sustainable and inclusive development of regions is of relevance. Enterprises play a special role in this process, as they are the basic elements of economic activity at the local level, sources of innovation, employment and social stability. To meet new requirements and challenges, these business entities must rethink their development strategies based on sustainability, inclusiveness and digitalization.

Digital transformation is a key tool for this change, as it allows enterprises not only to increase efficiency and competitiveness, but also to ensure environmental responsibility, social sensitivity and adaptability to a changing environment (Schwab, 2016). In Ukraine, digitalization has been recognized as a priority of state policy, especially in the context of post-war reconstruction. Leading companies are already implementing digital initiatives, which indicate the formation of a favorable institutional environment for the development of the digital economy (Melnyk, 2025).

However, despite the obvious benefits of digitalization, the success rate of relevant projects remains low – more than 70% of digital transformations in the world fail (Schniering, 2023). The main barriers include a lack of holistic strategy, weak leadership, resistance to change, and low digital competence among staff (O'Brein et al., 2024; Kelly, 2023). This indicates the need to create integrated mechanisms for managing digital changes that would consider not only technical, but also organizational, cultural and social factors.

Recent research substantiates the need for a systematic approach to managing the digital transformation of enterprises. Verhoef et al. (2021) and Vial (2019) emphasize the importance of the coordinated development of such factors as digital leadership, organizational culture, data management, staff development and

management support. However, most existing approaches focus either on large multinational corporations or on technological aspects, without considering regional specifics, conditions of uncertainty, and instability.

There is also a research gap on how digital transformation can drive sustainable and inclusive development for small and medium-sized enterprises in regions, especially in transition economies. Therefore, the purpose of this study is to develop a conceptual approach to the deployment of regional enterprises through digital transformation, considering environmental, social, and economic sustainability factors.

Data and Methods. The proposed model is grounded in the concept of dynamic capabilities (Teece et al., 1997) and integrates best international practices (McKinsey, 2018; Westerman et al., 2014; Weill et al., 2013). The research methodology involves theoretical modeling and synthesis based on a review of relevant academic and practical literature. The model integrates five interrelated components crucial for managing digital transformation: strategy, structure, processes, resources, and culture.

Results. The integrated model is illustrated in Figure 1.

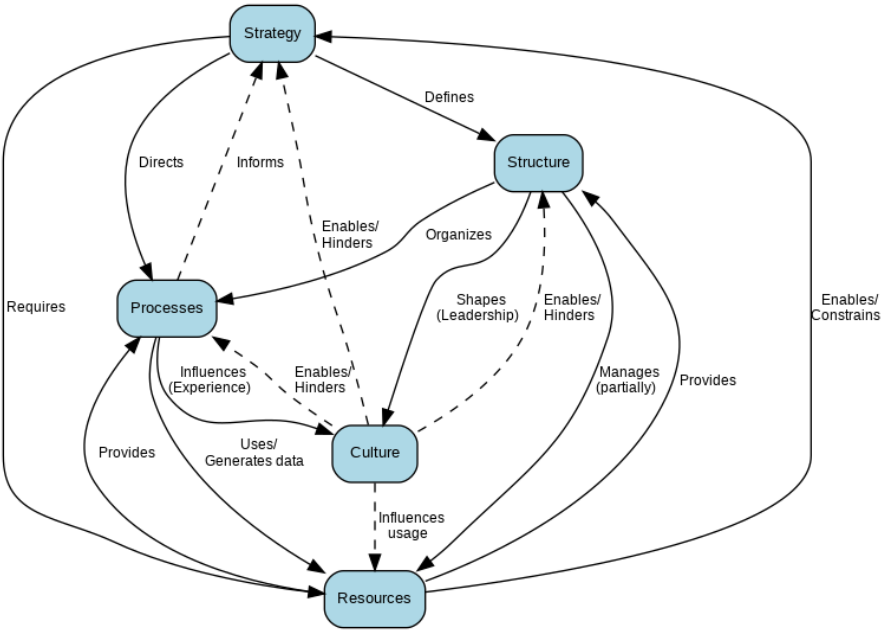

Fig. 1. Conceptual model of the components' interconnection in the digital transformation management mechanism of an enterprise

The strategy defines the digital vision of the enterprise, its transformation goals, and key change vectors and considers environmental and social priorities. The

structure reflects the adaptation of organizational design: the introduction of new roles (in particular, the introduction of the positions of CDO – Chief Digital Officer or DTO – Digital Transformation Officer), as well as the construction of digital management systems. Processes include optimization and automation of business processes based on digital technologies with a focus on energy efficiency, reducing emissions and optimal resource consumption. Resources include technology, finance, data and human capital management, with an emphasis on the development of digital competencies and continuous staff training. Culture shapes the enterprise's readiness for change, innovation, and customer focus, and supports responsible leadership and shared values.

The application of this model allows enterprises not only to implement technological innovations, but also to achieve tangible results in the field of sustainable development, such as optimization of energy and material resource consumption; reduction of waste and greenhouse gas emissions through intelligent management of production processes and logistics; extension of the product life cycle through predictive maintenance and repair capabilities, etc.

Conclusion. The advantages of the proposed conceptual model are the application of a holistic approach to digital transformation, integration of technological solutions with environmental and social objectives, and focus on long-term values and regional development using the potential of key digital technologies (Internet of Things, big data, artificial intelligence, blockchain, digital modeling). However, the implementation of the model requires considering several limitations. Among them are the uneven development of digital infrastructure, lack of investment, and low digital literacy in small and medium-sized businesses. The model also requires adaptation to industry and regional specifics. Considering the advantages and limitations of the proposed scientific development, further research in this area should focus on empirical testing of the model in the conditions of Ukrainian regions; developing indicators for assessing the effectiveness of digital transformation in terms of sustainability; finding mechanisms for intersectoral cooperation (business – government – communities) to support inclusive digital development.

Overall, digital transformation can become not only a tool for improving the efficiency of enterprises, but also a powerful catalyst for sustainable and inclusive regional development. Its success depends on the ability of enterprises to integrate digital solutions into the strategic, structural, process, resource and cultural dimensions of their activities. The proposed model creates the basis for such an approach, opening opportunities for the formation of a new development paradigm that combines innovation, responsibility and sustainability in the long term.

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RESEARCH ON INNOVATIVE SOLUTIONS IN IRRIGATION MANAGEMENT FOR ENSURING ECO-ECONOMIC SUSTAINABILITY OF WATER AND SOIL RESOURCES

***Liudmyla Usata**, Senior Researcher*
***Serhii Usatyi**, PhD, Head of the Department*
Institute of Water Problems and Land Reclamation of NAAS, Ukraine

Introduction. Soil and water conservation has become a priority for advancing irrigation technologies, reflected in various scientific projects and international initiatives (FAO Strategic Framework 2022-31, 2021; ICID, 2023; COP28, 2023; EU Mission, 2021-2024; Horizon Europe, 2024). Four key tasks guide research and innovation: i) addressing knowledge gaps in soil management under irrigation in a changing environment; ii) promoting sustainable practices to combat water scarcity and soil degradation; iii) developing tools for integrated soil and water management; iv) enhancing communication and partnerships to tackle water and soil issues. Additionally, there is a lack of critical analysis of practices with significant advantages for irrigation development.

Data and Methods. The study was conducted within the framework of the fundamental research projects funded by the state budget: "Investigation of the patterns of irrigation water quality formation and the development of a methodology for assessing and forecasting its impact in the 'irrigation source-irrigation system-soil-plant' chain" (Project No. 0121U109493) and "Study of the processes of forming the productive and ecological functions of soils under drip irrigation conditions and development of a methodology for forecasting soil processes" (Project No. 0116U003966). The research utilized analytical and statistical methods, the case method, and cross-sectoral analysis.

Results. Soil and water conservation is a global priority, viewed as a "virtual" Sustainable Development Goal due to its foundational role in ecosystem health (United Nations Development Programme, 2021–2024). FAO emphasizes their critical importance through the initiative "Soil and Water: The Source of Life" (Global Symposium on Soils and Water, 2023; World Soil Day, 2023), calling for urgent collective action. This issue is central to post-war recovery and climate adaptation efforts in Ukraine. Integrated soil and water management, particularly through adequate irrigation, underpins agricultural innovation and is vital for food security and ecosystem resilience.

Ukraine, facing russian aggression, urgently needs measures to ensure food security, including irrigation integration (Teixeira et al., 2023). This aligns with the UN Strategic Framework for 2022–2031, promoting efficient, inclusive, and sustainable agri-food systems to achieve the SDGs by 2030 (FAO Strategic Framework 2022-31, 2021). The country's food security index, particularly in "Stability and Adaptability," is 43.5/100, ranking 94th globally (Maryna et al., 2023;

Timkovan, 2023). This decline is due to the war, which disrupted irrigation water availability and hindered the development of irrigated agriculture since 2022.

As noted by many researchers, the role of irrigation in ensuring food security under changing climatic conditions is becoming increasingly multifaceted and complex. The altered frequency of extreme weather events adversely affects the availability and quality of irrigation water, impacting the adaptation of existing irrigation methods and techniques, the operational requirements for technical equipment, and the regulatory frameworks for irrigation to optimize soil-plant interactions. All these factors necessitate innovative approaches to sustainable water resource management in water-scarce regions, where the persistent shortage of high-quality irrigation water poses a constant challenge to implementing hydro-reclamation measures. Most research targets innovations to boost soil water retention and green water use, using soil organic carbon (SOC) as a key indicator of degradation and water scarcity (Balyuk et al., 2024). Improving water use efficiency remains key to food security. Addressing soil salinization and degradation in irrigated farming is vital for soil health. Risk-based water quality assessment guides decision-making at all governance levels and for pollution sources (Khilchevskyi et al., 2024).

Modernizing agriculture via irrigation technologies highlights precision farming, smart sensors, and AI (Machine Vision and AI in Agriculture Production, 2024). With GIS and satellite data (EOS Data Analytics, PlanetLabs) refining land and water management, these tools enhance decision-making, system efficiency, and yield. Digital platforms (StartUs Insights Discovery Platform, Nexus, AgriLinx) support soil monitoring, crop forecasting, and irrigation efficiency, transforming data logistics and promoting sustainable production.

One innovative solution is using renewable energy in irrigation through solar-powered systems (EU Mission, 2021-2024). While offering cost savings and lower emissions, challenges include high initial costs and the need for technical expertise. Still, experts emphasize their importance for advancing agriculture and ensuring food security.

Future expansion of irrigated agriculture will increasingly rely on drainage water reuse. Successful strategies have been implemented in countries like the USA, Turkey, and India, often within synergistic reclamation systems. Recirculating drainage water – collecting, storing, and reusing it during water shortages – offers higher crop yields and better irrigation water quality. This is especially effective in regions with closed drainage systems and variable rainfall. The Transforming Drainage project (USDA, 2016; Frankenberger et al., 2017) in the USA proved this approach's sustainability, increasing yields and water quality. It is now part of the Landscape Conservation Practice Standard. In the western US, drainage reuse for drip irrigation enhances crop resilience and supports ongoing research into its effects on soil health. Overall, such methods promote ecological sustainability and adaptation in irrigated agriculture.

A vital solution has been the updating of the issue of developing an innovative policy and standardizing the provision of services and financing mechanisms for irrigation (Hryhorieva, 2024). Public-private partnerships in this sector demonstrate successful models of cooperation that leverage the strengths of both sectors to improve the management of water and soil resources. Thematic studies of these partnerships show how they can effectively mobilize resources, share knowledge, and foster innovation in irrigation and drainage systems. For smallholder farms, access to innovative financial solutions, such as microcredit and investment mechanisms, is crucial for implementing sustainable irrigation projects. These financial tools enable investments in necessary infrastructure and technologies, contributing to the implementation of long-term irrigation development programs. The foundations of policies that promote efficient water use and ecological sustainability are also critically important. The development and implementation of this policy ensure that irrigation methods align with broader environmental goals and resource conservation strategies. These innovative approaches in policy, service provision, and financing mechanisms are foundational for improving agricultural water resource management and ensuring future food security.

The call for soil health preservation and improved water quality is closely linked to the urgent and coordinated actions needed to mitigate the impacts of climate change (EU Soil Strategy for 2030, 2021; ICID Congress, 2023; EU Science Hub; Joint Research Centre). Among these, global agri-food systems play a crucial role, as concluded by the UN and the International Fund for Agricultural Development (IFAD), in adapting to climate change, mitigating its consequences, protecting and preserving biodiversity, and creating inclusive and sustainable livelihoods. A primary goal in forming agri-food systems should be the expansion of soil productivity restoration through irrigation, which will reduce the vulnerability of agricultural producers, strengthen integrated water resource management, and minimize climate and environmental risks (World Climate Summit COP28, 2023; FAO, IFAD, 2023; Alberti et al., 2024). In Ukraine, local agri-food systems can become an effective tool for adapting irrigated agriculture to the new realities of wartime and further development in the context of large-scale destruction of the engineering melioration infrastructure of the water management complex, ensuring food security in the country and counteracting soil degradation and its consequences associated with the military actions of the russian federation and climate change. With sustainable development principles in mind, agri-food systems can function as powerful means of climate change mitigation, with their transformation playing a key role in achieving global environmental goals and the Sustainable Development Goals. Accordingly, these issues are of particular importance in Ukraine in restoring sustainable agricultural production in regions of the country, where economic development priorities have been based on the use of irrigation as a core element to enhance the productive function of soils.

Conclusions. Using innovative solutions for irrigation management will ensure the ecological-economic sustainability of water and soil resources. In this context,

understanding the interconnection of "water-soil-plant-food and environmental security" will become an understanding of the need for a comprehensive approach to irrigation management to ensure the sustainability of irrigated soils. In the future, these soils will successfully improve water quality and ensure the ecological integrity of agri-food systems.

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MODELING THE DIGITALIZATION OF SUSTAINABLE DEVELOPMENT, TAKING INTO ACCOUNT THE SPATIAL DEVELOPMENT OF THE COUNTRY'S REGIONS

***Inna Yatskevych**, Doctor in Economics, Professor*
Odesa State Academy of Civil Engineering and Architecture
***Dmytro Bedrii,** Doctor of Technical Sciences, Associate Professor, Senior Researcher, Acting Director, State Enterprise "Ukrainian Scientific Research Institute Of Radio And Television", Professor of the Department of Artificial Intelligence and Data Analysis, Odesa Polytechnic National University*
***Olena Zhuran,** PhD, Associate Professor of the Department of Artificial Intelligence and Data Analysis Odesa Polytechnic National University*
Ukraine

Introduction. In recent years, digital transformation has become a key factor in shaping the sustainability of enterprises that seek to have a positive impact on the environment and social processes, while ensuring long-term stability and profitability. Combining the principles of sustainable development with the latest technologies opens up great opportunities for integrating effective practices into business processes, rationalizing resource use, and reducing environmental impact.

The use of digital solutions not only improves the efficiency of business operations, but also improves the environment, especially taking into account regional specifics within the country. Digitalization is gradually penetrating all levels of interaction with the natural environment – from monitoring the state of ecosystems to resource management, changing consumer behaviour, and transforming markets.

Modern technologies are helping to solve environmental challenges and build smart cities, where the introduction of digital systems for transport, energy and waste management helps to reduce emissions and improve the energy efficiency of buildings. This directly contributes to the implementation of Sustainable Development Goals (SDGs) №9 "Innovation and Infrastructure" and №11 "Sustainable Cities and Communities" (17 Sustainable, 2025), which is especially important in the context of martial law in Ukraine and in the context of global cooperation (SDG 17) (17 Sustainable*, 2025*).

However, digital transformation is not an automatic guarantee of sustainable development. It is important to take into account the social and environmental impacts of digital technologies to avoid increasing social inequality or harming the environment. In addition, equal access to digital tools should be ensured for all segments of the population to help prevent a digital divide. Thus, an urgent task is to form a relationship between digitalization and the sustainable development of socio-economic systems in the context of spatial development of regions.

