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ARTIFICIAL INTELLIGENCE AS A STRATEGIC INSTRUMENT FOR THE MODERNIZATION OF UKRAINE'S ECONOMY

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The monograph is devoted to a comprehensive analysis of artificial intelligence as an indicator of modernization of the Ukrainian economy. The essential characteristics of AI in a turbulent external environment have been studied. The current state and experience of developed countries of the world regarding the use of AI in order to modernize the economy are analyzed. The expediency of using and developing AI taking into account strategic challenges for the modernization of the economy and ensuring the sustainable development of society is substantiated. Tools for the formation of state policy for the modernization of the economy of Ukraine based on the use of artificial intelligence are proposed.

The monograph is based on the results of research within the framework of the project of basic scientific research, applied scientific research, scientific and technical (experimental) developments on the topic No. 2/25 "Artificial intelligence as a tool to counter disinformation during the war and post-war economic recovery in Ukraine" (state registration number 0125U000996) (01.01.2025–31.12.2027).

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

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МІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ
ЗАПОРІЗЬКИЙ НАЦІОНАЛЬНИЙ УНІВЕРСИТЕТ

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ШІ ЯК ІНСТРУМЕНТ ЗАБЕЗПЕЧЕННЯ МОДЕРНІЗАЦІЇ ЕКОНОМІКИ УКРАЇНИ

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Монографія присвячена всебічному аналізу штучного інтелекту як індикатора модернізації економіки України. Досліджено сутнісні характеристики ШІ в умовах турбулентного зовнішнього середовища. Проаналізовано сучасний стан та досвід розвинених країн світу щодо використання ШІ з метою модернізації економіки. Обґрунтовано доцільність використання та розвитку ШІ з урахуванням стратегічних викликів задля модернізації економіки та забезпечення сталого розвитку суспільства. Запропоновано інструменти формування державної політики модернізації економіки України на основі використання штучного інтелекту.

Монографія базується на результатах досліджень у рамках проєкту фундаментальних наукових досліджень, прикладних наукових досліджень, науково-технічних (експериментальних) розробок на тему № 2/25 «Штучний інтелект як інструмент протидії дезінформації під час війни та повоєнного економічного відновлення в Україні» (державний реєстраційний номер 0125U000996) (01.01.2025–31.12.2027).

Монографія призначена для науковців, викладачів, студентів вищих навчальних закладів, аспірантів, докторантів, практиків, представників державних органів влади та місцевого самоврядування, бізнесу, адміністративного персоналу університету, представників громадянського суспільства, громадськості та всіх зацікавлених осіб.

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CONTENT

ЗМІСТ

PREFACE

The current stage of global economic development is characterized by a transition towards a digital model in which knowledge, innovation, information resources, and next-generation technologies play a key role. One of the most influential technologies of today is artificial intelligence (AI), which is gradually becoming a strategic factor in economic development, labor productivity growth, and the formation of new competitive advantages for countries. For Ukraine, which is undergoing large-scale economic transformations, facing wartime challenges, and requiring post-war recovery, the use of AI is becoming an important prerequisite for the modernization of the economic system.

Global economic development trends indicate that countries actively investing in digital technologies, research and development (R&D), gain significant advantages in terms of productivity, innovation capacity, and competitiveness. Artificial intelligence is becoming one of the key drivers of technological development, as it enables the automation of complex processes, forecasting, analysis of large volumes of data, and support for strategic managerial decision-making. Therefore, creating favorable conditions for AI development is an important component of state policy aimed at economic modernization.

One of the key prerequisites for the use of artificial intelligence in Ukraine is the need for structural transformation of the economy and the transition from a predominantly raw-material-based development model to an innovation-oriented one. Traditional factors of economic growth are gradually losing their dominant role, while knowledge, technologies, and digital competencies are becoming the main resources of competitiveness. The use of AI makes it possible to create new high-tech industries, modernize existing enterprises, and integrate Ukrainian businesses into global technological value chains.

An important prerequisite for the development of artificial intelligence is the formation of digital infrastructure at both the state and business levels. The availability of high-quality telecommunications networks, cloud technologies, e-government systems, open data, and digital platforms creates the foundation for the effective use of AI solutions. In recent years, Ukraine has made significant progress in the digitalization of public services, creating a favorable environment for the further implementation of artificial intelligence technologies.

Another important prerequisite is the development of human capital and the formation of digital competencies. Artificial intelligence requires not only technical specialists but also managers, economists, analysts, and professionals from various fields who are capable of effectively applying new technologies. Therefore, modernization of the education system, development of STEM fields, and training of specialists in data analytics, machine learning, and digital management are essential conditions for building Ukraine's AI ecosystem.

A significant prerequisite for the implementation of AI is the development of scientific potential and innovation activity. The creation of new technological solutions requires the intensification of fundamental and applied research, the development of university-based science, and cooperation between research institutions and businesses. The level of R&D funding determines a country's ability to create its own technologies rather than merely utilize imported solutions.

An important role in the development of artificial intelligence is played by state support for innovative entrepreneurship. The formation of a competitive technology sector requires mechanisms to stimulate startups, venture capital financing, technology parks, and innovation clusters. The experience of leading countries demonstrates that cooperation between the state, science, and business creates the conditions for the rapid diffusion of AI technologies across various sectors of the economy.

Another important prerequisite is the need for the digital transformation of Ukraine's industry. A significant share of manufacturing enterprises

requires technological modernization, improved energy efficiency, and process automation. The use of artificial intelligence in industry enables the implementation of predictive maintenance systems, robotic manufacturing, product quality control, and optimization of production operations. This creates the foundation for the development of Industry 4.0 and enhances the competitiveness of Ukrainian industry.

Under the conditions of war and Ukraine's post-war recovery, the importance of artificial intelligence is significantly increasing. AI technologies can be used to assess the scale of destruction, plan reconstruction processes, manage logistics operations, optimize the use of public resources, and improve the efficiency of managerial decision-making. Thus, AI can become an important tool not only for economic development but also for strengthening national resilience.

Another important prerequisite is the formation of an appropriate legislative environment. Ukraine has already established basic regulatory conditions for the development of the digital economy, particularly through the Concept for the Development of Artificial Intelligence, legislation in the fields of digital technologies, data protection, and innovation activities. However, further development requires the adoption of specific AI-related legislation that will ensure a balance between stimulating innovation and managing potential risks.

An important factor in AI development is Ukraine's international integration and cooperation with leading technology-oriented countries. Participation in international digital initiatives, adaptation of European standards for artificial intelligence regulation, and attraction of foreign investment will contribute to accelerating the technological modernization of the economy. Ukraine's integration into the European digital space creates additional opportunities for the development of AI companies and access to advanced technologies.

Thus, the prerequisites for the use of artificial intelligence for the modernization of Ukraine's economy are comprehensive in nature and encompass technological, economic, institutional, educational, and legal dimensions. The implementation of these prerequisites will

enable the formation of a modern innovation-driven economy, enhance the competitiveness of Ukrainian enterprises, ensure the efficient use of resources, and create the foundation for sustainable national development amid global technological transformations.

The monograph places particular emphasis on the study of theoretical, methodological, and applied aspects of using artificial intelligence as a strategic factor in the modernization of Ukraine's economy. It reveals the role of AI technologies in ensuring the digital transformation of economic processes, improving the efficiency of public administration and business operations, developing innovation potential, shaping a competitive economy, and creating conditions for sustainable post-war recovery of Ukraine. The monograph highlights current trends in the development of artificial intelligence within the global and European economic environment and identifies opportunities for adapting relevant international experience to Ukrainian realities.

The collective monograph contains theoretical generalizations, scientific findings, analytical materials, conclusions, and practical recommendations regarding the formation of an effective state policy for the use of artificial intelligence in the modernization of Ukraine's economy. Particular attention is paid to the issues of digitalization of the economic environment, development of innovation infrastructure, implementation of Industry 4.0 technologies, increasing labor productivity, supporting high-tech production, and ensuring the economic resilience of the state in the face of global challenges.

The materials of the collective monograph will be useful for researchers, academic staff, higher education students, postgraduate students, doctoral candidates, representatives of state authorities and local governments, business representatives, university administrative staff, civil society organizations, experts in the field of digital transformation, and all stakeholders interested in studying the use of artificial intelligence as a tool for economic development and modernization.

The collective monograph was prepared based on the results of research conducted within the framework of fundamental research projects, applied research projects, and scientific and technical (experimental) developments under Project No. 2/25 entitled “Artificial Intelligence as a Tool for Countering Disinformation During the War and Post-War Recovery of Ukraine’s Economy” (state registration number 0125U000996).

CHAPTER 1.
THEORETICAL AND METHODOLOGICAL FOUNDATIONS OF USING AI FOR THE MODERNIZATION OF UKRAINE'S ECONOMY

1.1. ESSENTIAL CHARACTERISTICS OF ARTIFICIAL INTELLIGENCE APPLICATION

The rapid development of digital technologies in the 21st century has led to significant transformations in all spheres of social life, economy, and governance. One of the most important technological innovations of today is artificial intelligence (AI), which is gradually evolving from a promising scientific concept into a practical tool for solving complex problems. The application of AI contributes to improving decision-making efficiency, automating routine processes, and creating new opportunities for the development of organizations and society as a whole.

The use of artificial intelligence has become particularly relevant in the context of global digital transformation of the economy. Enterprises across various industries are actively implementing intelligent systems to analyze large volumes of data, forecast market trends, optimize business processes, and enhance competitiveness. Due to its ability to rapidly process information and identify hidden patterns, AI is becoming an important factor in the innovative development of modern business.

The use of AI in management activities is gaining increasing importance. Modern machine learning algorithms and analytical platforms provide support for managerial decision-making based

on objective data analysis, which helps reduce uncertainty and improve the quality of strategic planning. As a result, organizations gain the ability to respond more effectively to changes in the external environment and adapt to new challenges.

The role of artificial intelligence in the development of the information society is equally significant. AI technologies are being applied in education, healthcare, public administration, finance, transport, and communications. They contribute to the personalization of services, improved access to information, and enhanced interaction between citizens, businesses, and public institutions. This creates the prerequisites for the formation of more efficient and customer-oriented models of governance.

In the context of war and hybrid threats, the relevance of artificial intelligence research is significantly increasing. Modern information attacks, the spread of disinformation, and manipulative content require the application of innovative technological solutions for the detection, analysis, and neutralization of information threats. AI provides opportunities for real-time monitoring of the information environment, automated content analysis, and identification of indicators of false information.