Data and Methods. The role of digitalization and sustainable development was studied by (Krasnostanova et al., 2023; Ghonchar et al., 2024; Nikitenko et al.,

2022). The work (Samojlovych, 2023) reveals that the study of sustainable development of the country/regions is realized in the context of social, economic and environmental components.

In the course of the study, the following scientific methods were used: theoretical generalization and grouping (to reveal the essence and content of the research); formalization, analysis and synthesis (to build the dependence of the impact of spatial development of the country's regions on the digitalization of sustainable development); logical generalization of the results (formulation of conclusions).

Results. Digital transformation significantly changes the conditions for the functioning of modern systems: it changes the basic framework, forms transnational ties and opens up new opportunities for business and regional development. This is especially important in the context of martial law in Ukraine and will remain relevant in the postwar period. Ensuring access to and secure use of digital data is crucial for optimizing the economic structure, increasing productivity, improving the efficiency of enterprises, attracting investment in the regions, and laying the groundwork for sustainable territorial development.

At the same time, digitalization and sustainable development are complementary approaches to spatial development aimed at improving the living conditions of the regional population. The introduction of digital technologies in spatial development involves the use of digital tools for collecting, analyzing and managing data characterizing socio-economic processes and the development of territories. This approach allows for modeling and forecasting of spatial changes, providing professionals with reliable analytics for making effective management decisions at the regional, local, and national levels.

Research in the field of sustainable development (Krasnostanova et al., 2023; Ghonchar et al., 2024; Nikitenko et al., 2022; Samojlovych, 2023) confirms that in the context of spatial development of regions, sustainable development should be interpreted as the ability of different territorial systems (city, region, industrial) to ensure social, economic and environmental sustainability, which are located in a certain territory and interact with each other and affect the functioning of the entire system and its development. This requires the development of strategies and programs aimed at the rational use of resources, strengthening social integration, and developing the region's economy and social infrastructure.

A number of studies have shown that digitalization and sustainable development in the context of spatial development are closely interrelated. Digitalization provides tools for analysis and modeling, while sustainable development determines the vector of targeted use of these tools to achieve spatial balance between them.

Ensuring sustainable regional development involves the introduction of digital solutions into the strategic planning complex. At the same time, the economic sustainability of a region is understood as the ability of the regional economy to function stably in the face of change, martial law, and external challenges. Social sustainability is the ability of social systems in a certain territory to maintain the stability and functionality of business structures in the long term. Environmental

sustainability, in turn, means the ability of natural systems to resist external influences and recover from them. Thus, the synergy of economic, social, and environmental sustainability creates the foundation for a harmonious system of sustainable development of territories, which is supported and strengthened by digital technologies.

The spatial development system in Ukraine, especially in the context of post-war recovery, is transforming towards strategic development with the active use of digitalization to achieve greater adaptability, efficiency, and sustainability both within the state and in the transnational space.

Digitalization opens up new horizons for long-term planning of territorial development. To effectively assess the impact of digital sustainable spatial development of regions, the authors recommend using a system of indicators that take into account the specifics of regional development:

- regional index of digital transformation of the Ukrainian region;
- performance of business entities at the regional level;
- volumes of goods and services sold at the regional level;
- population in the region.

At the same time, the analysis of the spatial development of the region is based on an assessment of the growth rates of the selected indicators.

Summarizing the above, the authors determine the dependence of the impact of the spatial development of the country's regions on the digitalization of sustainable development:

$$D = f(\Delta FR; \Delta Q; \Delta P), \quad (1)$$

where D is the index of digital transformation of a region of Ukraine, %; Δ FR is the rate of change of financial results from ordinary activities of enterprises before taxation by region of Ukraine, %; ΔQ is the index of industrial production in a region of Ukraine, %; ΔP is the rate of change of population in a region of Ukraine, %.

Summarizing the above, we can build a regression model that has the following expression:

$$D = 0{,}162 - 0{,}12 \cdot \Delta FR + 0{,}018 \cdot \Delta Q - 0{,}019 \cdot \Delta P \quad (2)$$

The developed model of the relationship between the digitalization of sustainable development and the factors that characterize the spatial development of the country's regions reflects the general logic of this process and makes it possible to take this model into account when assessing the digitalization of sustainable development.

Conclusions. In the framework of this study, the spatial development of regions (regional, local, state) is considered as a dynamic and long-term process, which necessitates the analysis of relevant indicators in a retrospective time frame. Therefore, it is advisable to assess the spatial development indicators on the basis of

studying the growth rates of the relevant indicators in the medium and long term, which allows identifying stable trends, patterns and phase changes in the structure of the spatial organization of territories.

The proposed dependence is based on the diagnosis of the transformation processes taking place within the studied territories through the prism of an integral indicator of spatial development. This indicator can be decomposed into separate components to identify the key factors influencing the intensity of spatial changes, as well as to conduct a comparative analysis between territories of different hierarchical levels – from regional to national.

The use of systematized statistical data of the State Statistics Service of Ukraine (State, 2025), published at the level of state, regional and local authorities, provides a wide range of application of the integral indicator both within individual administrative-territorial units and in interregional comparisons. The unification of methodological approaches to the formation of the database creates the basis for a qualitative comparison of the pace of spatial development between different levels of entities, for example, an analysis of the relationship between regional and national development dynamics.

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ARTIFICIAL INTELLIGENCE METHODS FOR SUSTAINABLE AEROSPACE SYSTEMS: A REVIEW OF PREDICTIVE AND GENERATIVE MODELS

***Oleh Murashko**, MSc, PhD Candidate,*
***Yurii Tkachov**, Candidate of Tech. Sci., Assoc. Prof.,*
Oles Honchar Dnipro National University, Ukraine

Introduction. This concise analytical review examines the role of artificial intelligence (AI) in fostering sustainability and innovation within aerospace systems, set against the backdrop of digital transformation in Industry 4.0 and Industry 5.0. The paper aligns with the theme of the "Digital Transformation, Industries 4.0 and 5.0 and Sustainable Development" session, as AI serves as a pivotal enabler for transitioning to environmentally responsible and economically efficient technological solutions. In the aerospace sector, optimizing operational processes, reducing emissions, extending component lifespans, and minimizing resource consumption are critical sustainability challenges. Predictive models enable the forecasting of equipment health (remaining useful life, RUL), thereby reducing maintenance uncertainty and preventing catastrophic failures at early stages. Generative models facilitate the creation of synthetic data and alternative design variants, significantly diminishing the need for costly physical testing and accelerating the certification of novel aerospace solutions. This review is structured into two main sections: (1) an analysis of predictive AI methods aimed at enhancing the reliability and efficiency of aerospace systems, and (2) an overview of generative models, focusing on innovative approaches to design and simulation in an ecologically sustainable context. The integration of these two strands addresses the conference's objective of harmonizing economic and environmental imperatives in the industry of the future.

Data and Methods. Predictive AI models leverage historical performance and operational data to forecast system health and maintenance requirements. In aerospace applications, accurate estimation of remaining useful life (RUL) of critical components—such as turbofan engines and aircraft bearings—underpins proactive maintenance planning and enhances safety management. For example, modified similarity-based approaches integrated with support vector machines (SVM) have demonstrated improved RUL prediction by effectively capturing degradation patterns in engine sensor data (Chen et al., 2017). Deep learning architectures augmented with explainable AI techniques further promote interpretability, enabling maintenance engineers to rationalize model outputs and support decision-making processes (Protopapadakis et al., 2022). Ensemble methods, notably random forests, deliver robust performance in high-dimensional prognostic tasks by automating feature selection and offering resilience to noise, thereby mitigating unplanned downtime and reducing maintenance expenditures (Sun et al., 2024). Conventional SVMs continue to be widely employed for both classification and regression

challenges in small-sample, high-dimensional contexts, including quality assessment of aerospace materials (Yuan et al., 2023). Decision trees present the advantage of transparent decision rules suitable for real-time diagnostics, whereas k-nearest neighbors variants—such as least squares-smoothed kNN (LS-sKNN)—facilitate accurate online RUL estimation in contexts like NASA turbofan engines (Viale et al., 2023; Qin et al., 2024). Moreover, the synergy between digital twin technology and predictive AI models supports continuous health monitoring and simulation-driven forecasting, thereby optimizing maintenance workflows. Physics-informed neural networks (PINNs) have been introduced to embed physical degradation laws directly into the neural learning process, ensuring that predictions remain consistent with underlying physics under varying operational conditions (Eivazi et al., 2022).

Generative models and their applications have recently become an integral component of digital transformation in aerospace engineering, owing to their capability to synthesize new data and design variants without resorting to costly physical testing. Generative Adversarial Networks (GANs) have been employed for aerodynamic design optimization; for instance, Chen et al. (2019) demonstrated that GANs can produce wing profiles with superior lift-to-drag ratios compared to traditional optimization algorithms (Chen et al., 2019). In the domain of air traffic management, recurrent GANs—specifically TimeGAN—are utilized to generate realistic four-dimensional (4D) flight trajectories for approach and holding patterns, proving particularly effective when real-world data are sparse, such as in simulations of rare or emergency scenarios (Wijnands et al., 2024). Variational Autoencoders (VAEs) constitute another critical class of generative techniques; by encoding design parameters into a latent space, VAEs enable interpolation between known configurations. Banh and Strobel (2023) highlighted the role of VAEs in creating flexible generative models and combining them with diffusion-based approaches to accurately capture complex physical phenomena (Banh & Strobel, 2023). Furthermore, GANs can serve as surrogate reliability models in structural system design, significantly reducing the computational burden of numerical simulations. Teng et al. (2024) illustrated that generative surrogate networks achieve reliable structural reliability assessments with lower computational costs than conventional methods (Teng et al., 2024). Collectively, these generative AI technologies form the foundation for advanced digital twin frameworks, reducing the risks and expenses associated with physical testing and expediting the development and certification cycles of innovative aerospace solutions.

Despite notable advances in the application of AI methods in the aerospace domain, researchers continue to face several methodological and practical challenges. First, in data-scarce scenarios, models often suffer from limited statistical power and poor generalization to unforeseen conditions. Second, the complexity of modern algorithms restricts their transparency and interpretability, complicating regulatory approval and standardization processes (explainability). Third, it remains critical to ensure compliance with industry-specific certification

and safety requirements, especially in mission-critical flight systems. Future research should focus on the development of hybrid architectures combining symbolic models and neural networks to balance performance and explainability; the integration of physics-informed neural networks (PINNs) to incorporate conservation laws and physical constraints during training, thereby enhancing prediction credibility; the use of digital twins to validate AI predictions through physically grounded modeling of real systems; and the design of automated validation and verification procedures that align with regulatory certification requirements.

Results. Analyzing of predictive models and generative models, it can be concluded that these models exhibit substantial potential to transform aerospace systems in the context of digitalization and sustainability. These methods contribute to the optimization of maintenance processes through accurate remaining useful life prediction; the acceleration of design and certification cycles via synthetic data and virtual testing; and the enhancement of operational efficiency by reducing downtime and costs. Particular attention should be given to the advancement of hybrid approaches that integrate physics-informed neural networks with classical methods, as well as the incorporation of digital twins for comprehensive system modeling. These developments will improve model reliability and support informed engineering decision-making in the aerospace domain.

Conclusions. From a broader perspective, the implementation of AI-based predictive and generative models in aerospace engineering directly supports the objectives of sustainable development and the European digital transition agenda. By enabling smarter resource utilization, minimizing downtime, and facilitating low-risk virtual certification environments, these technologies serve as critical enablers for Industry 4.0 and 5.0 paradigms in the aerospace sector. As such, their integration contributes not only to the advancement of aerospace systems but also to a more resilient, innovative, and ecologically responsible European industrial ecosystem.

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DIGITAL INNOVATIVE SOLUTIONS IN THE MANAGEMENT OF OIL AND GAS ENTERPRISES

***Taras Martyn**, Postgraduate Student,*
Ivano-Frankivsk National
Technical University of Oil and Gas, Ukraine
***Vitalii Nitsenko**, Doctor of Economics,*
Professor, Department of
Entrepreneurship and Marketing
Ivano-Frankivsk National
Technical University of Oil and Gas, Ukraine
vitalii.nitsenko@nung.edu.ua

Introduction. Today, the oil and gas industry stands at a crossroads that will shape its development for decades to come. In light of accelerating climate change, the future of fossil fuels is becoming increasingly uncertain, while renewable energy sources are rapidly gaining momentum. Although fossil fuels still maintain a dominant position, the pressure on the sector is intensifying.

In the context of global competition, oil and gas enterprises are compelled to explore new pathways to strengthen their competitiveness. "In order for the industry to continue generating prosperity, it must continuously adapt to evolving challenges. This continuous adaptation is only possible through constant innovation" (Voronkova & Metelenko, 2023).

Digital innovations are emerging as a key instrument in achieving this goal, as they not only enable cost reduction and efficiency enhancement, but also facilitate the development of new business models tailored to the demands of the modern market. The integration of digital technologies is poised to revolutionize the oil and gas industry by optimizing production, improving safety, and reducing the sector's environmental footprint.

However, digitalization itself may also present a range of challenges. The transition to new technologies will require substantial investments in workforce upskilling. Studies indicate that "70 percent of complex, large-scale transformation programs fail to achieve their stated objectives." (Busy et al., 2016).

Data and Methods. Data constitute a critical resource for oil and gas companies, potentially playing a decisive role in operational success. Enterprises collect vast volumes of information from sensors and equipment distributed across extensive geographic areas. The primary challenge lies in efficiently gathering data from specific points, analyzing it in real time, and leveraging the insights to enhance operational performance. To ensure that the extracted information delivers maximum business value, three core tasks must be addressed: automating the data collection process, integrating information from diverse sources, and conducting deep analytical assessments to support timely decision-making.

Modern technologies enable real-time data analysis and its effective integration into business processes. Data analytics plays a pivotal role in providing timely information, thereby improving operational outcomes. These data can be employed to optimize production processes and support the transformation of business models.

In this study, we consider the enterprise as a complex system in which digital innovations influence all levels of management—operational, tactical, and strategic. Our analysis focuses on the interrelations between digital technologies and business processes, as well as the impact of digitalization on the efficiency and profitability of enterprises.

The analysis of digital innovations in the management of oil and gas enterprises will be based on a combination of systems and process approaches, along with economic and mathematical modeling. The primary tools employed include Big Data, the Internet of Things (IoT), Artificial Intelligence (AI), cloud technologies, and blockchain.

Results. Digital transformation is a time-consuming and challenging process; therefore, oil and gas companies must clearly understand the necessary steps to ensure a smooth transition (see Fig. 1).

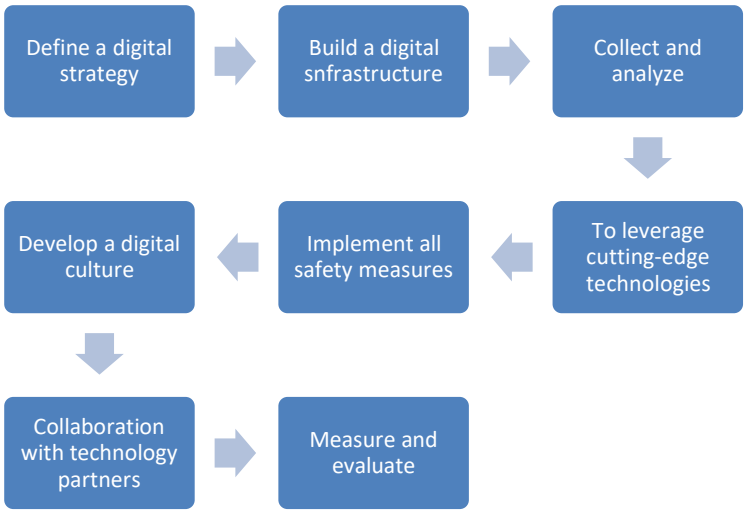

Fig. 1. Steps for Implementing Digital Transformation.

Step 1. Define key business objectives, assess current technological capabilities, and create a roadmap for digital transformation. This step is crucial as it allows for a clearer understanding and identification of the necessary actions to be taken.

Step 2. Update the existing infrastructure or invest in new technological platforms to support digital innovations.

Step 3. Focus on creating a data collection plan from various sources, including sensors, machines, and human operators. By analyzing these data using various

analytical tools, insights into operational performance can be gained, helping to identify areas that need improvement.

Step 4. The oil and gas business will significantly benefit from IoT, AI, cloud computing, and other technologies that optimize business processes, enhance decision-making, and elevate the business to a new level. New technologies in the oil and gas industry could provide companies with a second wind.

Step 5. Reliable security measures must be implemented to protect confidential data. The business must update its online protection, as cybersecurity gaps can be costly. Security measures may include encryption, multi-factor authentication, and regular security audits.

Step 6. The next step is the development of a digital culture within the organization, fostering innovation, collaboration, and continuous learning. The company should also provide employees with opportunities for training and development to acquire digital skills and knowledge.

Step 7. Collaboration with technology partners, suppliers, and other stakeholders will be valuable to leverage their expertise and capabilities in achieving digital transformation. This may include collaboration in research initiatives to co-create new technologies, share data, and exchange ideas.

Step 8. By tracking progress using key performance indicators (KPIs), the success of the transformation can be compared against objectives and areas for improvement can be identified. The results of digital transformation initiatives should be evaluated over time to gain insights into their success in improving business operations, customer experience, and other key areas. Finally, customer feedback should be used to further refine the strategy and optimize the roadmap.

In the short term, this reorganization will lead to record profits for oil and gas companies. However, the future of the industry will largely depend on responsible and well-thought-out actions. Any mistakes made at this stage could lead to severe consequences.

Conclusions. Thus, the relevance of digital innovations in the management of oil and gas enterprises cannot be overstated. They have become a key factor for the stable development of the industry, ensuring its flexibility and ability to adapt to rapidly changing conditions. Success depends on comprehensive improvements and the ability to effectively address challenges. The only viable and effective approach to solving these challenges is accelerating digital transformation through investments in modern technologies for the oil and gas sector, particularly the IoT and AI.

The scientific novelty of digital innovations in the management of oil and gas companies lies in the integration of modern technologies and management methods, which opens new horizons for optimizing production processes, enhancing efficiency, and reducing environmental impact. These innovations not only modernize traditional management approaches but also create new opportunities for research and development in the industry.

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PECULIARITIES OF THE STOCK MARKET DEVELOPMENT IN UKRAINE

Olena Novosolova**,** *PhD, As. Prof.,*
Kherson National Technical University
Tamila Chyzhova**,** *PhD, As. Prof.,*
Kherson National Technical University

Introduction. In the current environment, the securities market is the driving force of the country's economic development. It is a barometer of economic efficiency and business expectations, facilitating the distribution and redistribution of accumulated capital to the most profitable and promising areas. It positively impacts other sectors of the financial services market (insurance, asset management, consulting, settlement and clearing operations, custody, and others). At the same time, the stock market plays an essential role in ensuring the balance of public and private finance through the placement of government debt securities, optimising the redistribution of capital between economic sectors, regions, and business entities in the course of credit and investment relations, and improving the efficiency of the economic system as a whole, i.e. The government debt securities market, as an essential component of the stock market, is the primary source of budgetary funds in the context of Russia's full-scale military aggression against Ukraine. Its development undoubtedly determines fiscal policy and significantly impacts the monetary policy of the National Bank of Ukraine (the 'NBU').

In today's environment, the stock market is an essential indicator of the state of the national economy. The value of stock market indices and their dynamic changes reflect the trends and prospects of the macroeconomic situation. For example, an increase in the index is evidence of a revival in investment activity and optimistic market expectations. In contrast, a decline in the index indicates a downturn in the economy and a deterioration in business activity.

Data and Methods. The use of stock indices is based on the assumption that fluctuations in the prices of shares in the 'index basket' most accurately characterise fluctuations in the market as a whole. The PFTS index (calculated since 1997) is most often used to assess the trends of the Ukrainian stock market (Fig. 1).

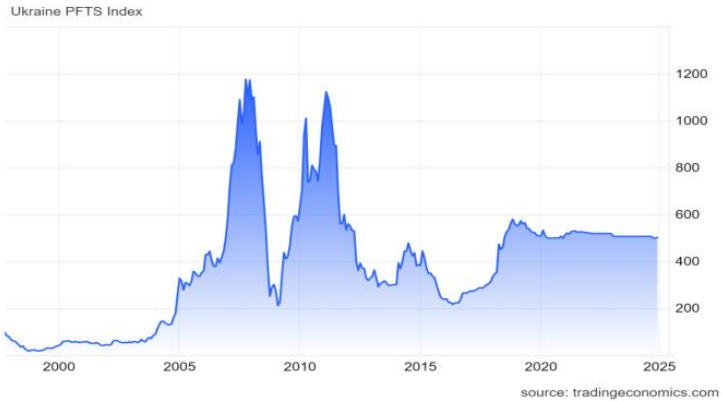

Fig. 1. Dynamics of the PFTS Index in Ukraine [1].

Results. Today, Ukraine's securities market is going through rather difficult times, as it has low investment attractiveness, given the difficult military, political and socio-economic situation. It is also worth noting that even before the start of Russia's full-scale military aggression against Ukraine in 2022, the domestic stock market had low liquidity and profitability.

The main reason for this is the unsatisfactory financial and economic condition of Ukrainian companies, the country's low credit rating, the low level of liquidity of traded securities, manipulation of prices for financial instruments, underdevelopment of markets for underlying assets, lack of financial capacity of ordinary citizens to become active participants in trading, i.e. As a result, foreign investors and rating agencies do not perceive the Ukrainian stock market as promising, and the securities of domestic companies as reliable and profitable investments, even though in 2018-2019 the domestic securities market became the fastest growing in the world.

Conclusions. Ukraine's stock market is still in its infancy for several reasons. First, there is a small number of securities in free circulation. By comparison, most ordinary citizens in countries with developed stock markets own shares in large enterprises, banks or government bonds. In domestic practice, large, successful enterprises have a relatively small amount of authorised capital, which is why their shares are concentrated in the hands of a relatively limited number of individuals. Public offerings of shares have not become a common practice for raising funds to expand and develop businesses financed mainly by loans. Even when such enterprises decide to place their securities on the stock market, they use international exchange platforms.

Secondly, due to the low-income population in Ukraine, the number of potential investors is relatively small. In addition, citizens' low level of financial literacy is becoming a significant barrier to market entry.

Thirdly, low investor confidence in domestic securities due to the risks of fraud and price manipulation limits the access of foreign capital to Ukraine. This problem has become even more complicated since the outbreak of full-scale war.

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FINANCIAL TECHNOLOGIES IN THE ERA OF ECONOMIC DIGITALIZATION

Vira Kudlai, *PhD, As. Prof*
Sofiia Vasylieva, *student*
State University "Kyiv Aviation Institute"

Introduction. This paper examines the key aspects of the development of financial technologies (FinTech) in the context of economic digitalization. In particular, it explores their impact on traditional financial services, enhanced accessibility, and increased transaction efficiency. The main challenges facing the FinTech sector are identified, along with the prospects for further technological advancements in the financial domain.

Data and Methods. The study is based on secondary data obtained from academic journals, official reports, and industry publications. Primary sources include peer-reviewed articles on FinTech, data from international financial institutions, and case studies of companies such as PayPal and Stripe. A qualitative methodology was applied, using thematic analysis to identify key trends and challenges in financial technologies. Comparative analysis was also used to evaluate the differences between traditional and digital financial services.

Results. Financial technologies have become a critical component of the modern economy, significantly transforming traditional financial services. Economic digitalization has opened new market opportunities and changed the way consumers and businesses interact with financial systems. FinTech encompasses a wide range of innovative solutions that increase the efficiency of financial operations, reduce costs, and improve accessibility to financial services.

In recent years, FinTech has seen rapid development across various financial service areas. One of the major trends is the rising popularity of mobile payment systems and online platforms that allow users to perform financial transactions quickly and conveniently.

FinTech contributes to lowering the cost of providing financial services. The provision of liquidity is the function of the banks that FinTech has principally disrupted and for which banks face most of competition (Murinde et al., 2022). Automation of processes such as payment processing and risk management enables

financial institutions to reduce operational expenses. Platforms like PayPal and Stripe allow businesses to handle payments efficiently and with minimal reliance on traditional banks.

Secondly, FinTech promotes financial inclusion. Thanks to technologies such as mobile wallets, users can perform financial operations without needing a traditional bank account. This is especially important for people in rural and remote areas where traditional banks are not present. The financial sector plays a central role in economic growth during the distribution of insufficient economic resources (Alawi et al., 2022). FinTech solutions help channel those scarce resources more efficiently to underserved populations.

The third important aspect is increasing the efficiency of financial services. Automating financial processes, such as lending or investment platforms, significantly reduces application processing time and minimizes the likelihood of errors caused by human factors. Examples of such technological implementation include the increasing adoption of big data processing technologies, improved methods for identification and risk assessment, algorithm-based investing, and the spread of user platforms used to analyze and optimize their investment portfolios. A major disruptor of traditional approaches in the financial sector has been the spread of blockchain technology and its application to enhance various aspects of the functioning of financial services markets (Danyl'kiv et al., 2022).

Blockchain ensures transparency and security of financial operations, as all transactions are recorded in a distributed ledger that cannot be altered or forged. This not only reduces the risk of fraud but also increases customer trust in financial institutions. For instance, many banks use blockchain to streamline interbank settlement processes, reducing the time and cost of transaction processing. Blockchain is also actively used in asset management systems, enabling faster access to ownership and transfer information – vital for investors who need to respond promptly to market changes.

However, despite the many advantages, financial technologies face certain challenges. First, regulatory barriers can hinder the development of FinTech companies. Many countries struggle to adapt their regulatory frameworks to new technologies, creating uncertainty for new market players trying to comply with legal requirements.

Second, cybersecurity threats are becoming increasingly relevant. They raise serious concerns about the protection of clients' personal data and the security of financial operations. Companies must invest in modern security technologies to protect their data and maintain customer trust.

Nevertheless, financial technologies continue to evolve, creating new opportunities for the economy. One key trend is the integration of FinTech with traditional financial institutions. Many banks are partnering with FinTech companies to implement innovative solutions and maintain competitiveness. This allows financial institutions to offer new services to clients while reducing costs.

Moreover, the globalization of financial technologies opens new opportunities for international trade and investment. FinTech companies can quickly expand into new markets, increasing competition and driving down consumer prices. This enables small businesses to access financing on a global scale.

Finally, social responsibility and sustainable development are also gaining popularity within the FinTech framework. Technologies can contribute to social development by providing access to financing for socially important projects. For example, microfinance platforms can assist small businesses working in environmental or social entrepreneurship sectors.

Conclusions. Financial technologies are a cornerstone of the evolving financial landscape. They merge innovative digital tools with financial services to deliver more efficient, accessible, and inclusive solutions. However, despite their benefits, FinTech faces ongoing challenges, particularly regarding security and regulation. Sustainable growth of financial technologies will require cooperation between technology firms, financial institutions, and regulators to create a secure and inclusive financial environment. Only under these conditions will FinTech continue to drive economic progress and ensure broader access to financial services for all.

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LEVERAGING SMART FACTORIES TO ADVANCE SDG 9 FOR SUSTAINABLE INDUSTRY, INNOVATION, AND INFRASTRUCTURE

Ihor Ponomarenko, *PhD Student,*
Sumy State University, Ukraine

Introduction. The global commitment to sustainable development underscores the need for industrial transformation to balance economic growth, environmental sustainability, and social equity. Sustainable Development Goal 9 (SDG 9), established by the United Nations, aims to build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation, addressing the interplay of industry, infrastructure, and technological progress (Infrastructure, 2023). Smart factories, driven by Industry 4.0 technologies such as the Internet of Things (IoT), artificial intelligence (AI), and robotics, offer a transformative approach to achieving these objectives. These systems optimize manufacturing processes, reduce waste, and enhance resource efficiency, contributing to sustainable industrial practices and innovation (The Future, 2023). The significance of this topic lies in its potential to reshape traditional manufacturing, aligning with global efforts to create resilient and inclusive industrial systems. However, challenges such as high implementation costs, technological integration complexities, cybersecurity risks, and workforce skill gaps hinder adoption, particularly for small and medium enterprises (SMEs) (Deloitte, 2025).

Data and Methods. This study used a descriptive method that allows for a systematic analysis of information on the implementation of smart factories. Data was collected from reports and open sources.

Results. Smart factories leverage a suite of Industry 4.0 technologies, including the Industrial Internet of Things (IIoT), artificial intelligence (AI), machine learning (ML), robotics, cloud computing, and advanced data analytics, to advance SDG 9's objectives of sustainable industrialization, resilient infrastructure, and innovation (The Future, 2023). IIoT enables real-time monitoring of equipment and processes through interconnected sensors, facilitating proactive maintenance and resource optimization (Manufacturing, 2025). AI and ML analyze vast datasets to predict equipment failures and recommend efficient production strategies, reducing waste and energy use (Manufacturing, 2025). Robotics automates repetitive tasks, enhancing precision and throughput, while cloud computing supports scalable data storage and analysis, enabling adaptive manufacturing systems (What, 2025). These technologies collectively contribute to SDG 9 by fostering resource-efficient industries (SDG 9.4), resilient infrastructure (SDG 9.1), and innovation (SDG 9.5).

The implementation of smart factories faces significant challenges that hinder their widespread adoption, particularly for SMEs and developing regions. High initial costs, often exceeding several million dollars, pose a formidable barrier, as the deployment of IIoT, AI, and robotics requires substantial investments in hardware, software, and infrastructure upgrades (The Future, 2023.). Technological

integration complexities further complicate adoption, as organizations face difficulties incorporating IIoT and analytics into legacy systems, compounded by the need for expert knowledge, as noted in Deloitte's smart manufacturing survey (Deloitte, 2025). Cybersecurity risks are a critical concern, with interconnected systems vulnerable to data breaches, a challenge highlighted in the World Economic Forum's Global Cybersecurity Outlook (Global, 2025). Workforce skill gaps exacerbate these issues, as the transition to smart factories demands proficiency in AI, IoT, and analytics, skills often lacking in traditional manufacturing workforces. In the developing economy, unreliable internet and power infrastructure intensified these challenges, restricting technology deployment (Automation, 2018).

Conclusions. This study confirms that smart factories are a critical mechanism for advancing SDG 9, promoting sustainable industrialization, resilient infrastructure, and innovation through IoT, AI, and robotics. The case studies demonstrate that these technologies optimize resource use, reduce environmental impact, and foster technological progress, aligning with SDG 9's objectives (Infrastructure, 2023). However, high implementation costs, cybersecurity risks, and workforce skill gaps limit inclusivity, particularly for SMEs and developing regions (Deloitte, 2025). These findings suggest that financial incentives, training programs, and robust cybersecurity frameworks are essential to ensure equitable adoption. By addressing these challenges, smart factories can drive a sustainable, innovative, and inclusive industrial future, advancing SDG 9's global objectives.