At the same time, the widespread adoption of artificial intelligence generates a number of new challenges and risks related to ethical issues, security, data privacy, and responsibility for decisions made by intelligent systems. This necessitates in-depth scientific understanding of the essential characteristics of AI, the mechanisms of its functioning, and the specific features of its integration into socio-economic systems. Addressing these issues is an important prerequisite for ensuring sustainable and secure development of the digital society.

Thus, the study of the essential characteristics of artificial intelligence application is relevant from both theoretical and practical perspectives. Understanding the nature, capabilities, and limitations of AI makes it possible to develop effective implementation strategies, improve organizational performance, and ensure societal resilience

to contemporary economic, technological, and information challenges. Such research is of particular importance for Ukraine in the context of digital transformation, martial law, and post-war economic recovery.

Artificial intelligence (AI) is one of the most important areas of modern digital technology development, encompassing the creation of computer systems capable of performing tasks that traditionally require human intelligence. These tasks include information analysis, learning from experience, pattern recognition, decision-making, forecasting, and natural language processing. The contemporary development of AI contributes to the transformation of economic, social, and managerial processes, which necessitates a clear understanding of its essence and content.

The scientific literature does not provide a single universally accepted definition of artificial intelligence, as researchers approach this concept from different perspectives: technical, cognitive, economic, and managerial. Some scholars emphasize the ability of systems to imitate human thinking, while others focus on the capability of performing intellectual functions through algorithms and computational models. This diversity of approaches demonstrates the complexity and interdisciplinary nature of the AI concept.

From the perspective of information technologies, artificial intelligence is considered a set of methods, algorithms, and software tools that enable the automated performance of intellectual operations. The foundation of modern AI systems consists of machine learning technologies, neural networks, natural language processing, and computer vision. Their application allows systems to accumulate experience, adapt to new conditions, and improve the accuracy of results without direct programming of each individual action. In economic and management sciences, AI is increasingly defined as a decision-support tool that enables effective analysis of large volumes of data and the generation of forecasts. Due to its ability to identify hidden patterns and automate complex processes, artificial intelligence is becoming an important factor in increasing labor

productivity, enhancing enterprise competitiveness, and promoting innovative economic development.

Thus, artificial intelligence should be considered as a complex of technologies, methods, and software solutions that provide computer systems with the ability to imitate certain human cognitive functions, learn from data, adapt to environmental changes, and make decisions aimed at achieving specific objectives. This interpretation most fully reflects the contemporary meaning of the AI (Table 1.1) concept and its role in the digital transformation of society.

The analysis of scientific approaches demonstrates that the concept of artificial intelligence has evolved from its understanding as a technology for simulating human thinking to its interpretation as a set of intelligent systems capable of independently analyzing data, learning, and making decisions. Despite differences in definitions, most researchers emphasize

Table 1.1 – Approaches to Defining the Essence of Artificial Intelligence (Foreign Authors)

Author	Definition of Artificial Intelligence	Key Focus
John McCarthy (1956)	The science and engineering of creating intelligent machines, especially intelligent computer programs.	Imitation of human intellectual activity.
Stuart Russell and Peter Norvig (2021)	AI is the study and creation of rational agents that receive information from the environment and perform actions to achieve specified goals.	Rational behavior of systems.
Elaine Rich (1983)	AI is a field of science that studies methods for enabling computers to perform tasks that humans currently perform better.	Reproduction of human intellectual abilities.
OECD (2019) [4]	A machine-based system that can make predictions, recommendations, or decisions influencing real or virtual environments.	Practical application and autonomy.
European Commission (2021) [5]	Software that demonstrates intelligent behavior by analyzing the environment and taking actions to achieve specific goals.	Data analysis and decision support.
UNESCO (2021) [6]	Technological systems capable of processing information and performing cognitive functions associated with human intelligence.	Ethical and social dimensions of AI use.

three key characteristics of AI: the ability to learn, adapt to changes in the environment, and perform intellectual functions.

Summarizing the presented approaches, it can be stated that artificial intelligence represents a complex of algorithms, models, and digital technologies that enable the automated performance of human cognitive tasks based on data analysis and machine learning. This understanding most fully corresponds to the current conditions of digital transformation of the economy and society and can serve as a theoretical basis for further research into the application of AI in the field of marketing management and countering disinformation (Table 1.2).

The analysis of the works of foreign and Ukrainian scholars (Tables 1.1–1.2) demonstrates the gradual evolution of the understanding of artificial intelligence from a technology for simulating human thinking to a comprehensive digital system that enables automated data analysis, learning, forecasting, and decision-making support. Ukrainian researchers primarily emphasize the role of AI in the digital

Table 1.2 – Approaches to Defining the Essence of Artificial Intelligence (Ukrainian Authors)

Author	Definition	Key Focus
Voronkova V. [41]	AI is considered a technology of digital transformation of society and a tool for the formation of an intelligent economy	Digitalization and social development
Cherep A. [42]	AI is a set of digital technologies designed to support managerial decision-making and improve the efficiency of enterprise activities	Enterprise management
Zhyvotova T.	AI serves as a tool for data analysis and the formation of competitive advantages for businesses	Enterprise competitiveness
Ponomarenko V.	AI is a complex of information technologies capable of modeling human intellectual activity	Information systems and modeling
Illiashenko S.	AI is considered a component of digital transformation of business processes and innovative development	Innovation and digital business

transformation of the economy, improving management efficiency, and ensuring enterprise competitiveness. This is particularly important in the context of Ukraine's post-war recovery, the development of the digital economy, and the implementation of innovative technologies in the fields of marketing management and countering disinformation.

The analysis of scientific literature demonstrates that the concept of artificial intelligence is one of the most debatable concepts in contemporary science. Despite the significant number of studies, there is no unified approach among scholars to its interpretation. This is explained by the interdisciplinary nature of AI, which is simultaneously the subject of research in computer science, cybernetics, economics, management, sociology, and other fields of knowledge. Accordingly, each researcher focuses on those characteristics that are most relevant to the objectives of their study.

The founder of the artificial intelligence concept, John McCarthy, defined AI as the science and engineering of creating intelligent machines. His approach became the foundation for the development of the classical theory of artificial intelligence, within which the main goal is to reproduce certain elements of human thinking through computer systems. This definition emphasizes the technological nature of AI and the possibility of modeling human intellectual activity.

A significant contribution to the development of artificial intelligence theory was made by Stuart Russell and Peter Norvig, who consider AI through the concept of rational agents. According to their approach, an intelligent system should not only analyze information but also make optimal decisions to achieve defined objectives. This perspective expands the traditional understanding of AI, as the focus shifts from the imitation of human thinking to the efficiency of system behavior and its ability to act autonomously under various environmental conditions.

Elaine Rich interprets artificial intelligence as a field of science concerned with creating computer systems capable of performing tasks that normally require human intelligence. The central element of her

approach is the functional ability of a system to solve complex problems, learn, and adapt to new conditions. This definition reflects a pragmatic approach to understanding AI as a tool for performing intellectual functions regardless of the specific methods of their implementation.

Modern international organizations, including the OECD, UNESCO [5–6], and the European Commission, define artificial intelligence as a system capable of processing information, generating recommendations, predicting outcomes, and influencing physical or digital environments. Unlike classical approaches, these definitions incorporate issues of ethics, security, algorithmic transparency, and responsibility for the results of intelligent systems' activities. This is associated with the rapid expansion of AI applications in the economy, public administration, and social life.

Ukrainian scholars V. Voronkova, A. Cherep [8], S. Illiashenko [11], L. Fedulova [13], and others mainly study artificial intelligence in the context of digital transformation of the economy and management. In their works, AI is considered as a tool for improving the efficiency of business processes, supporting managerial decision-making, automating production, and developing innovative models of enterprise development. Particular attention is paid to the ability of intelligent systems to process large volumes of data and provide competitive advantages to business entities.

The generalization of scientific approaches allows us to conclude that the modern understanding of artificial intelligence goes far beyond its initial interpretation as a technology for simulating human thinking. Most contemporary researchers consider AI as a complex of algorithms, software solutions, and digital technologies that enable systems to learn, adapt to environmental changes, analyze data, and make decisions. Based on the conducted analysis, artificial intelligence can be defined as a set of technologies and information processing methods that enable computer systems to perform human cognitive functions, support decision-making processes, and create new value in various areas of social and economic activity.

Today, artificial intelligence is regarded as one of the key drivers of digital transformation of the economy and society. Its implementation significantly improves organizational efficiency, optimizes resource utilization, and accelerates decision-making processes. As a result, AI is gradually transforming from an auxiliary tool into a strategic resource for the development of enterprises and public institutions.

One of the main advantages of artificial intelligence is its ability to rapidly process large volumes of data. Modern information systems generate enormous amounts of structured and unstructured information that cannot be effectively processed by humans. AI enables real-time data analysis, identification of patterns, and the generation of well-founded analytical conclusions.

An important advantage of AI is the improvement of forecasting accuracy. Machine learning algorithms are capable of identifying hidden relationships between variables, which enables the development of more accurate forecasts in economics, finance, marketing, and management. This reduces the level of uncertainty and contributes to more effective managerial decision-making.

Artificial intelligence also enables the automation of routine processes. Many operations that were previously performed manually can now be fully or partially automated. This makes it possible to reduce time costs, minimize the likelihood of human errors, and increase overall labor productivity within organizations [15].

Another important advantage is the personalization of services and products. AI analyzes user behavior, preferences, and interaction history, which makes it possible to create individualized offers. This is particularly important in marketing, education, e-commerce, and service industries, where customer orientation is a key success factor.

Equally significant is the ability of AI to continuously learn and adapt. Unlike traditional information systems, intelligent algorithms can improve their performance based on new data. This allows systems to remain relevant even under conditions of rapid changes in the external environment [15–20].

In modern conditions, the use of AI to enhance security and ensure timely threat detection is becoming increasingly important. Intelligent systems are capable of analyzing large volumes of data in real time, enabling the rapid identification of suspicious activities in cyberspace, financial operations, and information flows.

One of the key areas is the application of AI in cybersecurity, where machine learning algorithms are used to detect anomalies in network traffic. Such systems can automatically identify unusual behavior of users or software, which often indicates attempts at unauthorized access or cyberattacks [21].