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INTANGIBLE ASSETS AS A BASIS FOR BRIDGING RESEARCH, INDUSTRY AND POLICY

Viacheslav Soloviov, *Dr.Sc., Prof.*
Institute for S&T Potential and Science History Study of NASU, *Ukraine*

Introduction. When we ensure the sustainability of development of countries and continents with the help of innovations, the question of what cognitive mechanisms ensure such sustainability often remains open. Of course, innovations are indeed the basis of development, but, nevertheless, not in general, but first of all, of the economy. It is believed that the new important factors of production required for the innovative development of the economy, the trend, as it were, from nothing, from nowhere (Schumpeter, 1934)). If innovations come from nowhere, can they be used as a man-made tool that ensures the sustainable comprehensive development of society? Can innovations become any problems in the history of other countries?

Data and Methods. It is generally accepted and well-known that it is the innovations embodied in the technological revolutions of the last centuries that contribute to the development of the world economy. This means that the steam engine is the basis of the first technological revolution, electricity is the basis of the second technological revolution, information technology is the basis of the third technological revolution. None of the traditional technological revolutions was carried out in accordance with any man-made plan. Moreover, the fact of a technological revolution is realized only after some time has passed since the application of the mentioned new guilty productive force. At the same time, there is a certain periodicity of these technological revolutions, which was convincingly established by N.D. Kondratiev (Kondratiev, 1935).

It is the presence of periodicity that allows us to predict the approach of a new surge of revolutionary transformations, which are expected to symbolize the transformation of new frontiers of the world economy. But at the same time, technological revolutions entail an aggravation of social problems in the form of wars and revolutions. Therefore, it would be desirable, if not to prevent these aggravations, then at least to mitigate their destructive effect. The 2020s, according to N.D. Kondratiev's periodicity of the emergence of technological revolutions, are the beginning of the fourth technological revolution. Its work is often based on considerations of artificial intelligence and continuous concentration. But it is possible that this will be the mass development of hydrogen energy.

If it is possible to predict the information-physical basis of the new technological revolution, then it is possible to understand that the accused may be responsible for the upheavals with the theme, in order to at least smooth them out. To solve this problem, it is necessary to analyze the social functions that ensure the comprehensive development of society, and citizens understand that they effectively implement these functions in the legislative and regulatory stage of our state. This will allow us to assess the quality of the implementation of these functions during periods of social upheavals and identify the cause of their possible inefficiency in order to eliminate these causes.

We will, following Emile Durkheim (Durkheim, 1933), take into account the presence of economic, scientific, administrative, military and religious social functions that should be adhered to, adhering to certain internal goals. It is important to understand the mechanisms of their mutual exchange with each other.

An important element of the harmonization of social functions are intangible assets (Wagenhofer, 2001; Baruch, 2001), which are intangible resources that can bring economic and social benefits, but at the same time, do not have a physical form. Examples of intangible assets include intellectual property (patents, copyrights, trademarks), brands, business reputation, technology, know-how and other knowledge and skills, the sources and bearers of which are members of society. It is intangible assets that ensure the unification of intellectual, economic and political efforts with the aim of harmonizing social functions, which can be considered through several key aspects.

Each of the social functions constantly solves the problems of its internal development and at the same time contributes to the common good.

The scientific social function for its own internal development is engaged in the development of new technological solutions for production and medical solutions to ensure natural life expectancy. The results obtained are disseminated for the benefit of other social functions through the education system and public information. An important task of the internal development of the scientific social function is the knowledge of the world around us in order to discover new life support resources and ways to manage them. Society responds to the scientific social function by increasing labor productivity, improving the quality of life, increasing life expectancy, reducing morbidity, and participating in the anticipation of social and natural disasters.

The economic social function for its own internal development takes measures to increase national income, create jobs, and develop infrastructure. At the same time, the prosperity of the private sector and the improvement of the standard of living of the population are important. For developed economies, investment in scientific research and social programs is mandatory. The reaction of society to the economic social function consists in increasing the welfare of citizens through the growth of wages and availability of goods and services, as well as in reducing the level of poverty and wealth inequality, which, naturally, leads to greater social

stability. Within the framework of the economic social function, the innovation process is born and formed.

The administrative social function, for its own internal development, takes care of the creation of consistent norms and rules that allow for the effective management of the material and social resources of society. The sphere of influence of the economic social function includes the establishment of law and order and ensuring security, including through the constant improvement of infrastructure and social services. Effective implementation of the administrative social function should ensure social sustainability and stability and, accordingly, prevent social conflicts and instability. This is possible only with high citizen trust in government institutions, as well as with sufficient civic activity and citizen participation in governance. An important role here is played by the ability to use large amounts of information in management, allowing for the establishment of cause-and-effect relationships and forecasting the development of events.

The military social function for its own internal development ensures that the system of ensuring national security and sovereignty of the state corresponds to the specifics of threats external to the state. It is in accordance with the specifics of these threats that the development and implementation of new technologies for defense should be organized in accordance with the level of science and the capabilities of the state economy. It is important to conduct military exercises and participate in international peacekeeping operations. The military social function promotes peace and stability, which allows focusing on socio-economic development. Here, it is necessary to take into account the influence of the military social function on social structures through military services and related activities (for example, the return of veterans to civilian life). In addition, it makes sense to stimulate such scientific military research that can be used for civilian purposes.

The religious social function for its own internal development pays attention to nurturing the population's commitment to moral and ethical standards, and promoting social cohesion. Support for humanitarian initiatives and charity, as well as cultural traditions, is important here. It is assumed that as a result, societies will be united around common values, which, in turn, creates stability and promotes social integration. It is through the influence on the moral aspects of life that individual and collective norms of behavior are formed.

Results. It can be assumed that each of the social functions has the ability to self-regulate in accordance with the Shewhart-Demming cycle (PDCA) (Chandrakanth, 2016), which in this case suggests the following iterative sequence: 1. Defining goals and identifying problems, which forms the basis for developing a development strategy for a particular social function. 2. Step-by-step implementation of this strategy through indicative planning. 3. Indicative planning allows organizing an assessment of the achieved results in comparison with the expected results. 4. If the results correspond to the expected ones, the strategy implementation should be continued; if not, the strategy implementation algorithm should be adjusted or its goals should be clarified.

At the same time, the goals and problems of each of the social functions can naturally change over time under the influence of external circumstances, including those generated by other social functions. In this regard, it is necessary to provide a mechanism for adapting the goals of different social functions to each other. Here, too, one can focus on iterative regulation of interaction, but based on the implementation of the Boyd cycle (OODA) (Boyd, 1987). According to the methodology of applying the Boyd cycle, the first step is to gather information in order to assess the environment (observation), so that in the second step this information is analyzed and a mental model of the situation is formulated (orientation), which will allow a decision to be made on the reaction to semantic signals from other social functions in accordance with the constructed model (decision). As a result, the stage of implementing the decision comes, and then a return to the first stage to assess the effects obtained (action). Evidence of the process of implementing the OODA cycle are intangible assets.

Intangible assets such as human capital, experience and expertise play an important role in bringing together research institutes, industrial enterprises and government agencies. Creating an ecosystem in which knowledge flows freely between these three sectors promotes innovation. In fact, intangible assets form the basis for partnerships between various actors representing different social functions: research centers, private companies and government agencies. These collaborations facilitate faster adoption of technologies in industry, including in the military and space sectors.

Conclusion. Growing attention in the world to sustainable development and social responsibility encourages companies and governments to invest in intangible assets, which help solve socially significant problems such as climate change or public health. The need for such a relationship requires a more balanced and integrated approach to policymaking in the field of science, technology and industry.

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EFFICIENCY OF TRANSFORMATION AND RESTRUCTURING OF UKRAINIAN DOMESTIC BUSINESS AMID CONTEMPORARY CHALLENGES

Oleksandra Karintseva,
Dr. Sc., Professor,
Mykola Kharchenko,
PhD in Economics, Associate Professor,
Sumy State University, Ukraine

Since the onset of Russia's full-scale invasion of Ukraine in 2022, Ukrainian businesses have faced unprecedented challenges. The conflict has led to significant disruptions in logistics chains, destruction of critical infrastructure, loss of skilled personnel due to mobilization and migration, and a sharp decline in demand for goods and services. According to the European Business Association (EBA), as of early 2025, 75% of companies are operating at full capacity, 24% with restrictions, and only 1% have ceased operations entirely. (1)

Simultaneously, global processes such as digitalization, shifts in international market structures, financial system instability, and climate threats have intensified the need for Ukrainian enterprises to not merely react but to undertake profound transformation and restructuring.

Business transformation in the current context is not merely about technical upgrades or adapting to constraints; it fundamentally involves a strategic overhaul of enterprise operations. This encompasses rethinking business models, reorganizing structures, adopting new management approaches, integrating digital technologies, and fostering innovation. Restructuring, in turn, entails specific changes in production processes, financial management, human resources policies, and market orientation. In many cases, these changes have been vital for business survival; in the best scenarios, they have laid the groundwork for growth even during crises.

Different sectors of the economy have adopted varied approaches to transformation. In agriculture, enterprises have increasingly utilized drones, satellite monitoring, and digital platforms for field management, reducing reliance on physical presence and enhancing production flexibility. The IT industry has demonstrated high adaptability through remote work capabilities, reorientation towards foreign clients, and sustained export activities. Manufacturers in the light industry have swiftly shifted to producing goods for the Armed Forces of Ukraine and humanitarian organizations, supporting the state while maintaining employment and financial stability [2].

Digitalization has emerged as a key vector of transformation. Over the past two years, numerous small and medium-sized enterprises have implemented CRM systems, e-commerce solutions, and automated accounting systems, facilitating new sales channels, improved customer service, and optimized internal processes. Additionally, companies have adopted agile management practices, reducing hierarchical structures and accelerating decision-making. Facing diminished domestic demand, many businesses have actively expanded into foreign markets, restructuring export strategies and logistics networks.

Despite numerous positive examples, transformation and restructuring processes are not without difficulties. One of the major obstacles is the instability of tax policy, complicating long-term planning. Moreover, many enterprises face limited access to financing, hindering investment in innovation. A significant number of companies suffer from a shortage of qualified labor due to mobilization and migration. Infrastructure destruction, particularly in frontline regions, remains a serious issue. As of early 2025, 75% of surveyed companies report losses of up to $1 million, 24% indicate losses between $1–10 million, and 16% have losses exceeding $10 million [1].

Nevertheless, Ukrainian businesses exhibit remarkable flexibility, resilience, and readiness for change. The effectiveness of enterprise transformation and restructuring is directly linked to their ability not only to adapt to new conditions but also to act proactively, laying the foundation for future development. Supporting this process requires comprehensive state policies aimed at stimulating digital modernization, encouraging innovation, developing export potential, and investing in education and workforce retraining. Only through the synergy of efforts from the state, businesses, and society can sustainable economic recovery be ensured, based on transformed and competitive national entrepreneurship.

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EUROPEAN VECTOR OF DEVELOPMENT OF UKRAINE'S INNOVATIVE ECONOMY IN THE CONDITIONS OF MODERN CHALLENGES

***Oleksandra Karintseva**, Dr. Sc. (Econ), Professor*
Sumy State University, Ukraine
***Mykhailo Chortok**, PhD-student*
Sumy State University, Ukraine

Modern Ukraine is facing unprecedented challenges, including a full-scale war, economic instability and political transformations. In these conditions, the development of an innovative economy becomes a key factor in ensuring sustainable economic growth and integration into the European space. The importance of innovative development is emphasized in numerous studies that emphasize the need to adapt European experience to Ukrainian realities [1].

One of the most serious factors hindering the innovative development of Ukraine is the consequences of armed aggression, which led to the massive destruction of scientific and industrial infrastructure. The destruction of universities, research centres and enterprises significantly complicate the conduct of scientific research and the implementation of technological innovations [2]. The forced migration of highly qualified specialists deepens the problem, because of which the scientific and technological potential of the country decreases, which negatively affects the innovative environment and international competitiveness.

At the same time, institutional barriers and financial constraints remain in Ukraine, which significantly hinder the development of innovative activities. Insufficient coordination between scientific institutions, business and government agencies, limited research funding, as well as the lack of effective mechanisms for commercializing the results of scientific developments and supporting startups remain a serious problem.

However, Ukraine's integration into the European innovation space opens new opportunities. Obtaining the status of a candidate country for joining the European Union creates prerequisites for participation in the Horizon Europe and Digital Europe programs. These programs provide financial and expert support for research projects, which contributes to strengthening the innovation potential of Ukraine. At the same time, expanding cooperation with European scientific networks ensures an increase in the quality of domestic research, access to modern scientific equipment, and the exchange of experience and technologies.

In this context, the definition of strategic directions for the development of the innovative economy is of particular importance. First, it is necessary to reform the institutional structure of innovation management, which should ensure effective interaction between all key stakeholders – scientific institutions, business and the state. At the same time, it is important to introduce transparent mechanisms for financing and assessing the effectiveness of innovation projects.

Further development of the innovative economy is impossible without creating a favourable environment for the development of startups and small businesses. This involves providing tax benefits, facilitating access to sources of financing, and developing business incubators and accelerators, which will help stimulate entrepreneurial activity and introduce new technologies. An equally important prerequisite for sustainable innovative development is the development of human capital, which requires the modernization of educational programs, reorientation to practical skills, and training of specialists capable of working in a high-tech economy.

Therefore, the development of an innovative economy is a strategic priority for Ukraine in the face of modern challenges. Integration into the European innovation space opens wide opportunities for scientific and technological progress. To realize this potential, it is necessary to implement comprehensive reforms focused on improving the institutional environment, supporting entrepreneurship and developing human capital.

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ON THE FORMATION OF THE STATE'S CRIMINAL LAW POLICY IN THE FIELD OF ENVIRONMENTAL PROTECTION

Olha Kolos, *PhD, As. Prof.*
Interregional Academy of Personnel Management

Introduction. For the future of our country, a properly developed criminal law policy in the field of environmental protection is no less important.

The doctrine of criminal law puts forward various approaches to systematization of criminal offenses in the field of environment. In general, the model of criminal prohibitions should include two large groups of criminal offenses: Group 1 – criminal offenses that encroach on environmental safety in general; Group 2 – criminal offenses that encroach on the established procedure for the protection of

environmental components: land and its subsoil, water resources, atmospheric air, forestry, flora and fauna.

Data and methods. The author analyzed the draft Law "On Amendments to the Criminal Code of Ukraine on Strengthening Liability for Criminal Offenses against the Environment" No. 6148 of 07.10.2021, subject of the right of legislative initiative – Cabinet of Ministers of Ukraine.

The study used a number of methods, including:

1. The general philosophical method of dialectic was used to clarify the social conditionality of both the institute of criminal offenses in the field of environmental protection as a whole and individual criminal offenses of this institute.

2. The use of the hermeneutic method facilitated the interpretation and interpretation of legal acts, draft legal acts, law enforcement acts and scientific works of scientists.

3. The dogmatic (formal legal) method was used in analyzing the legal constructions of the corpus delicti of criminal offenses under Art. 236–254 of the Criminal Code of Ukraine. Well as in analyzing the elements and signs of corpus delicti of these criminal offenses (both from the standpoint of criminal law doctrine and legislative technique) and the reaction to the latter in law enforcement practice.

4. The comparative method was also used, which made it possible to compare the provisions of the current Criminal Code of Ukraine (Criminal, 2001) the draft law proposed by the Ukrainian government (Draft Law, 2021), and the draft of the new Criminal Code of Ukraine (Draft of the new Criminal Code of Ukraine, 2025). In addition, the comparative method made it possible to identify the main directions of foreign practice of legislative regulation of criminal liability for certain environmental criminal offenses in the criminal legislation of individual states.

Results. The author identifies several important problems that this project contains.