The use of artificial intelligence to combat financial fraud is also highly important. Banking and financial institutions implement intelligent systems that analyze transactions and detect suspicious operations, preventing theft of funds and money laundering.

Another significant area is information security and countering disinformation. AI enables the analysis of large volumes of content on social networks and in the media, identifying fake information, manipulative messages, and coordinated information attacks, which is particularly relevant in the context of hybrid threats.

Artificial intelligence is also applied in security systems for critical infrastructure. It is used to monitor the condition of energy, transport, and utility systems, allowing the prevention of accidents, technical failures, and external interference.

A separate aspect that should be emphasized is the role of AI in risk forecasting. Through the analysis of historical data and the modeling of possible development scenarios, intelligent systems can predict potential threats and contribute to the development of preventive security measures [22].

Thus, the use of artificial intelligence in the security domain enables not only a response to threats but also their prevention, significantly increasing the effectiveness of protecting information, economic, and social systems.

Intelligent systems are used for cyberspace monitoring, anomaly detection, information flow analysis, and countering disinformation.

This makes them an important tool for ensuring information and economic security.

The analysis of the main advantages of artificial intelligence demonstrates that this technology is a key instrument of modern digital transformation (Table 1.3). AI provides significant improvements in information processing efficiency, forecasting accuracy, and the quality of managerial decisions. Due to its ability to automate routine processes and personalize interaction with users, artificial intelligence creates new competitive advantages for businesses and public institutions [19].

The ability of AI to learn and adapt is of particular importance, as it allows systems to remain effective under conditions of dynamic changes in the external environment. At the same time, its application in the security domain enables more efficient threat detection, particularly in cyberspace and the information environment. Therefore, artificial intelligence acts as a multifunctional technology that simultaneously increases productivity, reduces costs, improves decision quality, and provides a new level of security.

Table 1.3 – Main Advantages of Artificial Intelligence [18–21]

No.	Advantage	Essence	Application Areas
1	Rapid data processing	Real-time analysis of large volumes of information	Business analytics, finance, public administration
2	High forecasting accuracy	Identification of hidden patterns and trends	Economics, marketing, logistics
3	Process automation	Replacement of manual operations with algorithms	Manufacturing, office processes
4	Personalization	Individual recommendations for users	Marketing, e-commerce, education
5	Adaptability	Self-learning of systems based on new data	All digital systems
6	Increased efficiency	Reduction of time and resource costs	Enterprises, public institutions
7	Enhanced security	Detection of threats and anomalies	Cybersecurity, information security

This determines its strategic importance for the development of Ukraine's economy, the digital transformation of businesses, and strengthening society's resilience to contemporary challenges.

Despite its significant advantages, the implementation of artificial intelligence is accompanied by a number of substantial obstacles that limit its large-scale adoption in the economy and management. These barriers are technological, economic, organizational, and social in nature and require comprehensive solutions at both the state and business levels.

One of the key challenges is the high cost of implementing AI technologies. The development, training, and maintenance of intelligent systems require significant financial investments in software, hardware, and qualified specialists. For many small and medium-sized enterprises, such expenditures remain excessively high [28–29].

An important obstacle is the shortage of qualified professionals. Effective use of artificial intelligence requires specialists in data science, machine learning, data analytics, and cybersecurity. Both Ukraine and the global community face a significant gap between the demand for and supply of such specialists, which slows down the process of digital transformation.

A significant barrier is the issue of data quality and accessibility. AI algorithms require large volumes of structured, reliable, and up-to-date information for training. Poor data quality, fragmentation, or lack of standardization negatively affect the accuracy of results and the efficiency of intelligent systems.

Equally important are cybersecurity risks and the protection of confidential information. The use of AI involves the processing of large volumes of personal and corporate data, which creates risks of data leakage, unauthorized access, or malicious use. This requires the implementation of enhanced information security measures.

Another significant challenge concerns the ethical and legal aspects of artificial intelligence use. The absence of clear international standards regarding responsibility for decisions made by algorithms creates legal uncertainty. In addition, issues related to discrimination, algorithmic bias, and transparency of AI system operations arise [30].

The use of artificial intelligence creates significant opportunities for improving enterprise performance; however, it also generates a number of ethical and legal challenges. Key ethical principles include transparency, fairness, non-discrimination, respect for privacy, and ensuring human oversight of automated decision-making processes. Compliance with these principles contributes to building user trust and minimizing the risks of negative technological impacts on society.

Legal regulation of artificial intelligence use is actively developing at the international level. In the European Union, the regulatory framework is based primarily on the AI Act, which introduces a risk-based approach to the application of artificial intelligence

Table 1.4 – Ethical and Legal Aspects of Artificial Intelligence Use

Aspect	Ethical Dimension	Legal Dimension
Algorithm transparency	Ensuring the comprehensibility of AI operating principles and the possibility of explaining decisions made by intelligent systems	Requirements for algorithm transparency and explainability in accordance with the EU AI Act and other regulatory frameworks
Personal data protection	Respect for users' privacy and minimization of data collection	Compliance with GDPR requirements and personal data protection legislation
Non-discrimination	Elimination of algorithmic bias and ensuring equal opportunities	Prohibition of discrimination and control over the use of data that may lead to unequal treatment
Responsibility	Defining the moral responsibility of AI developers and users	Establishing legal liability for harm caused by decisions or actions of AI systems
Intellectual property	Ethical use of copyrighted materials for model training	Compliance with copyright law, licensing conditions, and rights to results created with AI involvement
Security	Prevention of misuse, manipulation, and dissemination of disinformation	Regulation of risks, cybersecurity issues, and AI use in accordance with international standards

systems and establishes requirements concerning security, transparency, risk management, and accountability.

The norms related to personal data protection, copyright, and cybersecurity are also of significant importance, as they define the legal boundaries for the use of intelligent systems. For international business enterprises, the integration of ethical principles and legal requirements into artificial intelligence implementation processes is an important condition for ensuring competitiveness and sustainable development. Combining technological innovations with proper corporate governance, internal policies for responsible AI use, and compliance with international regulatory requirements makes it possible to reduce

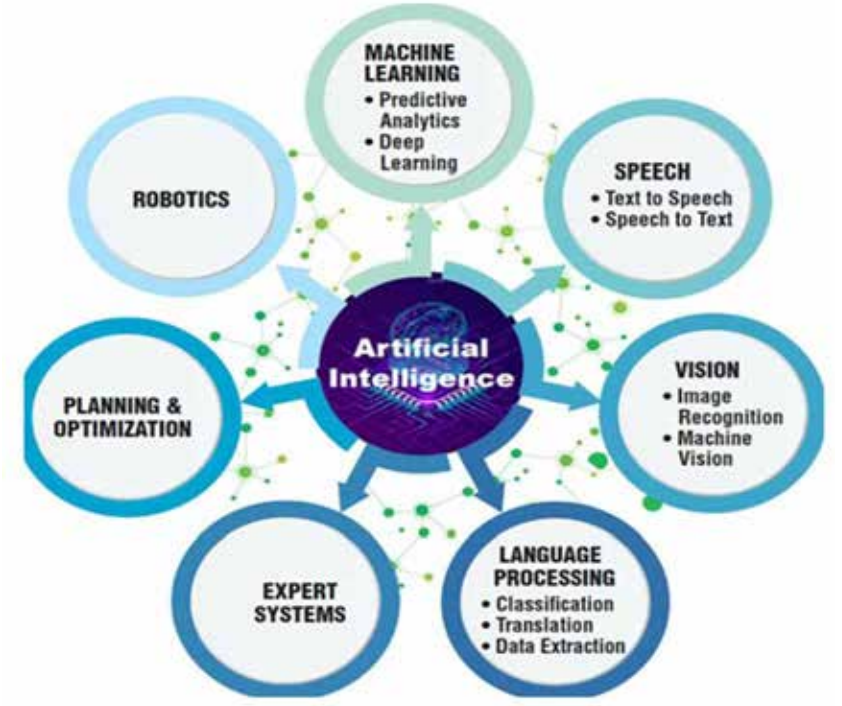

Figure 1.1 – AI

legal risks, increase the trust of partners and consumers, and ensure the responsible application of modern digital technologies.

Another obstacle is the low level of digital readiness of some organizations. Many enterprises lack the necessary infrastructure, digitalization strategies, or management culture focused on innovation implementation. This slows down the integration of AI into business processes.

Thus, the use of artificial intelligence is accompanied by a complex set of interrelated barriers that hinder its full-scale implementation in the economy and management. The most critical challenges include financial constraints, a shortage of qualified specialists, data quality issues, and cybersecurity risks.

At the same time, ethical, legal, and organizational barriers play a significant role and require systematic regulation and adaptation of management approaches. Overcoming these challenges is possible only through comprehensive digital transformation, development

Table 1.5 – Main Barriers to the Use of Artificial Intelligence

No.	Barrier	Essence of the Problem	Consequences
1	High implementation costs	Significant expenses for technologies, equipment, and specialists	Limited adoption among SMEs
2	Shortage of qualified personnel	Lack of specialists in data science and AI	Slowdown of digitalization processes
3	Data-related problems	Low quality and fragmentation of information	Reduced accuracy of AI models
4	Cybersecurity risks	Threats of data leakage and unauthorized access	Violation of information security
5	Ethical and legal issues	Lack of clear AI regulation	Legal uncertainty
6	Insufficient digital infrastructure	Lack of technological foundation	Slow implementation of innovations
7	Organizational unpreparedness	Resistance to change and lack of implementation strategies	Inefficient use of AI

of educational potential, and the formation of modern innovation infrastructure. Therefore, despite existing difficulties, artificial intelligence remains a strategically important technology, and eliminating barriers to its implementation is a necessary condition for increasing economic competitiveness and improving management efficiency.

Ethical, legal, and organizational barriers also significantly influence the pace of artificial intelligence adoption, requiring systematic regulation and the adaptation of managerial approaches. Addressing these challenges is possible only through comprehensive digital transformation, strengthening educational capacity, and developing modern innovation infrastructure. These aspects determine the quality and speed of AI integration into socio-economic systems.

One of the key ethical issues is the risk of algorithmic bias. Artificial intelligence learns from historical data, which may contain hidden discriminatory patterns of behavior. As a result, AI systems can reproduce or even reinforce social inequalities in the decision-making process.

A significant ethical challenge is also the problem of algorithm transparency. Many modern AI models, particularly deep neural networks, operate as a "black box," making it difficult to understand the logic behind their decisions. This creates challenges for monitoring, auditing, and building trust in the results generated by intelligent systems.