Problem 1: The model of systematization of criminal legal prohibitions in the field of environmental protection is not systematic, logical, and proportional. Here are some examples. Example one (in the context of strengthening liability for violations of waste management legislation). Thus, with regard to **ATMOSPHERIC AIR**, the draft law proposes to retain Article 241 "Air Pollution" (obviously, a general rule) and supplement the Code with a novelty rule, Article 2411 "Violation of the requirements of the legislation on carrying out activities related to ozone-depleting substances and fluorinated greenhouse gases" (a special rule).However, it should be noted that the general rule provides for a much more severe sanction (a fine of eight to ten thousand tax-free minimum incomes or imprisonment for up to three years, with deprivation of the right to hold certain positions or engage in certain activities for the same period) than the sanction provided for in the special rule (a fine of three hundred to six hundred tax-free minimum incomes or restriction of liberty for up to two years or imprisonment for the same period). The question arises: what is the reason for this position?

Instead, a completely opposite approach has been demonstrated in relation to the protection of **WATER RESOURCES**. The draft law proposed for consideration provides for only one Article 242 "Pollution of surface, ground and sea waters (water bodies)", thus combining two separate articles of the current CC of Ukraine, Article 242 "Violation of water protection rules" and Article 243 "Sea pollution", while violating the rule of formation of qualified and especially qualified species (see below).

Obviously, such a proposal seems illogical and disproportionate given the real state of water bodies in Ukraine and their value.

Example two (in the context of the correlation between the protection of environmental components). With regard to the **PROTECTION OF WILDLIFE**, the proposed draft law provides for the creation of one single criminal offense under Article 248 "Illegal hunting, fishing, hunting for fish, game or other aquatic resources". In terms of its regulatory content, this article covers three currently effective Articles 248, 249 and 250 of the Criminal Code of Ukraine. At the same time, the draft law again grossly neglects the rules for the formation of qualified and especially qualified species, since part two of the proposed article is nothing more than a separate independent criminal offense (blasting), which is not well-grounded and raises a number of questions.

Instead, a completely opposite approach is proposed for the protection of **WOOD**, as the draft law provides for: Article 246 "Illegal logging"; Article 246^1 "Violation of the rules of harvesting wood within the forest fund"; Article 246^2 "Illegal transportation, storage or sale of wood".

Problem 2. Lack of differentiation of liability for intentional and negligent criminal behavior. When analyzing this draft law, attention is drawn to the fact that the proposed draft law does not provide for a mechanism for differentiating liability for intentional and negligent manifestations of prohibited behavior. It should be noted that the scientific literature expresses the position that, following the concept of subjective incrimination and taking into account the fundamental difference in the socio-political essence and legal nature of intentional and negligent crimes, it is impossible to provide for liability for intentional and negligent crimes in the same article of the criminal law.

Here is an example of a violation of the rule of differentiation of liability for intentional and negligent criminal behavior in the draft law No. 6148 and its consequences for qualification.

The current version of Part 1 of Art. 236 "Violation of Environmental Safety Rules" of the Criminal Code of Ukraine, as a general rule, is characterized by a negligent form of guilt. Establishing direct intent regarding the consequences provided for in Article 236 is generally the basis for qualifying the act as ecocide or as a crime against the foundations of national security of Ukraine, against life and health of a person, property, etc. In the version of this article proposed by the draft law, part two is envisaged, which contains several qualifying features: 1) repeatedly;

2) by prior conspiracy by a group of persons; 3) causing material damage in a significant amount.

The presence of part two itself with the qualifying features “repeatedly”, and especially “by prior conspiracy by a group of persons”, prompts a simple question: what form of guilt does part one imply in this case – intentional or negligent? The answer to this question leads to a number of the following questions:

1) how, in this case, to distinguish between the corpus delicti under Article 236 “Violation of environmental safety rules” of the draft law and such crimes as Article 441 ‘Ecocide’ or Article 113 “Sabotage”?

2) why does part one, which contains as one of the consequences “causing death or harm to the health of one or more people and other grave consequences”, provide for the following sanction – “restriction of liberty for a term of one to three years or imprisonment for the same term, with deprivation of the right to hold certain positions or engage in certain activities for up to three years”?

3) how should the sanction of a criminal offense under Article 236 of the draft law be correlated in this case? of the draft law and the sanction of a criminal offense under Article 237 of the draft law should be correlated. According to the logic of the draft law, the most severe punishment will be imposed not on those who intentionally caused an environmental emergency by prior conspiracy of a group of persons (there can be no complicity in negligent crimes), but on those who evade carrying out decontamination or other remedial measures to eliminate or remedy the consequences of pollution or contamination on land that has been contaminated or polluted.

Conclusions. First of all, it is worth noting that the model of systematization of criminal law prohibitions in the field of environmental protection requires a more conceptual approach, systematicity, logic, universality, proportionality, and transparency. The architectural design of criminal offenses should not be skewed towards one object of protection.

The problem of differentiation of liability for intentional and negligent criminal behavior also needs to be addressed at the conceptual and systemic level. Obviously, negligent acts should be clearly distinguished from intentional ones. Currently, this approach has been taken as a basis by the drafters of the new Criminal Code of Ukraine.

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THEORETICAL APPROACHES TO DEVELOPING ENTERPRISE POTENTIAL IN A CIRCULAR ECONOMY

***Lyudmila Progoniuk**, Associate Professor at the Department of Public Management and Administration and International Economy of the National Agrarian University of Mykolayiv, Ukraine.*

Abstract. The article explores the features of formation and development of the economic potential of an enterprise in the conditions of a circular economy. The main scientific approaches to defining the essence and content of enterprise potential are analyzed, a structural model of forming enterprise potential is presented, and the concept of "enterprise potential development" is defined. External and internal factors and conditions of development, as well as characteristic features of potential in a closed cycle economy, are considered. It is noted that the process of enterprise potential development in the conditions of a circular economy requires the formation of a number of important properties, such as innovativeness, synergy, uniqueness, dynamic capabilities, the ability to develop based on the reuse of products and production eco-friendliness.

Introduction. Acceleration of the development of economic sectors in the conditions of traditional, resource-dependent production models leads to serious negative changes in the environment. This results in the degradation of natural resources and the accumulation of a large amount of waste, which can be transformed into valuable products or energy in other conditions. Sustainable economic growth, together with environmental preservation, is only possible through production that operates on the principles of a circular economy, which is based on the efficient use, reuse, and recycling of resources. Therefore, interest in implementing alternative production models that meet economic, environmental, and social requirements becomes extremely relevant for many enterprises in various economic sectors. For successful implementation of such models, the ability to develop the corresponding potential in enterprises is necessary. Effective management of the development of this potential becomes a necessary condition for survival, uninterrupted functioning, and development of enterprises. All this emphasizes the importance of scientific research in the field of development of enterprise potential in the conditions of a circular economy.

Research on various aspects of enterprise potential attracts significant attention from many scholars. Among domestic researchers, the works of Yefanov V. (2024), which focused on identifying shortcomings of linear models through the prism of resource and waste components, as well as reviewing the conceptual principles of the circular economy, stand out. Bespalyy Y. (2024) delved into studying the theoretical foundations of the circular economy and examined models for its formation. Reshetilov G. (2023), in his dissertation research, substantiated the

conceptual foundations, improved theoretical and methodological positions, and developed practical recommendations for the development of the circular economy in the region. Recognizing the importance of the scientific works of domestic scientists, it is important to note that research on issues related to the essence, content, formation, and management of enterprise potential in modern conditions is insufficient. In particular, the problems that arise in connection with the development of potential in the context of the circular economy remain overlooked by researchers.

Data and Methods. The research is based on scientific works, the concept of sustainable development, and Internet resources. The following methods were used in the research process: induction, deduction, analysis, synthesis, generalization, abstraction, methods of systems analysis, and a synergistic approach.

Results. An inevitable consequence of further economic growth is an increase in the utilization of natural resources and consumption waste, which in turn exacerbates the burden on the environment. This indicates that the traditional linear model of the economy is no longer efficient. The new model of economic development is a circular economy, which is based on resource regeneration and rational use. It involves the creation of new alternative economic approaches aimed at minimizing the negative impact of human activity on the environment. One of the key features of the circular economy is the view of waste as valuable resources, rather than just trash (Yessenbekova, 2021). Circular bioeconomics is considered more effective than traditional linear economics, as it provides a conceptual basis for the use and management of renewable natural capital to achieve sustainable prosperity in harmony with nature (Arefieva, 2021).

Today, according to various estimates ranging from 7% to 9%, the world economy is transitioning to a circular model. Trend analysis shows that in the future, the role of the circular economy will continue to increase. This is evidenced, in particular, by the development of the Chinese economy after the COVID-19 crisis. Economic restructuring is leading China from a model of economic growth based on industrial investments to a model based on high-tech consumption. Ukraine is facing some important issues in the context of implementing a circular economy, such as resource problems including uneven distribution and utilization of resources, their irrational use, and a noticeable decrease in reserves. Another important issue is environmental pollution, which includes excessive accumulation of waste in cities, ecological problems, and impact on climate change. In these circumstances, one of the top priorities for management is assessing current and forming future opportunities for enterprises, that is, evaluating and developing their potential.

The concept of potential provides possibilities, level of strength, or a set of resources of a specific object or subject necessary to accomplish certain tasks. In economics, the concept of potential reflects the available opportunities, resources, reserves, and means that can be used to achieve the goals of the organization. An analysis of the concept of "economic potential" has allowed to identify various approaches to defining its essence and content.

One of the most common approaches is the resource approach, which considers the economic potential as the totality of available resources for economic activity. Understanding potential as a combination of resources is considered fundamental and a basis for further development, but it does not take into account the possibility of using various innovative combinations to improve qualitative and quantitative characteristics. Some scientists, such as O.O. Hetman and K.L. Andreev, consider potential as a system of material and labor factors necessary to achieve production goals, and focus on its potential capabilities. This approach focuses only on utilizing opportunities, without attention to their creation.

Another approach involves defining economic potential as the overall capacity of the sectors of the national economy (Herasymchuk, 2003). It traces a close connection between economic potential at the meso level and the production function of economic entities as a whole. However, research on the potential of individual enterprises, which is the basic category of economic potential, is overlooked. The main resource of an enterprise is its production potential, which consists of the interaction of key elements such as personnel with necessary professional skills and corporate culture, machinery and technologies, management system, and information support of the production process. Its implementation leads to the formation of the potential (based on the achieved actual) volume of production of goods, provision of services, or performance of works.

The market potential of an enterprise expresses the opportunities of the enterprise to meet the needs of consumers for specific goods or services. It is formed through the interaction of the production and marketing activities of the enterprise, taking into account the level of business activity in the economy as a whole and directly in its segment, and acts as an intermediary between the production and overall potential of the enterprise. The result of using market potential is the potential volume of sales, based on the already achieved actual level. In the context of a circular economy, the issue of developing the potential of an enterprise becomes particularly relevant, where materials used are processed or returned to the biosphere without negative impact.

The features of a company's potential and its development are revealed through the characteristics of the circular economy. In a circular economy, a company's potential can be defined as its ability to use its competencies and resources to achieve necessary results while considering sustainable development. This is achieved through the implementation of closed-loop production cycles that encompass the processing of secondary raw materials and resource regeneration.

It has been defined that both internal and external factors influence the development potential of an enterprise: economic, political, socio-cultural, legal, security, and environmental factors. The most significant are the system of internal factors to ensure a stable competitive position of the enterprise, as they are actively influenced by the enterprise itself.

Conclusions. The conditions of a circular economy contribute to the sustainable development of an enterprise through continuous improvement of the resource and

competency system. This allows for the achievement of strategic goals through closed-loop production cycles, the reuse and rational use of resources, and their replenishment. The mission and goals of our enterprise are focused on creating productions that operate on the basis of sustainable development principles. To achieve these goals, we invest in both capital assets and the development of our personnel. Our management system is geared towards an intellectual-innovative process, and the organizational culture of the enterprise supports the development of creativity and innovation among all employees. We implement resource-saving technological innovations and promote changes in the thinking and behavior patterns of our personnel. Through motivational management, we create an atmosphere of creativity and provide appropriate incentives for development at all levels and in all areas of the enterprise's activities.

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INNOVATIVE TECHNOLOGIES FOR SUSTAINABLE ECONOMIC GROWTH: RELEVANCE AND NECESSITY FOR UKRAINE

Oleksandra Karintseva, *Dr. Sc., Prof.,*
Sumy State University, Ukraine
Mykola Kharchenko*, PhD in Economics, As. Prof.,*
Sumy State University, Ukraine
Andrii Deineka, *Phd Student*
Sumy State University, Ukraine

The war has radically changed the structure of Ukraine's economy. Although the country currently relies partially on external aid and consumer demand, future development will be possible only through innovation.

In January 2025, the government approved the Strategy for Digital Development and Innovation Activity of Ukraine (WINWIN) until 2030, which outlines strategic goals, principles, directions, and tasks of state policy to stimulate digital transformation as well as support business and startups.

On November 29, 2024, the Cabinet of Ministers of Ukraine approved new tasks and indicators aimed at achieving the Sustainable Development Goals of Ukraine for the period up to 2030.

Analysis of key innovation indicators in Ukraine during 2011–2021 showed a declining trend in such indicators as expenditures on research and development, the number of researchers, and patent applications. According to the State Statistics Service of Ukraine, R&D expenditures in 2011 amounted to UAH 8.5 billion, which was 0.65% of GDP. In 2019, these expenditures increased to UAH 17.3 billion, but their share of GDP decreased to 0.43% [1]. At the same time, this occurred alongside an 18% decrease in the number of researchers. Patent activity in Ukraine also showed a declining trend, decreasing by 42% from 2011 to 2020 [1].

This highlights the need to implement effective strategies for the country's sustainable economic growth.

Among the current directions for innovative economic growth in the country's economy, the following can be noted:

*Innovation as a driver of sustainable development***.** Innovation activities ensure stable quality economic growth, increase labor productivity, and enhance the competitiveness of the national economy.

Digitalization of the economy. The development of digital technologies (artificial intelligence, blockchain, Internet of Things) provides transparency of processes, increases labor productivity, and promotes environmental sustainability in production.

*Green energy***.** Investments in renewable energy sources (solar, wind, hydro energy) contribute to decarbonization of the economy and energy security.

Circular economy. Innovative approaches to recycling, reuse, and waste minimization reduce environmental impact and create new markets.

Sustainable agribusiness. Smart farming, biotechnology, and automation promote efficient use of water, soil, and fertilizers without harming ecosystems.

Social innovations and inclusivity. Technologies facilitate the inclusion of vulnerable groups in economic activities, development of educational platforms, and digital services.

Partnership and global cooperation. International technological initiatives, technology transfer, and investments are key to achieving the UN Sustainable Development Goals.

Consideration of challenges and risks. It is important to consider risks of digital inequality, job losses due to automation, and ethical aspects of using advanced technologies.

The implementation of innovative technologies in such areas as digitalization of the economy, green energy, circular economy, sustainable agribusiness, social innovations, and international cooperation can enhance Ukraine's competitiveness, create new jobs, attract investments, and integrate the country into global economic processes.

Thus, to ensure sustainable economic growth and recovery of Ukraine, efforts should focus on developing an innovative economy, supporting scientific research, implementing digital technologies, and actively engaging in international cooperation. These measures will contribute to increasing the country's competitiveness and its integration into the global economy.

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DECOUPLING ANALYSIS OF ECONOMIC GROWTH AND ENVIRONMENTAL IMPACT IN UKRAINE

***Lesia Voliak**, PhD, As. Prof.,*
National University of Life and Environmental Science of Ukraine, Ukraine

Introduction. In the current context, there are persistent trends indicating increasing environmental risks associated with economic development. Achieving higher economic performance often results in the depletion of natural resources and an intensification of anthropogenic pressures on the environment. Therefore, it is crucial to timely assess and forecast the environmental consequences of economic growth not only at the national level but also at regional and local scales.

Various technological innovations, as well as organizational and economic management tools implemented by governmental authorities and economic entities, can serve as factors mitigating negative environmental impacts. In this regard, increasing attention has recently been devoted to the transition toward "green" growth, which aims to improve population welfare and quality of life while ensuring a significant reduction in ecological risks. One of the key objectives of green growth globally is the achievement of a decoupling effect, which reflects the economy's ability to grow without a proportional increase in environmental pressure (Ivanov et al., 2020).

In recent years, the decoupling factor has increasingly been used to explain the relationship between economic growth and environmental pollution. This indicator illustrates the progress of economic greening processes and enables the assessment of how various factors dynamically influence reductions in environmental pollution (Litvak & Litvak, 2017).

Nevertheless, there remains a pressing need for further research into promoting sustainable regional development and substantiating the importance of achieving the decoupling effect. This is essential for the implementation of modern resource-efficient technologies and the intensification of ecological transformation processes within the economy.

Data and Methods.

This study analyzes the relationship between economic growth and environmental impact in Ukraine over the period 2013–2023. The following indicators are used:

Nominal GDP growth rate (%) – reflects changes in Ukraine's economic performance. The data were obtained from the official website of the Ministry of Finance of Ukraine.

CO_2 emissions growth rate (%) – serves as a core indicator of environmental pressure. Annual CO_2 emissions data were collected from the State Statistics Service of Ukraine.

Primary Energy Consumption (PEC) growth rate (%) – represents total energy demand before transformation processes. These data were retrieved from YCharts, a financial and economic data platform that compiles statistics from international energy agencies and industry sources.

All indicators are expressed as annual growth rates (%) to allow for comparability and the calculation of decoupling factors.

To determine the presence of decoupling, two decoupling factors are calculated:

Decoupling factor (GDP–CO_2) = GDP growth rate – CO_2 emissions growth rate

and

Decoupling factor (GDP–PEC) = GDP growth rate – Primary Energy Consumption growth rate

These decoupling indicators demonstrate the relative growth of the economy versus environmental pressure. A positive value indicates decoupling (i.e., economic growth with reduced or slower-growing environmental impact), while a negative value reflects recoupling or unsustainable growth patterns.

Interpretation Framework:

The classification of decoupling follows international standards:

Absolute decoupling – GDP increases while CO_2 emissions or PEC decline.

Relative decoupling – GDP and environmental indicator both grow, but GDP grows faster.

No decoupling or negative decoupling – Environmental indicators grow faster than GDP, or GDP falls while environmental pressure rises [3].

Results. The analysis of decoupling dynamics in Ukraine from 2013 to 2023 reveals fluctuating interactions between economic growth, carbon emissions, and primary energy consumption (Fig. 1). Throughout this period, nominal GDP demonstrated a generally positive trend with notable volatility, particularly in 2015, 2021, and 2023. CO_2 emissions and primary energy consumption, while generally following GDP, exhibited more moderate and inconsistent growth patterns, leading to variations in decoupling performance.

In the immediate post-2013 period, negative decoupling is observed. During 2014 and 2015, despite increasing GDP, CO_2 emissions and energy consumption did not decline proportionally, resulting in strongly negative decoupling factors (GDP–CO_2: -2.02 and -0.64, respectively). This suggests that economic expansion during these years remained tightly coupled with environmental degradation, possibly due to industrial inertia and delayed structural energy reforms.

A temporary shift occurred in 2016, where relative decoupling was achieved (GDP–CO_2: 0.41; GDP–PEC: 0.23), indicating that economic growth outpaced emissions and energy use. However, this was short-lived; 2017 and 2019 returned to negative decoupling trends, signaling persistent challenges in breaking the link between economic and environmental trajectories.

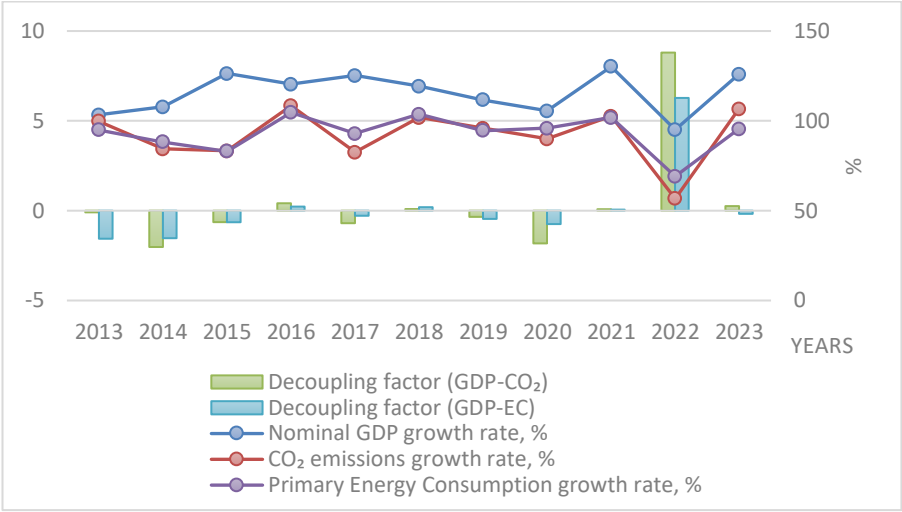

Fig. 1. Dynamics of nominal GDP growth, CO_2 emissions growth, primary energy consumption growth, and calculated decoupling factors (GDP–CO_2 and GDP–PEC) in Ukraine, 2013–2023 (Ministry of Finance of Ukraine, 2025; State Statistics Service of Ukraine, 2025; YCharts, 2025)

From 2021 onwards, some positive signals emerged. Relative decoupling was marginally restored in 2021, followed by a striking instance of absolute decoupling in 2022. That year, GDP contracted significantly due to the full-scale war, while CO_2 emissions and primary energy consumption declined even more sharply, resulting in exceptionally high decoupling indicators (GDP–CO_2: 8.80; GDP–PEC: 6.28). This phenomenon, however, reflects crisis-induced suppression of economic and industrial activity rather than deliberate decarbonization or energy transition policies.

In 2023, economic recovery was accompanied by a resurgence in CO_2 emissions (+6.62%) and moderate growth in energy consumption (+2.9%). Nevertheless, a positive GDP–CO_2 decoupling factor (0.26) suggests that emissions increased at a slower rate than economic output, signaling initial signs of structural resilience and potential for future low-carbon growth. Conversely, the GDP–PEC decoupling factor remained negative (-0.18), implying that energy demand rebounded faster than expected, likely due to infrastructure rebuilding and increased production activities.

Overall, the data illustrate Ukraine's inconsistent path toward sustainable growth. While short-term relative and even absolute decoupling occurred sporadically, long-term structural decoupling remains limited. The findings highlight the critical need for targeted green recovery policies, energy efficiency investments, and low-carbon innovation to ensure that post-war reconstruction supports not only economic revival but also environmental resilience.

Conclusions. The decoupling analysis of Ukraine's economic growth from environmental pressures over the period 2013–2023 reveals a complex and uneven trajectory of sustainable development. The decoupling factors between nominal GDP and CO_2 emissions, as well as primary energy consumption, suggest that Ukraine experienced fluctuating levels of relative and absolute decoupling, interspersed with phases of recoupling and environmental regression. A particularly notable finding is the sharp spike in both decoupling factors in 2022, reflecting a strong relative decoupling, primarily attributable to the war-induced economic contraction alongside reductions in energy use and emissions. However, this atypical year does not reflect long-term systemic improvements but rather a distortion caused by exogenous shocks.

Throughout the analyzed decade, Ukraine achieved intermittent positive decoupling (e.g., in 2016, 2018, 2021, and 2023), indicating partial success in improving energy and carbon efficiency of economic activities. However, these gains were often offset by years of strong recoupling, where economic growth was accompanied by disproportionately higher emissions or energy use (e.g., in 2014, 2015, and especially 2020). These inconsistencies reflect structural vulnerabilities, energy inefficiencies, and the volatility of Ukraine's economic-environmental interactions, particularly under conditions of political instability and war.

Future research should aim to disaggregate decoupling trends by industry and region, incorporate real GDP and purchasing power parity metrics, and explore the role of technological innovation, renewable energy deployment, and policy reforms in shaping Ukraine’s path toward sustainable development. With Ukraine's reconstruction and EU integration on the horizon, ongoing monitoring of decoupling dynamics will be vital to guide environmental and economic policymaking.

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ECOSYSTEM SERVICES AS A KEY FACTOR OF SUSTAINABLE DEVELOPMENT AND ECONOMIC WELL-BEING

Maksym Kyrylenko, *Phd Student,*
Sumy State University
Scientific supervisor – Associate Professor ***Inna Koblianska***

Ecosystem services play a fundamental role in ensuring sustainable development and economic well-being. This term encompasses many benefits people derive from ecosystems, including providing food and water, climate regulation, biodiversity conservation, and cultural and recreational values. Recognising their importance is becoming increasingly relevant under growing anthropogenic pressure on natural resources, particularly due to warfare and environmental consequences.

The preservation and sustainable use of ecosystem services is a key component toward the sustainisation of the economy (a term reflecting the transition to a systematically sustainable and ecologically integrated economic system) and improved societal well-being.

This research highlights the significance of preserving ecosystems and their services due to their essential role in sustainable development and economic prosperity.

According to the commonly accepted classification, ecosystem services fall into four main categories: provisioning, regulating, cultural, and supporting services [3]. Sustainable development implies a balanced integration of economic growth, social well-being, and environmental stability. Ecosystem services contribute to this balance by providing vital resources and conditions for economic development, environmental conservation, and improving human quality of life.

Healthy ecosystems help reduce the cost of water and air purification, lower the risks of natural disasters, and enhance agricultural productivity. For example, pollination of entomophilous crops can increase yields by 20–60% [1].

Economic well-being is closely connected to ecosystem services. Natural resources support many key sectors such as agriculture, forestry, fisheries, and tourism. Effective management of ecosystem-based resources helps to preserve their productivity and secure long-term economic stability. Investments in ecosystem conservation and restoration can foster economic growth through improved land productivity, new jobs in ecotourism, and better public health outcomes.

However, ecosystem vulnerability to anthropogenic impacts must be taken into account. Pollution, climate change, biodiversity loss, and land degradation negatively affect the ability of ecosystems to provide essential services. Therefore, integrating ecosystem services into decision-making processes at all local and global levels is critical. This integration involves ecosystem service valuation, inclusion in national accounting, developing nature-focused policies, and broad stakeholder engagement.

One example of successful integration of ecosystem services into economic policy is implementing payment for ecosystem services (PES) schemes [2]. The main goal of PES is to encourage environmentally responsible behaviour and create

financial incentives to protect natural resources. This approach contributes to biodiversity conservation and ecological improvement and brings economic benefits to local communities.

Conclusion: Ecosystem services are key to sustainable development and economic well-being. Their importance cannot be overstated, as they provide fundamental conditions for human life and prosperity. Integrating ecosystem services into decision-making and policy development aimed at their protection and sustainable use is a necessary step toward the sustainability of the economy and harmonious coexistence between humanity and nature.

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ANALYSIS OF ROBOTICS USE CASES IN RESTAURANTS

Sofiia Romanchenko, *student,*
Oleksandra Karintseva, *Dr. in Economic Sciences,*
Svitlana Tarasenko, *PhD in Economic Sciences,*
Sumy State University, Ukraine

Introduction. The restaurant industry is undergoing transformation driven by advancements in robotics, which not only modernize service delivery but also reconfigure the nature of interaction between the customer and the establishment. In the current era of digital transformation, the integration of robots into processes such as food preparation and service, guest interaction, and logistics has transitioned from a novel concept to a strategic and rational measure aimed at enhancing operational efficiency, reducing operational costs, and ensuring sanitary safety. Leading countries, including Japan, China, South Korea, and the United States, are actively incorporating automated solutions into the restaurant sector, where robots are fulfilling the roles of servers, chefs, and customer service consultants.

The aim of this study is to systematize global use cases of robotic technologies in the restaurant industry in order to identify the benefits, limitations, and context-

specific implications of their implementation, with particular attention to the potential for application in Ukraine.

Data and Methods. The research is based on a comparative case study approach, utilizing secondary data from scientific literature, industry reports. Descriptive method is applied to examine robotics integration in restaurant operations across five countries (China, Japan, South Korea, and the United States). The study also applies elements of SWOT analysis to assess the strengths, weaknesses, opportunities, and threats associated with robotic systems in food service.

Results. A vivid illustration of robotics integration in the restaurant industry is the Sushi Saito chain in Tokyo, where the humanoid robot Pepper is employed. It greets customers, provides dish recommendations, and creates a welcoming atmosphere, particularly appealing to younger audiences. This contributes positively to customer loyalty, although the robot's linguistic functionality remains limited (Stars and Stripes, 2024). In China, PuduBot is used in Haidilao restaurants to autonomously deliver orders from the kitchen to tables, eliminating the need for waitstaff. This innovation has reduced staff workload and cut salary expenses by nearly one-third (Pudu Robotics).

In the United States, **Flippy**, a burger-flipping robot, operates in White Castle restaurants, automating food preparation. This allows for minimized errors, faster service, and compliance with high hygiene standards. However, the proliferation of such technologies has raised concerns among staff regarding potential job displacement (Food & Wine, 2023). In South Korea, the **Dilly Dally** chain uses delivery and disinfection robots, a practice that became critically important during the COVID-19 pandemic (Reuters, 2020).

A synthesis of global case studies indicates that robots most frequently perform tasks such as taking orders, preparing food, delivering dishes, and basic customer communication. This contributes to faster service, standardized quality, cost reduction, and minimized physical contact, particularly relevant in the post-pandemic period. In Japan and South Korea, the use of robots forms part of the broader digitalization of daily life, whereas in many European countries, customers prefer human-centered service. In Ukraine, a hybrid model may be most appropriate for quick-service restaurants, cafés with digital interfaces, and establishments in tourist areas. Therefore, the successful application of robotics in the restaurant sector depends on technological adaptability, legal support, and cultural sensitivity to consumer preferences.

The operation of robotic systems requires not only technical maintenance but also software support tailored to the specific format of the establishment. The reliability of such systems depends on network stability, timely software updates, and the availability of qualified personnel to manage technical failures. In case of system malfunction, it is necessary to swiftly switch to manual operation, which presupposes a backup human workforce. In many countries, legal frameworks are already being developed to regulate liability for failures in autonomous systems. In

the future, it may become possible to insure risks associated with the use of robots in public service.

The ethical dimension of robotics deployment also deserves attention; the depersonalization of communication may affect customer satisfaction, especially in fine dining segments. The psychological factor must also be considered: not all visitors are ready to entrust their food experience to a machine. While children are often intrigued by robots, older customers may experience distrust or discomfort. Therefore, the design, voice features, and behavior of robots should be adapted based on principles of inclusivity.

Another promising direction is the integration of artificial intelligence into robotic systems. This would enable learning from user data, enhance service personalization, and forecast demand. For instance, a robot could recommend dishes based on previous customer orders or seasonal preferences. At the same time, the risks of collecting and processing personal data increase, necessitating strict compliance with privacy regulations.

Innovative cases also reveal the potential for using robots in self-service zones, drive-thru systems, culinary shows, and educational institutions. Technologies allow robots to be integrated with a restaurant's CRM systems, opening up new opportunities for marketing. For example, a robot could remind customers about loyalty points or current promotions (SavorEat, 2023). Some startups are also developing solutions to adapt robots to narrow spaces, irregular layouts, and even mobile use in outdoor settings. In the future, fully automated mobile food trucks are expected to emerge (OLHSO, 2024).

Overall, robotics in the restaurant industry does not replace humans but rather acts as a partner capable of enhancing productivity and reducing routine workload. The success of such transformations largely depends on audience perception as well as the ability of business owners to adapt to new realities. The shift toward hybrid service models is not only a technological transition but also a sociocultural challenge that will shape the face of the gastronomy sector in the coming decade.