Legal barriers are associated with the lack of a clear regulatory framework governing the use of artificial intelligence. The issue of responsibility for erroneous or harmful decisions made by algorithms remains unresolved. This creates risks for businesses, public institutions, and users.

Legal barriers to the use of artificial intelligence are primarily related to the insufficient development of a comprehensive regulatory framework that would regulate the design, implementation, and application of AI systems.

Despite the active development of international legislation, many countries still lack clear regulations regarding legal liability for decisions

Figure 1.2 – Conceptual Framework of Legal Challenges in Artificial Intelligence Governance

made with the use of artificial intelligence, the protection of copyright for content created or used by AI, as well as ensuring algorithmic transparency and personal data protection. This creates legal uncertainty for businesses and complicates the widespread adoption of intelligent technologies across various fields of activity.

Organizational barriers (Table 1.6) are manifested in the low level of business readiness for the implementation of innovations. Companies often lack digital transformation strategies, an appropriate management culture, or internal competencies required to work with AI technologies. This slows down the integration of AI solutions into business processes.

Infrastructure constraints also significantly affect the development of artificial intelligence. Insufficient digital infrastructure, limited access to high-performance computing resources, and high-quality data centers reduce the possibilities for large-scale implementation of AI solutions.

Table 1.6 – Main Legal Barriers to the Use of Artificial Intelligence

Legal Barrier	Essence of the Problem	Possible Consequences
Lack of comprehensive legislation	Insufficiently clear legal and regulatory framework governing the development, implementation, and use of AI systems	Legal uncertainty for developers, businesses, and users
Uncertainty of legal liability	Lack of clear rules regarding responsibility for errors or damage caused by AI-based decisions	Difficulties in dispute resolution and compensation for losses
Personal data protection	Risks of unlawful collection, processing, and use of personal information	Violation of privacy rights and imposition of penalties
Intellectual property	Lack of regulation regarding rights to content created using AI and the use of copyrighted materials for model training	Copyright disputes and violations of licensing conditions
Algorithm transparency	Absence of requirements for explainability and openness of AI models' operating principles	Reduced user trust and difficulties in auditing AI-based decisions
Lack of unified international standards	Differences in legal regulations governing AI among countries	Complications in international cooperation and scaling of digital businesses
Regulation of high-risk systems	Insufficiently detailed requirements for the use of AI in critical sectors (healthcare, finance, transport, etc.)	Increased legal and reputational risks for organizations

Economic barriers remain among the most significant challenges. The high cost of developing, implementing, and maintaining artificial intelligence systems limits their adoption, especially among small and medium-sized enterprises. This creates a technological gap between large corporations and other market participants.

Cybersecurity threats also represent a serious challenge. The use of AI involves the processing of large volumes of personal and corporate data, which increases the risks of data leakage or malicious

use. This requires continuous improvement of information protection systems.

Social barriers should also be highlighted, particularly concerns about job losses resulting from automation. Insufficient understanding of the role of AI in society contributes to distrust of technologies and slows down their adoption. Addressing these challenges requires active information and educational policies.

The analysis demonstrates that the barriers to artificial intelligence adoption are complex in nature and encompass ethical, legal, economic, organizational, infrastructural, and social dimensions. The most critical challenges remain the lack of algorithmic transparency, insufficient regulatory frameworks, and the limited digital readiness of organizations.

At the same time, overcoming these barriers is possible only through a systematic approach that involves the development of digital infrastructure, improvement of legislation, enhancement of digital literacy among the population, and formation of an innovation-oriented management culture. Therefore, the effective use of artificial intelligence depends not only on technological advancement but also on society's ability to adapt to the new conditions of the digital economy and ensure a balanced combination of innovation, security, and ethical standards.

Adaptation of artificial intelligence to the conditions of the modern economy is a complex and multi-level process that involves the integration of intelligent technologies into business processes, management systems, and market mechanisms. This process is accompanied by the transformation of traditional economic models under the influence of digitalization and automation (Table 1.7).

The first stage of adaptation is the digitalization of the economic environment, which involves the transformation of data and processes into a digital format. At this level, the information foundation for the further application of artificial intelligence algorithms is created, including Big Data, cloud technologies, and information collection systems. Digitalization of the economic environment is one

Table 1.7 – Main Barriers to the Use of Artificial IntelligenceTable

No.	Barrier	Essence of the Problem	Consequences
1	Ethical bias	Algorithms reproduce discriminatory data patterns	Unfair decisions
2	Lack of AI transparency	"Black box" nature of algorithms	Lack of trust
3	Legal uncertainty	Lack of regulation regarding responsibility and liability	Legal risks
4	Organizational unpreparedness	Lack of strategies and competencies	Slow implementation
5	Infrastructure constraints	Insufficient level of digital infrastructure	Limited scalability

of the key factors of modern socio-economic development, involving the transformation of information, business processes, managerial functions, and economic interactions into a digital format through the use of modern information and communication technologies. Its main goal is to create a unified digital space in which data becomes a primary economic resource, while rapid data processing ensures more effective managerial decision-making. Through digitalization, enterprises gain the opportunity to automate production and administrative processes, increase labor productivity, reduce operational costs, and ensure higher quality of products and services.

In the modern digital economy, data is becoming a strategic asset of an enterprise. The use of digital platforms, cloud services, the Internet of Things (IoT), Big Data technologies, blockchain, and artificial intelligence enables the integration of all business processes into a unified information system. This allows enterprises to monitor their activities in real time, respond quickly to changes in the external environment, forecast demand, optimize logistics processes, and improve resource management efficiency. Digitalization creates the informational foundation for the functioning of modern artificial intelligence algorithms, as their effectiveness directly depends on the availability of large volumes of high-quality digital data.

An important direction of digital transformation is the automation of business processes. Enterprises are gradually moving from traditional document management to electronic workflows, implementing ERP, CRM, SCM, and BPM systems that provide comprehensive management of resources, customer relationships, supply chains, and business processes. Automation of routine operations reduces the time required to perform production and administrative tasks, decreases the number of human errors, and improves the quality of managerial decisions. At the same time, digitalization contributes to the formation of digital ecosystems in which all participants of economic activity interact through shared information platforms.

Digitalization is of particular importance in the context of international business. The globalization of economic processes requires rapid information exchange between countries, partners, and customers. Digital technologies ensure the integration of international supply chains, remote management of production processes, e-commerce, digital financial transactions, and international electronic document management. This significantly reduces time and financial costs, increases the transparency of business operations, and promotes the development of international cooperation.

An integral component of the digital economy is the use of Big Data technologies. Every day, enterprises accumulate vast amounts of information related to production, financial operations, consumer behavior, marketing campaigns, logistics, and equipment performance. These data become the foundation for the functioning of artificial intelligence systems capable of identifying hidden patterns, forecasting future trends, making automated decisions, and optimizing business processes. The higher the level of enterprise digitalization, the greater the effectiveness of machine learning algorithms and analytical models.

Along with numerous advantages, digitalization also generates new challenges. The main ones include ensuring cybersecurity, protecting personal data, maintaining enterprise information security,

the need to modernize digital infrastructure, the shortage of highly qualified IT specialists, and the uneven level of digital development across different regions and sectors of the economy. Issues related to ensuring the reliability of digital systems, the continuity of information platform operations, and protection against cyberattacks are becoming increasingly important, especially in the context of military threats and global digital interaction.

For Ukraine, digitalization of the economic environment is one of the priority directions for post-war recovery and integration into the European digital space. The development of e-governance, digital public services, e-commerce, digital infrastructure, and the implementation of artificial intelligence technologies correspond to the strategic goals of the country's digital transformation. Further development of the digital economy will contribute to increasing the competitiveness of Ukrainian enterprises, expanding their presence in international markets, accelerating innovation-driven development, and forming a modern model of economic growth based on knowledge, data, and digital technologies.

Therefore, digitalization of the economic environment is a fundamental prerequisite for the development of artificial intelligence and the digital economy as a whole. The transformation of data and business processes into a digital format provides the informational foundation for the use of intelligent algorithms, promotes management automation, increases enterprise efficiency, and enables the creation of new competitive advantages. The comprehensive combination of digitalization and artificial intelligence technologies will determine the further development of international business, the innovation-driven economy, and the digital society.

The second important stage is the integration of AI into enterprise business processes. This includes the automation of operations, implementation of analytical systems, chatbots, recommendation algorithms, and forecasting tools. At this level, AI begins to directly influence management efficiency.

One of the most important stages of digital transformation of modern enterprises is the integration of artificial intelligence (AI) technologies into business processes. Unlike traditional automation, which involves performing predefined operations according to established algorithms, artificial intelligence systems are capable of analyzing large volumes of data, learning from accumulated experience, predicting outcomes, and supporting managerial decision-making. This enables enterprises not only to improve the efficiency of individual functions but also to fundamentally transform their business models, ensuring flexibility, adaptability, and rapid response to changes in the external environment.

One of the most widespread areas of artificial intelligence application is the automation of operational processes. AI algorithms perform routine administrative tasks, automatically process documents, recognize textual and visual data, verify contracts, invoices, and financial documents, monitor production operations, and optimize internal document management. The use of Robotic Process Automation (RPA) technologies in combination with artificial intelligence significantly reduces the time required for repetitive operations, minimizes human errors, and allows employees to focus on strategic tasks.

An important component of AI integration is the implementation of intelligent analytical systems. Through the use of machine learning technologies, enterprises can analyze large volumes of structured and unstructured data, identify hidden patterns, evaluate the efficiency of business processes, and forecast possible development scenarios. Intelligent business analytics provides managers with reliable information for making managerial decisions, assessing financial risks, analyzing consumer behavior, planning production, and developing long-term enterprise development strategies.

Intelligent chatbots and virtual assistants have become widely adopted, providing automated interaction between enterprises and their customers, partners, and employees. Using Natural Language

Processing (NLP) technologies, they can respond to user inquiries, provide consultations, process orders, assist in selecting products and services, deliver technical support, and accompany customers throughout all stages of interaction with the company. The use of chatbots enables continuous 24/7 customer service, reduces customer support costs, and increases customer satisfaction levels.

Another important area is the application of recommendation algorithms. Based on the analysis of purchase history, user behavior, demographic characteristics, and individual preferences, artificial intelligence systems generate personalized offers of products and services. Such algorithms are widely used in e-commerce, digital marketing, financial services, online education, and media platforms. Personalization helps increase sales conversion rates, improve average purchase value, strengthen customer loyalty, and create long-term competitive advantages for enterprises.

Forecasting tools based on machine learning algorithms are of particular value for modern businesses. They enable enterprises to predict product demand, changes in market conditions, financial performance, insolvency risks, potential disruptions in supply chains, equipment failures, and other critically important events. The use of predictive analytics contributes to inventory optimization, more efficient resource utilization, timely risk management, and increased enterprise resilience in an unstable economic environment.

The integration of artificial intelligence covers virtually all functional areas of enterprise activity. In manufacturing, AI ensures intelligent management of technological processes and predictive maintenance of equipment. In logistics, it optimizes transportation routes, warehouse operations, and inventory management. In marketing, algorithms analyze consumer behavior, forecast the effectiveness of advertising campaigns, and personalize communication with customers. In the financial sector, artificial intelligence is used for credit risk assessment, fraud detection, budget planning, and automation of financial analysis. In human resource management,

AI systems assist in recruitment, employee competency analysis, workforce demand forecasting, and performance evaluation.

At the same time, successful artificial intelligence integration requires a comprehensive approach. Enterprises need to ensure high-quality digital infrastructure, integrate information systems, accumulate reliable data, develop employees' digital competencies, comply with cybersecurity requirements, protect personal data, and adhere to ethical principles of AI use. Important conditions also include adaptation of organizational structures, support for an innovation-oriented corporate culture, and development of digital transformation strategies.

Thus, the integration of artificial intelligence into business processes is one of the key factors in improving the efficiency of modern enterprises. Automation of operations, the use of analytical systems, chatbots, recommendation algorithms, and forecasting tools contribute to productivity growth, improvement of managerial decision-making quality, enhancement of customer service, and strengthening of enterprises' competitive positions in the digital economy.

The third stage involves training and adapting algorithms to the specifics of the economic environment. Artificial intelligence uses machine learning to analyze historical data, identify patterns, and adjust its models according to changes in market conditions and consumer behavior.

The fourth stage is the optimization of decision-making processes. At this level, AI is used as a tool for supporting managerial decisions, enabling managers to obtain more accurate forecasts, assess risks, and develop effective enterprise development strategies.

The fifth stage involves scaling the use of artificial intelligence across various sectors of the economy. After successful implementation in individual companies, technologies are expanded at the sectoral and national levels, covering finance, logistics, industry, education, and public administration.

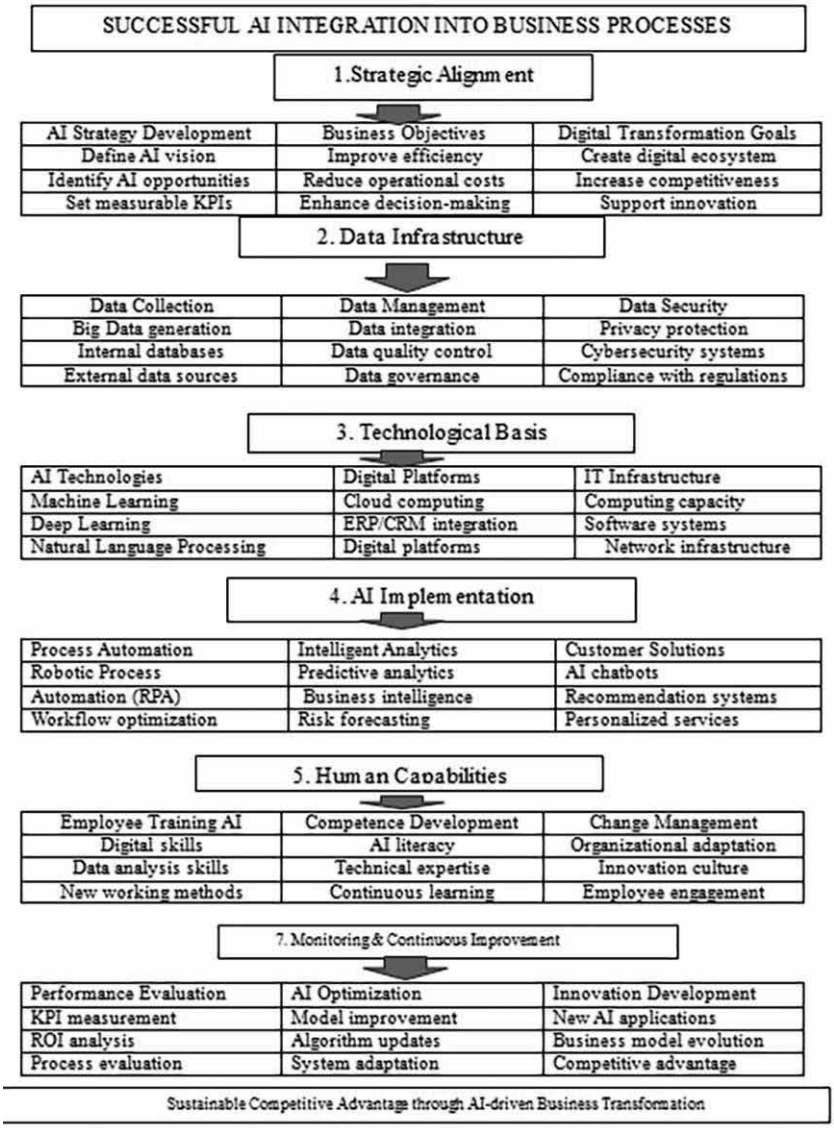

Figure 1.3 – Comprehensive Framework for Successful Artificial Intelligence Integration into Business Processes

The sixth stage is the formation of new AI-based business models. This includes the emergence of platform-based economies, digital ecosystems, automated services, and personalized products based on data analysis and user behavior patterns.

The seventh stage is regulatory and ethical adaptation, which involves the development of legal frameworks, security standards, and ethical principles for the use of artificial intelligence. This is necessary to minimize risks and ensure the sustainable development of technologies.

The eighth stage is the achievement of digital economy maturity, when artificial intelligence becomes an integral part of all economic processes, ensuring their automation, flexibility, and high efficiency.

Therefore, the process of adapting artificial intelligence to economic conditions is a gradual and comprehensive phenomenon that encompasses technological, managerial, and institutional changes. It begins with the digitalization of data and culminates in the formation of a mature digital economy in which AI becomes a key element of all economic processes.

Table 1.8 – Stages of Artificial Intelligence Adaptation to Economic Conditions

No.	Stage	Content	Result
1	Digitalization of the economy	Transformation of data into digital form	Formation of an information base
2	AI integration	Implementation of AI into business processes	Automation of operations
3	Algorithm training	Machine learning based on economic data	Increased model accuracy
4	Decision-making support	Use of AI in management processes	Reduction of risks
5	Scaling	Expansion of technologies across sectors	Systematic implementation
6	New business models	Platforms and digital ecosystems	Innovation-driven economy
7	Regulation	Legal and ethical standards	Safe use
8	Economic maturity	Full integration of AI	High efficiency of systems

It is important to emphasize that the effectiveness of adaptation depends not only on the level of technological development but also on the readiness of businesses, governments, and society to embrace changes. Successful integration of artificial intelligence ensures increased productivity, competitiveness, and resilience of economic systems in the long term.

Equally important for the development and practical application of artificial intelligence are cybersecurity risks and the protection of confidential information. Since AI systems operate with large volumes of data, including personal, financial, and corporate information, the likelihood of unauthorized use or data breaches increases. This creates serious threats both for individual users and for organizations and public institutions.

One of the key challenges is cyberattacks targeting artificial intelligence systems. Attackers can carry out attacks on machine learning models by modifying input data or algorithms in order to obtain distorted results. Such attacks as data poisoning or adversarial attacks can significantly reduce the reliability and accuracy of intelligent systems.

An important threat is the leakage of users' personal data. AI systems are often integrated into online services, social networks, financial platforms, and e-commerce, which involves the processing of sensitive information. In the case of insufficient protection, this data may become subject to theft or unauthorized sale.

Another significant risk is the lack of transparency in data usage. Users do not always understand what specific data is collected, how it is processed, and for what purposes it is used by AI algorithms. This reduces trust in technologies and creates ethical and legal controversies.

The risk of unauthorized access to artificial intelligence systems should also be highlighted. In the event of a breach of corporate or government platforms, attackers may gain access to critically important information, which can result in financial losses or disruption of management systems.

Another problem is the insufficient level of cybersecurity in many organizations. The implementation of AI technologies often advances faster than the development of information security systems, creating

additional vulnerabilities. This is particularly characteristic of small and medium-sized enterprises, which often lack sufficient resources for comprehensive data protection.

Risks associated with the manipulation of artificial intelligence outputs should be highlighted separately. Attacks on algorithms can lead to distortion of analytical data, which affects managerial decisions, financial forecasts, and strategic planning. This may result in serious economic consequences.

The risks of manipulating artificial intelligence results require particular attention. Attacks on algorithms or intentional distortion of input data can lead to inaccurate outcomes of analytical information processing. In such cases, the system generates incorrect conclusions, which directly affects the quality of managerial decisions.

Such threats are especially dangerous when AI is used in financial analytics, market forecasting, cybersecurity, and strategic planning. Distorted data can lead to inaccurate forecasts, inefficient resource allocation, or the adoption of ineffective management decisions.

The most common types of attacks include data poisoning, when an attacker intentionally introduces incorrect information into the training dataset, and adversarial attacks, which modify input parameters in such a way that the model produces false results. These attacks reduce the reliability and stability of artificial intelligence systems.

Another important aspect is hidden manipulation through algorithmic bias or the use of biased data. In such cases, AI may unintentionally reproduce certain distorted patterns, which negatively affects the objectivity of analytical results.

Therefore, the risks of manipulating artificial intelligence (Table 1.9) outputs represent a serious threat to decision-making systems. Their mitigation requires the implementation of multi-level data control, verification of the quality of training datasets, regular model audits, and the use of advanced cybersecurity methods.

The risks of manipulating artificial intelligence outputs represent one of the most serious challenges facing modern intelligent systems.