Conclusions. The implementation of robotics in the restaurant business demonstrates high potential for improving service efficiency, optimizing costs, and minimizing the impact of human error. An analysis of global use cases shows the success of automated solutions across various regions, particularly in Asia and the United States. Robots are capable of performing repetitive tasks with high precision, contributing to the consistency of service quality. However, a complete replacement of human labor remains inappropriate at this stage, given the importance of emotional connection in the hospitality industry.

A hybrid model of human–machine collaboration currently appears to be the most optimal approach for integrating innovation without losing the human touch in service. Future research should focus on refining technical solutions and considering the cultural and behavioral characteristics of consumers.

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INNOVATIVE ECOLOGICAL COMPONENT IN THE FORMATION OF THE ECONOMIC POTENTIAL OF AN ENTERPRISE

Jia Wei, *student,*
Sumy State University, Ukraine

The integration of innovative ecological components into the structure of an enterprise's economic potential represents a crucial step in aligning business practices with the demands of sustainability and long-term value creation. In a world increasingly shaped by environmental constraints and the urgent need to address climate change, enterprises are being challenged to rethink the foundation of their economic strategies. The traditional model of maximising short-term profits without considering environmental impacts is no longer viable in the face of global resource depletion, tightening environmental regulations, and shifting consumer expectations. Thus, innovation in the ecological sphere is not merely a matter of compliance or corporate social responsibility - it is becoming a key driver of competitiveness and resilience.

Ecological innovation involves the development and implementation of new technologies, processes, and management practices that reduce the environmental footprint of production while enhancing economic performance. Such innovations might include the adoption of cleaner production techniques, renewable energy sources, circular economy models, waste minimisation strategies, and eco-design of products and services. When integrated thoughtfully into the operations and strategic planning of an enterprise, these measures can significantly increase resource

efficiency, lower operational costs, and open access to new markets focused on environmentally responsible products. Moreover, they can foster a culture of innovation among employees and build stronger relationships with stakeholders who value transparency and environmental commitment.

From an economic standpoint, the inclusion of ecological innovations can also improve the long-term valuation of an enterprise by reducing environmental risks and future liabilities. Investors and financial institutions are increasingly incorporating environmental, social, and governance (ESG) criteria into their decision-making processes, rewarding businesses that demonstrate proactive environmental strategies. This shift means that an enterprise with a strong ecological component in its development model is more likely to attract investment, secure favourable financing, and maintain a stable reputation in turbulent market conditions.

In addition, ecological innovation contributes to the differentiation of a company's brand and enhances its competitive positioning. As consumers become more environmentally conscious, their purchasing decisions increasingly favour companies that demonstrate a genuine commitment to sustainability. Enterprises that lead in eco-innovation are not only able to capture this growing demand but also to influence industry standards and regulatory frameworks in their favour. This leadership, in turn, reinforces their role as pioneers in sustainable development, creating a virtuous cycle of growth and ecological responsibility.

In conclusion, the incorporation of an innovative ecological component into the formation of an enterprise's economic potential is both a strategic necessity and an opportunity. It allows businesses to meet environmental challenges with creativity and foresight, transforming them into sources of competitive advantage. By embedding sustainability into the core of economic activity, enterprises can not only ensure their own long-term viability but also contribute meaningfully to the broader goal of building a sustainable global economy.

SIGNIFICANCE OF THE LANGUAGE OF SUSTAINABLE BRANDS IN CHANGING THE AUDIENCE'S BEHAVIOUR TOWARD THE FUTURE

Iryna Ushchapovska, *PhD, As. Prof.,*
Sumy State University, Ukraine

Language is a common bond used to form socio-economic interests and improve the system of cultural values. Language functions in a society characterized by a certain social structure. The denotative and connotative meanings we give words are intentionally constructed to clarify communication. The same processes occur during brand communication. Jean Monet module "Fostering EU practices of education for sustainable development through the brand language: interdisciplinary studies" is about transferring sustainability procedures to the language field and combining economic, environmental, cultural, and linguistic competencies. Thus, educational sustainability is holistically related to economic, environmental, linguistic, and cultural sustainability.

Brand language is a system of signs and symbols to communicate a brand with its audience. Consumer behavior and interaction with the brand depend on the brand's verbal identity (style and vocabulary), used in the communicative process (Ushchapovska: 209). It is important to consider all the factors influencing language use – from the speakers' characteristics to the features of a specific speech act.

Brand language is multimodal, using various semiotic resources: verbal, visual, auditory, and sensory, which are represented in their own way in communication. However, they do not exist separately but converge, complementing the message's meaning, coexist, and interact, thereby enhancing the effect of pragmatic influence on the consumer as a recipient. Combining visual, auditory, and verbal means into a specific multimodal system creates a memorable brand language that significantly impacts the consumer audience. Any company, product, or service will not succeed if it cannot identify itself and show its difference from others by creating a name, logos, and symbols, using colors and graphics, illustrations, using a particular vocabulary and style of speech.

Elements of different semiotic origins represent the structure of the brand language. From the perspective of multimodality, these elements combined into modes have specific lexical-semantic characteristics. It is worth noting that we have isolated the elements of the brand language to analyze their structural and semantic characteristics. However, when they encounter communicative situations, they converge, cooperate, and become similar, acquiring each other's functions.

Verbal elements of the brand language, representing the verbal mode, are name, tagline and slogan, mission statement, storytelling, and descriptive text. Nonverbal elements of the brand language represent different modes, namely visual, auditory, and sensory. Visual elements are logotype, color, and typeface. Audial elements are a jingle and a sound logo. Sensory elements are flavor, taste, and texture.

Language is one of the most important determinants of any brand, defining and reflecting its priorities. However, we often perceive a brand as a visual design system. As a result of digitalization, the verbal components of brand language are often ignored by companies in favor of logos or graphic design, and language is often simplified to abbreviations, memes, and restrictive symbols.

In the modern world, language is a powerful semiotic resource that is the basis of successful competitive brands. Linguistic tools turn words into brand assets, setting prospects for developing the brands themselves and emotionally connecting consumers with them. Brand language becomes an emotional trigger for purchasing decisions. Under the influence of brand language, certain patterns of attitude towards it are created, its values are formed, and a social and emotional connection with consumers is established.

Creating brand language and consistently using linguistic tools in names, advertisements, slogans, and promotional materials not only helps customers use the exact words to identify the brand but can also prevent competitors from using the brand in their own, often negative, contexts. Brand language reflects the brand's competitive strategies, contributes to the definition of the brand as a cultural phenomenon, and contributes to consumer brand identification.

Language reflects a brand's priorities. Developing and consistently using recognizable language creates a lasting brand impact on the consumer audience, who, in turn, use the same verbal elements when talking about the brand. This interaction allows effective brand advertising to be passed on from mouth to mouth, attracting new customers and increasing profits.

Choosing vocabulary and style is a key factor in creating a brand language. Vocabulary is the vocabulary used in different communicative situations, while style signals the position of a particular brand. If companies promote the same product, for example, ground coffee, the choice of vocabulary – classic (Fine Latin coffee) or modern (Our welcome back blend) – shapes brand associations. Style is consistently followed in every element of the brand language – from font and color to product descriptors on the packaging.

The formation of brand language depends on two things: the positioning of the brand in the market and the brand identity that the company creates. Depending on the position in the market, we divided brands into leading brands, challenger brands, cult brands, craft brands, budget brands, and quality brands.

Brand language reflects the values and strategy of the brand. The brand is represented emotionally, thus establishing its connection with the audience. The gold standard of brand language is when the brand becomes a generalized way of referring to the product.

One of the best examples is Disney's brand language. Verbal markers such as "magic," "kingdom," "dreams," and "fantasy" are associated with this brand. Disney has built its brand on a much larger foundation than a visual logo; it promises a kingdom of magic, fantasy, and dreams, never losing the opportunity to use its "brand" words (Thellefsen: 53). These words are constantly repeated in all

communicative situations from television to the Internet, in Disney advertising campaigns, song lyrics, and storylines, and on the Disney Channel. The brand constantly and consistently uses verbal markers in its language to create stable associations and unmistakable recognition:

Brand language – its corporate identity – is not spontaneous but strategically planned with the obligatory use of branded vocabulary and adherence to style. Language as a way of communication and representation of the brand's individuality undergoes a process of development and formation. It results from language planning and the company's language policy (Sorko: 17-18).

The vocabulary and style of the verbal mode of the brand language are implemented in the following polysemiotic blocks: nominative-representative (name), attractive-appellative (tagline and slogan), intentional-axiological (mission statement), narrative (storytelling), and descriptive (descriptive text).

Thus, the structure of the brand language is represented by elements of different semiotic origins. The verbal elements of the brand language are the name, tagline, slogan, mission statement, storytelling, and descriptive text. Visual elements are the logo, color, and font. The auditory elements are the jingle and the sound logo, and the sensory elements are the smell, taste, and texture. The vocabulary and style of the verbal mode are implemented in polysemiotic blocks such as nominative-representative, attractive-appellative, intentional-axiological, narrative, and descriptive.

In this context, defining the concept of a "sustainable brand" is necessary. Therefore, sustainable brands apply and advocate sustainable practices in their business. They use brand communication tools to convey sustainability benefits to their consumers, thus encouraging them to make conscious decisions about this brand. A sustainable brand must effectively integrate its statements into its business plan and put them into practice.

According to O. Sprinkel, a sustainable brand has a meaning or purpose that goes beyond making money; instead, it seeks to improve the well-being of humanity and all living things on our planet. A sustainable brand views people as creative agents, not consumers, and understands the life cycle of all its activities and their environmental impact. Therefore, such a brand strives for constant innovation and minimizes its environmental impact. This definition emphasizes the communicative nature of the brand, to influence the target audience and thus pragmatically change its behavior.

Strong, enduring brands can initiate profound changes in people's lives and balance the interests of three usually opposing parties – consumers, companies, and society. A brand combines functional and emotional characteristics that consumers perceive as an added value, a unique experience, and a fulfilled promise. Branding – the process of creating a brand – has become "the story of belonging and pervasion" because it allows consumers to express their interests, attitudes, preferences, and overall personality through the brands they consume.

Since sustainability is about the future, which cannot be sacrificed for the present, such intentions for the future are represented in a mission statement, which describes the brand's purpose and goals. A mission is a clear, concise, and consistent statement of the brand's reasons for existing now. *Our Roadmap starts with our mission, which is enduring. It declares our purpose as a company and serves as the standard against which we weigh our actions and decisions* (The Coca-Cola Company). *A vision is a description of the future goal, which gives a mental picture of where the brand wants to be. Our vision serves as the framework for our Roadmap and guides every aspect of our business by describing what we need to accomplish to continue achieving sustainable, quality growth* (The Coca-Cola Company). *Brand values are the ideals and principles that guide a brand's behavior and actions, define its character, and current and future goals. Our values serve as a compass for our actions and describe how we behave in the world* (The Coca-Cola Company). Together, mission, vision, and values create a consistent message for optimal brand communication with its target audience.

Thus, a mission statement as an emotionally powerful communication tool is important in achieving sustainable development goals. In a mission statement, a brand assures consumers that it is acting sustainably and in a balanced way for the future of the planet and society: *Our purpose is to make sustainable living commonplace… We strive to do better for our planet and our society, not just less harm. We want to act on the social and environmental issues facing the world, and we want to enhance people's lives with our innovative, sustainable, and high-quality products* (Unilever).

Using markers of inclusion, the brand creates a noticeable social impact on consumers through its mission: *OUR MISSION. To inspire and nurture the human spirit – one person, one cup, and one neighborhood at a time. OUR VALUES. With our partners, our coffee, and our customers at our core, we live these values: Creating a culture of warmth and belonging, where everyone is welcome. Delivering our very best in all we do, holding ourselves accountable for results. Acting with courage, challenging the status quo, and finding new ways to grow our company and each other. Being present, connecting with transparency, dignity, and respect. We are performance-driven through the lens of humanity* (Starbucks).

Leading brands in the field of sustainable development include the principle of sustainable development in their mission statements, which means that sustainable development and environmental protection are among the reasons for the existence of these brands. A good mission statement focusing on sustainability keeps a company on the right track in adverse times and helps in the "eternal battle between commercialization and values."

By speaking the language of sustainability, brands can win the market, attract environmentally conscious consumers, and thus influence society. However, we should not forget about the so-called "greenwashing" – a form of advertising or marketing in which green PR and environmental marketing are deceptively used to convince the public that the organization's products, goals, and policies are

sustainable and environmentally friendly. However, in practice, this is not confirmed by the company's actions, and sometimes, on the contrary, it is the opposite of the mission and vision statements. Therefore, the verbal component of the brand identity must correlate with its behavior and practical activities.

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GREEN ECONOMY AND THE GENDER DIMENSION

Tanya Kharchenko, *D. in Law,*
Chief Specialist of the Gender Equality Monitoring Department
and non-discrimination department of human rights compliance
Department of Chief Inspection and Rights Compliance
National Police of Ukraine

Introduction. The concept of a green economy has gained significant attention in recent years as a strategy to achieve sustainable development while ensuring environmental protection and economic growth. However, one of the critical aspects that must be considered is the role of gender in this transformation. The intersection of gender and the green economy is crucial for ensuring equitable access to resources, opportunities, and decision-making processes. Women, particularly those in developing countries, often face structural barriers that limit their ability to benefit from green economic initiatives. This paper explores the gendered implications of

the green economy, highlighting the challenges women face and the opportunities available to bridge the gender gap in this sector.

Data and Methods. This study is based on a qualitative analysis of existing literature, policy documents, and statistical reports related to the intersection of gender and the green economy. The research employs a desk review methodology, analyzing international publications from organizations such as UN Women, the World Bank, the OECD, and the ILO, as well as academic studies on gender equality and sustainable development.

The sources were selected based on their relevance to key thematic areas: access to natural resources, green jobs, financing for women entrepreneurs, education and training in green sectors, and policy recommendations. Comparative analysis was used to identify common challenges and opportunities for women's participation in the green economy globally, with particular attention to the situation in developing countries.

Additionally, gender-sensitive frameworks were applied to assess how green economy strategies can either reinforce or reduce existing gender disparities. The research did not include primary data collection but relied on secondary sources published between 2012 and 2022, ensuring a comprehensive overview of recent developments and best practices in the field.

Results. The green economy and the gender dimension are important components of sustainable development, as environmental changes often have differential impacts on different population groups, including women. Women, especially in developing countries, often face limited access to natural resources, such as land, water, energy, and financing. This is due to social and cultural constraints that prevent them from fully accessing these resources, which ultimately impairs their ability to adapt to environmental crises (UN Women, 2015).

For example, when environmental conditions deteriorate (droughts, floods), women in rural areas may have to spend more time searching for water or fuel, which limits their opportunities for career development and economic participation (World Bank, 2013).

However, the green economy has significant potential to reduce gender inequality. It contributes to the creation of new jobs and businesses in sectors such as renewable energy, energy efficiency, and waste management. This can create new opportunities for women if they have equal access to these opportunities (UN Environment Program, 2016).

In particular, green jobs and enterprises can be important elements for ensuring economic equality between the sexes if women have access to green technologies, entrepreneurship, and investment in these sectors (Binns, 2016).

Investing in the education and training of women in fields related to environmental technologies and sustainable development is an important step in ensuring equal labor market opportunities for women (OECD, 2017). For example, creating specialized programs to train women in areas such as renewable energy,

natural resource management, and sustainable business will allow women to take up key positions in green sectors (Schalatek & McFarlane, 2014).

Financing is another important component in empowering women in the green economy. Women often face difficulties in obtaining financing for business start-ups due to social and economic barriers. Therefore, it is important to create policies that promote women's equal access to green investments and financing (Elson, 2012). Supporting women entrepreneurs in green sectors can not only contribute to economic development, but also help reduce gender inequality (ILO, 2017).