Table 1.9 – Risks of Manipulating Artificial Intelligence Outputs

No.	Type of risk	Essence	Possible Consequences
1	Data poisoning	Intentional introduction of distorted data into training datasets	Incorrect models and forecasts
2	Adversarial attacks	Deliberate modification of input data to deceive the model	False analytical results
3	Manipulation of training data	Use of biased or incomplete data	Distorted analytics
4	Algorithmic bias	Built-in or unintended biases within the model	Unfair decisions
5	Input data substitution	Replacement or falsification of information	Distortion of results
6	Model hacking	Unauthorized interference with algorithms	Loss of control over the system
7	Forecast manipulation	Intentional influence on analytical outcomes	Incorrect managerial decisions

Distortion of input data or targeted attacks on algorithms can significantly reduce the accuracy of analytical models and lead to incorrect managerial decisions.

The most critical threats are data poisoning and adversarial attacks, as they directly affect the training process and operation of AI models. This creates risks for financial stability, cybersecurity, and strategic planning.

Therefore, minimizing such threats requires a comprehensive approach that includes data quality control, regular algorithm audits, implementation of cybersecurity systems, and continuous monitoring of artificial intelligence performance.

In summary, cybersecurity and the protection of confidential information are critically important conditions for the safe use of artificial intelligence. Effective solutions to these challenges require the implementation of modern encryption technologies, multi-level data protection mechanisms, regulatory frameworks, and continuous monitoring of cyber threats.

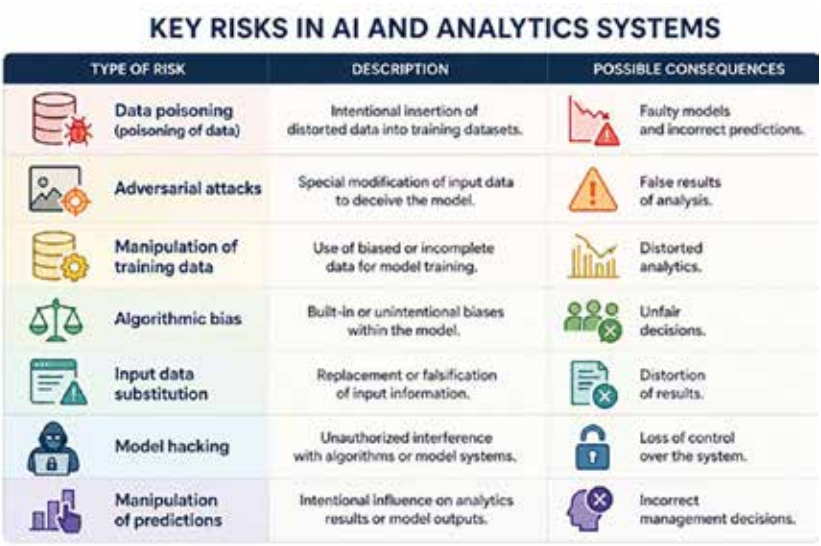

Figure 1.4 – Risks of Manipulating Artificial Intelligence Outputs

Artificial intelligence (AI) is one of the key technologies of the modern digital economy, enabling the automation of intelligent processes, processing of large volumes of data, and support for decision-making. Its essence lies in the ability of computer systems to perform functions traditionally associated with human intelligence, including analysis, forecasting, learning, and adaptation.

Under current conditions, AI is considered a complex of algorithms, models, and technological solutions that allow systems to learn from data and improve results without direct programming of every individual action. This creates a new level of interaction between humans, technologies, and economic processes.

An important characteristic of AI application is its ability to process large volumes of information quickly and efficiently. This enables the identification of hidden patterns, forecasting, and the generation of analytical insights that improve the effectiveness of managerial decisions.

Another significant feature is the automation of routine processes, which reduces time costs, minimizes human errors, and increases labor productivity. This is particularly important for businesses, financial institutions, and public administration.

AI also enables the personalization of services and products through the analysis of user behavior and individual needs. This contributes to the development of marketing, e-commerce, and service models focused on individual consumers.

An important advantage is the ability of AI systems to self-learn and adapt, allowing them to operate effectively in a rapidly changing external environment. As a result, AI continuously improves its accuracy and functionality.

The role of AI in the field of security should also be emphasized, as it is used for detecting cyber threats, analyzing anomalies, countering disinformation, and protecting information systems. This makes AI an important component of modern cybersecurity.

At the same time, the use of artificial intelligence is accompanied by a number of risks, particularly in the areas of cybersecurity, data protection, and manipulation of algorithmic outcomes. This requires strengthening control mechanisms, ethical regulation, and legal frameworks.

Additional barriers include the high cost of implementation, the shortage of qualified specialists, insufficient digital infrastructure, and organizational unpreparedness of enterprises. All these factors affect the speed and scale of AI adoption.

Thus, artificial intelligence is a multifunctional technology that combines significant advantages with potential risks. Its effective use depends on the level of digital transformation of the economy, the quality of managerial decisions, and society's ability to adapt to new technological conditions.

1.2. ECONOMIC MODERNIZATION AS AN INDICATOR OF ENSURING SUSTAINABLE DEVELOPMENT

Economic modernization under current conditions is one of the key factors in ensuring sustainable development of the state and strengthening its national security. It involves the renewal of production systems, the introduction of innovations, the digitalization of economic processes, and the improvement of resource management efficiency. In the context of global transformations, technological changes, increasing international competition, and the emergence of new economic risks, the ability of a country to adapt to contemporary challenges determines its economic resilience and development prospects. Modernization processes involve not only the renewal of production capacities but also the formation of a new quality of the economic system based on innovation, digital technologies, effective governance, and rational resource utilization.

In the modern interpretation, economic modernization is a comprehensive process of structural transformations aimed at increasing the competitiveness of the state, developing productive forces, and creating conditions for long-term economic growth. It encompasses technological modernization of enterprises, development of innovation infrastructure, digitalization of business processes, improvement of public administration systems, and formation of a favorable environment for entrepreneurial activity. Such an approach enables a transition from an extensive development model, primarily based on the exploitation of natural and labor resources, to an intensive model in which knowledge, innovation, and human capital become the main sources of economic growth.

One of the most important directions of economic modernization is innovative development, which ensures the creation of new products, technologies, and managerial solutions. In the modern economy, innovations determine the ability of a state to compete in international markets and ensure technological independence. The development of science, support for research and development, and

stimulation of innovation activities of enterprises create the foundation for the formation of a high-tech economy. For Ukraine, this direction is of particular importance in the context of post-war recovery, as it makes it possible not only to restore destroyed production capacities but also to create a modern economic model oriented toward European development standards.

An important component of modernization is the digital transformation of the economy, which changes traditional approaches to the organization of production, management, and interaction between economic actors. The use of digital platforms, Big Data, artificial intelligence, automated management systems, and cloud technologies contributes to increased productivity, cost reduction, and faster managerial decision-making. Digitalization also enhances the transparency of economic processes, helps reduce corruption risks, and creates new opportunities for the development of small and medium-sized enterprises.

Economic modernization is directly linked to ensuring the economic security of the state, since a modern competitive economy is the foundation of national independence and resilience. Dependence on outdated technologies, imports of critical resources, or specific external markets creates additional threats to national security. In contrast, the development of domestic production, technological competencies, innovation capacity, and strategic industries enables the reduction of economic vulnerability and strengthens the state's ability to withstand external challenges.

Economic modernization becomes particularly important in the context of crisis situations, including military conflicts and large-scale economic disruptions. Ukraine's experience demonstrates that the resilience of an economic system depends on its level of adaptability, technological advancement, and ability to rapidly restructure production and management processes. The use of digital technologies, development of the defense-industrial complex, support for critical infrastructure, and implementation of innovative solutions are becoming essential elements in ensuring national resilience.

An important prerequisite for successful modernization is the development of human capital, since professional knowledge, competencies, and the ability to learn determine the effectiveness of using new technologies. The modern economy requires specialists with digital skills, the ability to work with innovative systems, and the capacity to make strategic decisions under conditions of uncertainty. Therefore, modernization must be accompanied by the reform of the education system, support for scientific research, and the creation of opportunities for professional development of the population.

In addition to technological and human resource aspects, economic modernization involves improving management systems at all levels. Effective public administration, strategic planning, transparent regulatory mechanisms, and support for entrepreneurship are necessary conditions for successful reforms. The modern model of economic development requires a transition from administrative governance to partnership-based interaction between the state, business, and society, which allows more effective use of the country's existing potential.

For Ukraine, economic modernization is also an important instrument of European integration and convergence with the standards of developed economies. Harmonization of economic processes with European Union regulations, development of a competitive environment, implementation of sustainable development principles, and advancement of the digital economy create conditions for Ukraine's more active participation in global economic processes. At the same time, modernization contributes to the formation of a more resilient economic system capable of ensuring social development, improving public welfare, and promoting efficient resource utilization.

Therefore, economic modernization is a strategic direction of state development that combines innovative, technological, managerial, and social transformations. It serves not only as a factor of economic growth but also as an important element of national security, as it strengthens the country's ability to withstand internal and external threats. Under current conditions, a modernized, digital, and innovation-driven economy

creates the foundation for sustainable development, increasing state competitiveness, and successful integration into the global economic space.

The relevance of this issue is determined by global transformations of the world economy, characterized by a transition toward an innovation-based and digital development model. Countries that fail to implement timely modernization lose competitiveness and economic resilience.

Modernization acquires particular significance in the context of increasing geopolitical instability and military threats. For Ukraine, this issue is critically important, as economic stability directly affects the country's defense capabilities and social resilience.

An important aspect is that economic modernization serves as an indicator of sustainable development. It reflects the ability of a country to maintain a balance between economic growth, social progress, and environmental security.

Contemporary approaches to modernization involve the active implementation of digital technologies, including artificial intelligence, Big Data, and automated management systems. These technologies enable higher production efficiency and improve the quality of managerial decision-making.

Equally important is the role of modernization in the formation of an innovation-driven economy based on knowledge and technologies. Such a development model ensures the long-term competitiveness of the state in international markets.

Economic modernization also directly affects the level of national security, as economic weakness is one of the key factors contributing to a state's vulnerability to external threats. A strong economy ensures financial and resource resilience, enables the state to respond effectively to crisis situations, maintain defense capabilities, ensure the functioning of critical infrastructure, and implement strategic development programs. Therefore, economic modernization is considered not only as a tool

for increasing competitiveness but also as an important component of the national security system.

Under contemporary conditions, the level of economic security of a state is largely determined by its ability to ensure internal stability, technological independence, and resilience to external influences. An outdated economic structure, a low level of innovation, and dependence on imports of critical goods and technologies can create significant risks for a country. In contrast, a modernized economic system based on innovation, digital technologies, and efficient resource utilization creates the foundation for reducing external dependencies and increasing national autonomy.

An important aspect of the relationship between economic modernization and national security is the development of strategic production sectors. Technologically advanced industry, a modern agricultural sector, energy independence, and developed transport infrastructure provide the state with the ability to independently meet critical needs of the population and the economy. In this context, modernization of production capacities contributes not only to economic growth but also to the formation of resilience against external economic and political risks.

A particularly important role in strengthening national security is played by the technological modernization of the economy. The use of modern technologies, automation, artificial intelligence, digital management systems, and innovative production models enables the improvement of economic process efficiency and reduces dependence on foreign technological solutions. For the state, this means strengthening technological sovereignty and the ability to independently create competitive products and services.

Economic modernization also contributes to strengthening the financial security of the state. Increased enterprise productivity, development of a competitive business environment, growth of investment attractiveness, and expansion of the tax base ensure the stability of public finances. This creates opportunities for financing the defense sector, social

programs, scientific research, education, and infrastructure recovery. Thus, economic growth becomes a resource foundation for implementing strategic state objectives.

In the context of global instability, an important direction of modernization is increasing the resilience of the economy to crisis phenomena. A modern economic system must be capable of rapidly adapting to changes, restoring production processes after crises, and ensuring the continuity of key sector operations. Therefore, the development of reserve production capacities, digital management platforms, diversification of economic relations, and support for innovation are essential elements of economic security.

For Ukraine, the issue of economic modernization is of particular importance due to the need to counter external threats, overcome the consequences of war, and ensure post-war recovery. Economic recovery should be based not only on the reconstruction of destroyed facilities but also on a transition toward a new development model that involves digitalization, innovation, integration into the European economic space, and the development of high-tech sectors. Such an approach will enable the formation of a more resilient state capable of effectively responding to future challenges.

An important outcome of modernization is also the enhancement of the competitiveness of the national economy at the international level. A state with a developed economy has greater opportunities to influence international processes, attract investments, expand exports, and build a positive economic image. Competitiveness becomes not only an economic advantage but also a factor of political independence and strengthening the state's position in the global arena.

Along with technological and financial aspects, economic modernization contributes to the development of human potential, which is one of the key elements of national security. The creation of highly productive jobs, development of education, science, and professional competencies ensure the formation of a society capable of effectively using new technologies and creating innovative

solutions. In this context, human capital becomes a strategic resource for state development.

Therefore, economic modernization is a comprehensive mechanism for strengthening national security, as it forms the financial, technological, production, and social resilience of the state. Under current challenges, only an economically developed, innovative, and adaptive country is capable of effectively protecting its interests, ensuring citizens' well-being, and maintaining strategic independence. Therefore, modernization of the economic system should be considered one of the main priorities of state policy and the foundation for long-term sustainable development.

It is important to emphasize that modernization processes contribute to improving the efficiency of public administration, reducing corruption risks, and enhancing the quality of public services. This strengthens citizens' trust in state institutions.

Under current conditions, economic modernization is also a response to the challenges of globalization, digital transformation, and integration into global economic systems. It enables a country to adapt to new rules of competition and technological development.

Therefore, the study of economic modernization as an indicator of sustainable development and national security is highly relevant, as it determines the state's ability to survive, develop, and ensure stability in the face of contemporary challenges.

An important aspect is that economic modernization serves as an indicator of the level of sustainable development. It reflects a country's ability to maintain a balance between economic growth, social progress, and environmental security. In this context, modernization processes determine the quality of the economic system and its compliance with modern global challenges.

First, economic modernization ensures increased production productivity through the implementation of innovative technologies, automation, and digitalization. This enables more efficient resource utilization and cost reduction, which are essential components of sustainable development.

Second, it contributes to the development of human capital, as new technologies require improving employees' qualifications, developing digital skills, and ensuring lifelong learning. This creates a more adaptive and competitive society.

Third, economic modernization creates conditions for innovation-driven growth based on knowledge, research, and technological development. Innovations become the main drivers of economic development instead of traditional resource-based factors.

Fourth, it ensures environmental sustainability through the implementation of green technologies, energy-efficient solutions, and reduction of negative environmental impacts. This is particularly important in the context of global climate change.

Fifth, modernization contributes to improving the quality of economic management through the use of digital tools, analytics, and artificial intelligence. This enhances transparency and efficiency in decision-making processes.

Sixth, it affects the level of social stability, as economic growth and the creation of new jobs help reduce social inequality and improve living standards.

Seventh, economic modernization is an important factor in increasing the competitiveness of the state at the international level. Countries with innovation-driven economies have greater opportunities for integration into global markets.

Eighth, it contributes to strengthening the financial resilience of the state through economic diversification and reducing dependence on raw-material industries. This helps decrease the risks of economic crises.

Ninth, modernization processes stimulate the development of infrastructure, including digital, transport, and energy infrastructure, which serves as a foundation for long-term economic growth.

Therefore, economic modernization as an indicator of sustainable development reflects a comprehensive process of balanced development of economic, social, and environmental systems, ensuring long-term stability and competitiveness of the state.

The concept of economic modernization in contemporary Ukrainian scientific thought is considered a multidimensional phenomenon encompassing structural, technological, institutional, and social transformations. It reflects the transition of economic systems toward more efficient, innovative, and competitive development models.

In the works of Ukrainian researchers, economic modernization is generally interpreted as a process of qualitative renewal of productive forces and production relations, which ensures increased labor productivity and improvement of living standards.

Thus, Fedulova L. considers modernization as an innovation-oriented process centered on the implementation of new technologies, knowledge, and digital solutions across all spheres of the economy.

Another approach is presented in the works of Illiashenko S., who emphasizes that economic modernization is directly connected with the innovative development of enterprises and the formation of competitive advantages.

Kraus N. focuses on digital transformation as the foundation of modernization, emphasizing the role of platform technologies and digital ecosystems in the new economic model.

In turn, Kraus K. views modernization as a component of Industry 4.0, where automation, robotics, and artificial intelligence play a key role.

Voronkova V. interprets economic modernization as an element of the broader process of forming an information society and digital civilization.

Cherep A. emphasizes the managerial aspect of modernization, highlighting the need to update enterprise management systems.

Zhivotova T. associates modernization with increasing enterprise competitiveness and efficient resource utilization under the conditions of the digital economy.

Fedulova L. also emphasizes the role of public policy in stimulating modernization processes through innovation infrastructure development and investment support.

In the works of Ukrainian scholars, modernization is often considered as a response to globalization challenges, involving the integration of the national economy into global markets based on innovation.

Some researchers emphasize that modernization is not only an economic but also a social process, as it affects employment structures, education levels, and the quality of life of the population.

Significant attention is also paid to the environmental dimension of modernization, which involves the implementation of green technologies and sustainable production models.

Summarizing the views of Ukrainian researchers, economic modernization is regarded as a comprehensive process encompassing technological innovations, institutional transformations, and socio-economic development.

The category of "economic modernization" (Table 1.10) is a multi-dimensional concept that in contemporary Ukrainian scientific thought is considered not only as a process of renewing the production base or technological re-equipment of enterprises but also as a comprehensive transformation of the economic system encompassing innovations, digitalization, improvement of management, development of human capital, and the formation of a new model of competitiveness. Ukrainian

Table 1.10 – Approaches of Ukrainian Scholars to the Concept of «Economic Modernization»

Author	Approach	Key Focus
Fedulova L. [37]	Innovation-oriented	Technologies and public policy
Illiashenko S. [38]	Innovation and management-oriented	Enterprise competitiveness
Kraus N. [39]	Digital	Digital economy and platforms
Kraus K. [40]	Industry 4.0	Automation and artificial intelligence
Voronkova V. [41]	Civilizational	Information society
Cherep A. [42]	Managerial	Modernization of management systems
Zhivotova T. [43]	Economic	Efficiency and resources

researchers emphasize various aspects of modernization processes depending on the subject of their scientific studies, which makes it possible to develop a comprehensive understanding of this category.

One of the most widespread directions in the study of economic modernization is the innovation-oriented approach, presented in the works of L. I. Fedulova [37]. The scholar examines modernization primarily through the formation of an innovation-based development model, where technological renewal, scientific advancement, the introduction of new knowledge into production activities, and active state support for the innovation sector play a key role. In this context, economic modernization is interpreted as a process of transition from a traditional resource-based model to a knowledge economy, in which competitive advantages are created through intellectual potential, scientific developments, and technological innovations. Particular attention is paid to the role of public policy, which should ensure a favorable environment for enterprise innovation activity, development of innovation infrastructure, and commercialization of research results.

The innovation and management approach of S. Illiashenko [38] expands the understanding of economic modernization by combining technological changes with the transformation of enterprise management systems. The researcher emphasizes that modernization should be aimed not only at creating or acquiring new technologies but also at developing effective mechanisms for their implementation and utilization. An important outcome of modernization processes is increasing enterprise competitiveness through the development of innovation potential, improvement of strategic management, marketing tools, and organizational models. Thus, modernization is viewed as a comprehensive transformation of an enterprise that encompasses production, managerial, and market components of its activities.

Of particular importance under modern conditions is the digital approach to economic modernization, presented in the studies

of N. Kraus [39]. The scholar considers digitalization as a fundamental factor in the structural transformation of the economic system. Within this approach, modernization is associated with the transition to a digital economy, the development of digital platforms, the use of big data, cloud technologies, electronic services, and new models of interaction between business, government, and consumers. Digital modernization transforms not only the technological foundation of the economy but also the very principles of business process organization, value creation, and enterprise management. It creates new opportunities for increasing productivity, reducing costs, and developing innovative business models.

A continuation of the digital direction is the concept of Industry 4.0, studied by K. Kraus [40]. Within this approach, economic modernization is viewed as a transition to a new technological paradigm based on automation, robotics, artificial intelligence, the Internet of Things, cyber-physical systems, and the analysis of large data sets. The author emphasizes that a modern enterprise should transform from a traditional production structure into a digital intelligent system capable of rapid adaptation to changes in the external environment. This approach is particularly relevant under conditions of global competition, as technological modernization becomes the foundation for ensuring long-term sustainability of enterprises and the economy as a whole.

The civilizational approach of V. Voronkova [41] considers economic modernization more broadly – as a component of society's transition to a new stage of development associated with the formation of an information society. Within this interpretation, economic modernization is not limited solely to technological changes but also includes the transformation of social relations, knowledge systems, management culture, and the role of individuals in economic processes. The main resources of development become information, knowledge, and society's ability to effectively utilize intellectual potential. This approach emphasizes that economic modernization is not only an economic process but also a social and civilizational transformation.