The green economy has the potential to make significant progress on gender equality, but this requires ensuring that women have equal access to resources, financing, education, and jobs in green sectors. This will help to create a more equitable environment for the development of sustainable economic practices and overcome environmental challenges (Kabeer, 2015).

Conclusions. The transition to a green economy presents both challenges and opportunities for advancing gender equality. While environmental changes disproportionately affect women, particularly in developing countries, the green economy offers new possibilities for addressing gender disparities. Ensuring women's equal access to resources, education, financing, and employment in green sectors is crucial for sustainable development.

By integrating gender-sensitive policies and programs, governments and international organizations can promote women's active participation in environmental initiatives. Investing in education and training for women in green industries will enhance their economic empowerment and foster innovation in sustainable practices. Additionally, facilitating access to financial support for women entrepreneurs in green sectors will contribute to closing the gender gap in economic opportunities.

In conclusion, achieving gender equality within the green economy is not only a matter of social justice but also a necessity for long-term economic and environmental sustainability. By addressing existing barriers and promoting inclusive policies, societies can unlock the full potential of both women and men in building a more resilient and sustainable future.

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PROBLEMS OF LAW ENFORCEMENT BY LAW ENFORCEMENT AGENCIES ARTICLES 369-3 OF THE CRIMINAL CODE OF UKRAINE

Mykola Kolos, *PhD, As. Prof.*
State Tax University, Ukraine
Serhiy Paranytsia*, PhD, As. Prof.*
Head of the Department of Law Enforcement
State Tax University, Ukraine

Introduction. The Law No. 743-VIII "On Prevention of Corruption Offenses from Influencing the Results of Official Sports Competitions" (On preventing, 2015) of November 03, 2015 amended the Criminal Code of Ukraine, namely, the Code was supplemented with Article 3693 "Unlawful Influence on the Results of Official Sports Competitions" (Criminal Code of Ukraine, 2001).

The need to supplement the Criminal Code of Ukraine with special anti-corruption provisions in the field of sports can be explained by a number of high-profile investigations recently conducted by international and Ukrainian sports organizations into corruption in domestic sports (in particular, football).

The Council of Europe Convention against the Manipulation of Sports Competitions played an important role (Council of Europe, 2014). The Council of Europe Convention against the Manipulation of Sports Competitions was adopted on September 18, 2014 in Maglingen (Swiss Confederation) at the 13th Conference of Council of Europe Ministers responsible for Sport. Currently, the Convention has been signed by 30 Council of Europe member states and Australia, of which seven states (the Portuguese Republic, the Kingdom of Norway, Ukraine, Moldova, the Swiss Confederation, Italy and Greece) have already ratified the Convention.

Ukraine signed the Convention on December 21, 2015, and ratified it on November 16, 2016, making Ukraine one of the leaders among European countries in the field of combating manipulation in sports.

The purpose of this Convention is to combat the manipulation of sports competitions in order to protect the integrity of sport and sports ethics in accordance with the principle of the autonomy of sport.

Date and Methods. The article is based on the laws and regulations of Ukraine, official documents, reports, criminal proceedings, and a number of scientific publications on the investigation of the crime under Article 369-3 of the Criminal Code of Ukraine. The authors have widely used the methods of description, analysis and synthesis, induction, analogy, generalization, and a number of other general scientific methods.

Results. The disposition of Part 1 of Article 369-3 of the Criminal Code of Ukraine establishes liability for influencing the results of official sports competitions by bribery, coercion or incitement or entering into a conspiracy regarding the results of an official sports competition in order to obtain an unlawful benefit for oneself or a third party or obtaining an unlawful benefit for oneself or a third party as a result of such acts.

Influence on the results of official sports competitions, in view of the content of Part 2 of Article 9 of the Law "On Prevention of Corruption Offenses Influencing the Results of Official Sports Competitions", is an act aimed at incorrectly changing the course of a sports competition or its result by fully or partially excluding the unpredictable nature of the competition and achieving a predetermined result. At the same time, incorrect changes in the course of a sports competition or its result should be understood as such actions or omissions of athletes, sports support personnel participating in a sports competition, or sports officials that:

1) deliberately violate the rules of the competition or do not violate them, but are not dictated by their natural course or medical conditions; and

2) were agreed upon in advance, i.e. before the start of the sports competition (or its separate stage), with the person who influences the results of the official sports competition.

According to the Law of Ukraine "On Prevention of Corruption Offenses Influencing the Results of Official Sports Competitions", sports competitions must be held in accordance with the rules of fair play.

Fair Play rules are generally recognized moral and ethical obligations of athletes, auxiliary sports personnel directly involved in a sports competition, and sports officials to strictly follow the rules of the competition, to prevent prohibited methods and techniques of fighting, rudeness, fraud, and other illegal acts as a means of achieving sports results.

Due to the specific nature of this crime, the initiation of a criminal investigation includes not only priority investigative (detective) actions, but also the interaction of the investigator with other state authorities.

The current CPC of Ukraine in part 1 of Article 214 establishes that the investigator, prosecutor immediately, but not later than 24 hours after filing a statement, notification of a crime or after independently identifying circumstances from any source that may indicate the commission of a criminal offense, is obliged to enter the relevant information into the Unified Register of Pre-trial Investigations and initiate an investigation. Taking into account the specifics of criminal acts of unlawful influence on the results of official competitions in Ukraine, the following grounds for entering information into the Unified Register of Pre-trial Investigations should be considered the most common:

1. Notification of managers or owners of enterprises where criminal acts of unlawful influence on the results of official competitions in Ukraine have taken place.

2. Notification of state authorities supervising compliance with the requirements of the legislation in this area.

3. Statements of the victim.

4. Reports published in the press.

The investigation begins with finding out what happened, what the consequences were, and whether the initial information contains signs of a criminal offense.

The main tasks of the initial stage are to establish: a) criminal actions regarding the unlawful influence on the results of official competitions in Ukraine that took place; b) the immediate cause of the event; c) the consequences that occurred; d) the person(s) who violated the rules. Based on these tasks and the current situation, the investigator puts forward versions, determines the direction of the investigation, and draws up a plan of investigative (search) actions.

Conclusions. In summary, dialogue and cooperation between public authorities, sports organizations, competition organizers and sports betting operators at the national and international levels, based on mutual respect and trust, are essential to finding effective common responses to the challenges posed by the problem of manipulation of sports competitions. The ratification of this Convention will contribute to the expansion of rapid, sustainable and properly functioning national and international cooperation to effectively combat the manipulation of sports competitions. And it is the law enforcement agencies that will be responsible for organizing the fight against the manipulation of sports competitions.

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RESTRUCTURING UKRAINE'S ECONOMY AMID DIGITAL TRANSFORMATION AND POST-WAR RECONSTRUCTION

Oleksandra Karintseva, *Dr. Sc., Prof.,*
Sumy State University, Ukraine
Mykola Kharchenko*, PhD in Economics, As. Prof.,*
Sumy State University, Ukraine
Oleksandr Jarosh, *Phd Student*
Sumy State University, Ukraine

Ukraine's economic restructuring in the context of digital transformation and post-war reconstruction is a multifaceted process that extends beyond the physical restoration of infrastructure. It involves a profound modernization of institutional, technological, and socio-economic foundations. This process is characterized by several unique features:

1. Synergy of Digital Transformation and Post-War Reconstruction

Since the onset of the full-scale war, Ukraine has intensified the digitalization of public administration and societal processes. Notably, the "Diia" application has become a key tool for providing public services online. Digital solutions are also employed for monitoring and coordinating reconstruction efforts, ensuring transparency and efficiency in resource utilization [1].

2. Prioritization of Critical and Digital Infrastructure Development

The restoration of energy systems, transportation networks, and logistics centers is being carried out with the integration of digital technologies. This includes the implementation of intelligent management and monitoring systems, enhancing the efficiency and safety of infrastructure. Additionally, the development of IT infrastructure, such as data centers and broadband internet, forms the foundation for establishing a new digital economy.

3. Emphasis on Human Capital and Digital Skills

To adapt to new economic conditions, Ukraine is implementing programs for retraining and upskilling the population in IT, digital management, and cybersecurity. This approach aims to engage internally displaced persons, veterans, and youth in the productive economy, promoting inclusivity and reducing social tensions.

4. Shift in GDP Structure: Growth of IT, Innovation, and Services

The Ukrainian IT industry has demonstrated resilient growth, even amid the war. In 2022, IT service exports reached a record $7.3 billion, constituting approximately 4.5% of GDP. This indicates a shift from a resource-based economy to one focused on knowledge and innovation [2].

5. Support from International Partners

The international community actively supports Ukraine's digital transformation and reconstruction. The European Commission has positively assessed Ukraine's progress in digitalization, particularly in implementing electronic identification and trust services, bringing the country closer to the EU's single digital market.

6. Reform of Public Administration

Digitalization of public administration contributes to increased transparency and efficiency. The introduction of e-government, open data, and automated administrative services reduces corruption levels and enhances trust in institutions. This is especially crucial for regions affected by hostilities, where digital solutions ensure equitable access to services and effective coordination of recovery processes.

Despite significant progress, considerable challenges remain. Unequal access to digital technologies between urban and rural areas, cybersecurity threats, demographic losses, and mass emigration diminish the country's labor potential. The success of restructuring hinges on the state's ability to balance strategic vision, swift implementation, and social justice.

In summary, Ukraine's economic restructuring amidst digital transformation and post-war reconstruction is a profound and comprehensive process encompassing technological, social, economic, and institutional changes. Its effectiveness depends on integrating digital tools across all sectors, developing human capital, and creating a conducive environment for innovation and sustainable growth.

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CHANGES OF THE INFORMATIONAL BASIS OF THE SOCIO-ECONOMIC SYSTEM GIVEN DIGITAL TRANSFORMATION[2]

Inna Koblianska, *PhD, As. Prof.,*
Sumy State University, Ukraine

Introduction. The changes that occur in the context of digital transformation can be interpreted as the formation and development of a socio-technical system (STS), in which information factors are one of the most important, as they ensure the interaction between the social and technical components. This study aims to demonstrate the main directions of transformation of the information basis of society's development, which ensure and stimulate further digital transformation.

Data and methods. The research is based on a detailed analysis and interpretation of the available data on the digitalisation of society and socio-economic processes.

Results. A socio-technical system combines elements of material and intangible nature. It is becoming increasingly apparent that virtualisation is a factor in such transformation. The foundations for virtualisation are laid by the capabilities of cloud technologies and the Internet of Things. A modern technology supporting virtualisation is the Digital Twin technology, which expands the possibilities for modelling processes, products and value chains.

The virtualisation of society is also evident. Social communication is becoming increasingly virtual. According to Statista (Statista, 2024a, 2024b), the global "digital population" (Internet users) in April 2024 was 5.44 billion people, which is 67.1% of the population. The average time spent by a person on social media alone in April 2024 was 143 minutes per day, which is more than 1.5 times higher than in 2012.

Virtualisation enables human-machine collaboration, thereby changing the vector of discussions from the displacement of humans, characteristic of Industry 4.0, to the interaction and importance of human skills to communicate with intelligent machines.

Collaborative intelligence is the basis for STS's formation, functioning and evolution. Its formation involves human cognitive abilities and technical components. Therefore, developing cognitive skills is one of the main factors of digital transformation.

In the context of the social component, this means training, development of specific skills, transformation of culture and values. Various assessments and analytical reports indicate that in 2030, digital skills (the ability to use digital technologies) will be critically important - more than half of modern activities will require digital knowledge and skills (Marr, 2023).

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The cognitive capabilities of a technical system are becoming decisive in the context of the effectiveness of STS. They are based on artificial intelligence technologies, environmental recognition, and processing of the received information. Statistical data illustrate the scale of development of the artificial intelligence sector, big data analytics, and robotic systems with relevant technologies. The market for wearable devices equipped with AI alone was estimated in 2023 at 27 billion USD, with a projected average annual growth rate of 26.4% to 166.7 billion USD in 2030 (Verified Market Research, 2023). AI allows for the "intelligence" of the technical component, enabling decision-making without human intervention, i.e. autonomy.

The system and data management in the organisation are the basis for establishing connections between different system elements. An essential aspect of the digital transformation and sustainability of the STS is the information ecology. This actualises the problems of ensuring information transparency, data quality, data openness, and information exchange. Today, there is evidence of a positive relationship between the publicity of government data and the country's economic results: open government data can contribute to generating additional economic value, which promotes innovation in various sectors. In addition, Information exchange and transparency, following data integrity standards, make it possible to lower the problem of information overload somewhat (by reducing the need to extract primary data), which can threaten the system's sustainability.

Conclusions. Digital transformation results in the formation of socio-technical systems (STS), which have the properties of the class of "systems of systems". Changes in the information factors of system development accompanying this process include virtualisation, cognitivisation, information transparency and sharing. They contribute to adaptability, evolution, contextual awareness and the establishment of communication between the STS' elements.

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METHODOLOGY FOR DETERMINING THE INTEGRAL LEVEL OF A COUNTRY'S CAPACITY TO IMPLEMENT ARTIFICIAL INTELLIGENCE TECHNOLOGIES

***Oleksandra Karintseva**, Dr.Sc., Prof.*
Sumy State University, Ukraine
***Svitlana Tarasenko**, PhD, As. Prof.*
Sumy State University, Ukraine

Introduction. In the context of integrating artificial intelligence (AI) into national economic processes, measuring a country's capacity to implement AI technologies is a pressing task. Such an assessment should take into account not only technical and infrastructural development but also factors related to workforce skills (the ability and qualifications of employees to interact effectively with AI) and the capacity for scientific research and development.

Data and Methods. The index method is applied in the research, with an adjustment for the event effect. Specifically, the integral index is formed through weighted aggregation of normalized indicators. The event study approach is used to evaluate the impact of significant events (such as regulatory changes, international agreements, or technological breakthroughs) on the dynamics of the country's capacity to implement AI technologies. This combination allowed the methodology not only to reflect the structural level of readiness but also to account for short-term shocks.

Results. Accordingly, the methodology for determining the integral level of a country's capacity to implement AI technologies involves constructing an integral indicator (index) that combines four key components: workforce skills development for Industry 4.0, research and development (R&D) capacity, technological and infrastructure level, and the dynamic effect of external and internal events that influence the innovation market.

The integral level of a country's capacity is proposed to be calculated using the following formula:

$$CAI=\alpha*W+\beta*R+\gamma*T+E$$

where

CAI - the integral level of a country's capacity to implement AI technologies (normalized in the range 0 to 1);

W - the workforce skills development index for Industry 4.0 (including indicators such as the share of employees with digital competencies, STEM education coverage, level of training in data science and AI, etc.) (range 0–1);

R - the research and innovation capacity index (including indicators such as the share of R&D expenditures in GDP, number of publications, patents, AI startups) (range 0–1);

T - the technological and infrastructure level of the national economy (availability of capacities and infrastructure/digitalization, IIoT processes enabling AI technologies) (range 0–1);

E - the event index, determined using the event study methodology, which reflects the impact of external and internal shocks on the integral level of a country's capacity to implement AI technologies (e.g., adoption of a national AI strategy, attraction of venture investments, international partnerships, changes in regulatory frameworks, etc.);

α, β, γ – weight coefficients reflecting the priority of each component for a given country (the sum of the weights equals one to normalize the contribution of structural components).

The event study method is used to quantitatively measure the impact of specific events on the integral level of a country's AI implementation capacity. For example, after the adoption of a data protection law, it is possible to assess whether there has been an increase in AI sector investment or a rise in R&D projects related to AI applications in the national economy. The methodology is based on identifying "abnormal changes" in indicators during the period after an event compared to the expected trend, allowing the identification of events that truly stimulate development versus those that are merely declarative.

Conclusions. The proposed methodology provides a framework for assessing a country's capacity to implement AI technologies. It's useful for estimation as initial country's capacity to implement AI as dynamic influence of events on it.

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