The management approach of A. Cherep [42] focuses on the need to modernize the management system as a key condition for economic development. The scholar emphasizes that technological and structural changes cannot be effective without the corresponding renewal of management mechanisms. Management modernization involves the implementation of modern strategic management methods, adaptive organizational structures, risk management systems, and digital tools for managerial decision-making. This approach is particularly important for enterprises operating under conditions of instability, global competition, and crisis phenomena.

The economic approach of T. Zhyvotova [43] emphasizes the effectiveness of modernization processes through the prism of improving resource utilization. Within this approach, modernization is considered a mechanism for optimizing production processes, rationally using material, financial, and labor resources, reducing costs, and increasing economic efficiency. The main criterion of successful modernization is not only the implementation of new technologies but also the achievement of a tangible economic effect – growth in productivity, profitability, and enterprise sustainability.

The analysis of the presented approaches demonstrates that Ukrainian scholars consider economic modernization as a comprehensive, multi-level process that combines technological, managerial, digital, social, and economic transformations. While the innovation approach focuses on the creation and implementation of new technologies, the digital and technological directions reveal the role of information systems, artificial intelligence, and automation. The managerial and economic approaches complement this perspective by highlighting the need to adapt organizational models and ensure the efficient use of resources.

Thus, the generalization of scientific viewpoints allows economic modernization to be defined as a process of systemic transformation of economic activity based on innovations, digital technologies, modern management practices, and the effective utilization of resource potential in order to ensure competitiveness, resilience, and long-term

development of economic systems. Under contemporary conditions, especially for Ukraine during the period of recovery and European integration, modernization acquires strategic importance, as it serves as the foundation for the transition toward an innovative, digital, and competitive economy.

The analysis of scientific approaches of Ukrainian researchers demonstrates that the category of economic modernization is multidimensional and interdisciplinary. It encompasses technological, innovation, managerial, social, and environmental dimensions of development.

Most authors agree that modernization is a key condition for increasing the competitiveness of the national economy, its integration into global markets, and ensuring sustainable development.

Therefore, economic modernization is not only an economic category but also a strategic instrument for societal transformation that determines the level of state development in the digital era.

The presented data demonstrate the uneven and crisis-cyclical nature of modernization processes, which is typical for economies undergoing structural transformation and facing increased security risks.

First, GDP dynamics reflect the high vulnerability of the economic system to external shocks. The decline in 2022 (–30%) indicates a sharp disruption of production and logistics chains, while the subsequent

Table 1.11 – Indicators of Economic Modernization (2020–2025)

Indicator	2020	2021	2022	2023	2024	2025
GDP growth, %	–4.0	3.4	–30.0	5.0	4.0	3.8
R&D expenditures, % of GDP	0.40	0.45	0.30	0.50	0.55	0.60
Share of the digital economy, % of GDP	6	7	8	9	10	11
Labor productivity (index, 2020=100)	100	105	80	92	98	103
GDP energy intensity (conditional index, 2020=100)	100	97	110	104	98	95
Investment in fixed capital, % of GDP	14	15	12	13	15	16
Foreign direct investment, % of GDP	2.5	3.0	1.2	2.0	2.8	3.2
Share of high-tech products in industry, %	10	11	9	12	13	14

recovery in 2023–2025 (3.8–5%) characterizes the stage of post-crisis adaptation. However, growth rates remain moderate, indicating limited depth of economic recovery.

Second, R&D expenditures, although demonstrating gradual growth from 0.4% to 0.6% of GDP, remain critically low compared with the benchmarks of innovation-driven economies (2–3% of GDP). This indicates insufficient institutional support for innovation and weak integration between science and business.

Third, the share of the digital economy shows steady growth (from 6% to 11% of GDP), which is a positive indicator of modernization. However, the pace of digital transformation remains moderate, preventing the formation of a fully developed digital economic model capable of significantly increasing productivity.

Fourth, the labor productivity index demonstrates a recovery trajectory after a sharp decline in 2022 (80 points). By 2025, the indicator almost returns to the baseline level (103), which indicates a partial restoration of resource utilization efficiency, but without a structural breakthrough.

Fifth, GDP energy intensity is gradually decreasing (from 110 in 2022 to 95 in 2025), representing a positive modernization trend. This may indicate both technological improvements and structural reductions in energy-intensive production, which have a dual effect on the economy.

Sixth, investment in fixed capital fluctuates within the range of 12–16% of GDP. Despite some growth in 2024–2025, this level remains insufficient for large-scale renewal of the production base, since a significant modernization breakthrough usually requires investment levels exceeding 20–25% of GDP.

Seventh, foreign direct investment demonstrates high volatility: a sharp decline in 2022 to 1.2% of GDP followed by a recovery to 3.2% in 2025. This indicates investors' sensitivity to political and security risks, as well as a gradual restoration of confidence in the economy.

Eighth, the share of high-tech products increases from 10% to 14%, which represents a positive but slow trend. This confirms that structural transformation of industry is taking place; however, it has not yet reached the critical mass required for a transition to an innovation-driven development model.

Overall conclusion: economic modernization has a fragmented nature. Certain indicators (digitalization, energy efficiency, and post-2023 investment recovery) demonstrate positive dynamics; however, systemic technological breakthrough has not yet occurred. This means that the economy is currently at the stage of adaptive modernization rather than an innovation-industrial transition, which directly affects the level of economic and national security.

The analysis confirms that for Ukraine, economic modernization should become a strategic priority of state policy aimed at accelerating technological renewal, strengthening innovation capacity, developing digital infrastructure, and ensuring long-term economic resilience.

Table 1.12 – Key Characteristics of Economic Modernization Processes (2020–2025)

Indicator	Trend	Interpretation
GDP dynamics	Crisis decline followed by gradual recovery	High dependence on external shocks and limited recovery potential
R&D expenditures	Slow increase from 0.4% to 0.6% of GDP	Insufficient innovation capacity and weak science–business cooperation
Share of the digital economy	Growth from 6% to 11% of GDP	Positive digital transformation trend, but incomplete digital transition
Labor productivity	Recovery after the 2022 decline	Restoration of efficiency without structural breakthrough
Energy intensity of GDP	Gradual reduction	Improvement of energy efficiency and modernization potential
Fixed capital investment	Growth to 16% of GDP	Insufficient level for large-scale modernization
Foreign direct investment	Recovery after crisis decline	Gradual restoration of investor confidence
High-tech production share	Growth from 10% to 14%	Slow movement toward an innovation-based industrial structure

Table 1.13 – Dynamics of Key Indicators of Innovation Development, Digital Transformation and Investment Activity of the Economy (2020–2025)

Indicator	2020	2021	2022	2023	2024	2025	Indicator Content
R&D expenditures, % of GDP	0.40	0.45	0.30	0.50	0.55	0.60	Level of innovation activity
Share of the digital economy, % of GDP	6	7	8	9	10	11	Level of digital transformation
Labor productivity (index, 2020=100)	100	105	80	92	98	103	Efficiency of resource utilization
GDP energy intensity (index, 2020=100)	100	97	110	104	98	95	Energy efficiency of the economy
Investment in fixed capital, % of GDP	14	15	12	13	15	16	Modernization investment potential
Foreign direct investment, % of GDP	2.5	3.0	1.2	2.0	2.8	3.2	Investment attractiveness
Share of high-tech exports, %	8	9	7	10	11	12	Technological complexity of exports
Share of innovation-active enterprises, %	15	16	12	17	18	20	Level of business innovativeness

The presented table characterizes the dynamics of key indicators of innovation development, digital transformation, and investment activity of the economy during 2020–2025. The analysis of the data demonstrates the significant impact of the crisis phenomena of 2022 and the gradual recovery of economic potential in subsequent years.

R&D expenditures increased from 0.40% of GDP in 2020 to 0.60% in 2025, indicating a gradual strengthening of attention to innovation-driven development. In 2022, a sharp decline to 0.30% was observed, which was caused by military and economic challenges. However, from 2023 onwards, a steady recovery in financing for scientific research and innovation activities can be observed.

The share of the digital economy (% of GDP) demonstrates continuous growth from 6% in 2020 to 11% in 2025. The almost twofold increase indicates the active implementation of digital technologies, the development of e-commerce, digital services, and the IT sector. It is particularly important that the positive trend continued even during the crisis period of 2022.

In 2021, labor productivity increased to 105 points; however, in 2022 it sharply decreased to 80 points, representing a 20% decline compared with the base year. Starting from 2023, gradual recovery is observed, reaching 103 points in 2025, which already exceeds the 2020 level. This indicates the restoration of production processes and the adaptation of enterprises to new economic conditions.

GDP energy intensity (index, 2020=100). A decrease in the index indicates an improvement in the energy efficiency of the economy. After an improvement in 2021 (97 points), the indicator deteriorated in 2022 to 110 points, which reflects an increase in energy consumption per unit of GDP. Subsequently, a positive trend can be observed: in 2025, the index decreased to 95 points, representing the best value during the entire analyzed period.

The volume of investment in fixed capital increased from 14% of GDP in 2020 to 16% in 2025. The lowest value was recorded in 2022 (12% of GDP), after which a gradual recovery began. The growth of investment activity indicates an expansion of the economy's modernization potential and the restoration of investor confidence.

The indicator of foreign direct investment (% of GDP) demonstrates a similar trend. After declining to 1.2% of GDP in 2022, it gradually recovered to 3.2% of GDP in 2025, which even exceeds the level of 2021. This indicates an increase in the international investment attractiveness of the economy and an improvement in the business environment.

The share of high-tech products in exports increased from 8% in 2020 to 12% in 2025. Despite a temporary decline to 7% in 2022, further growth indicates the gradual complication of the export structure and the development of knowledge-intensive industries.

The number of enterprises engaged in innovation activities increased from 15% to 20% during the analyzed period. In 2022, the indicator decreased to 12%; however, by 2025, it reached its maximum value. This indicates a strengthening of the innovation orientation of businesses and an increase in their adaptability to modern challenges.

The analysis shows that 2022 became a turning point due to a significant deterioration in most indicators, including labor productivity, investment activity, innovation performance, and high-tech exports. At the same time, since 2023, a stable positive trend has been observed across almost all areas.

The main positive trends in 2020–2025 include:

– a 50% increase in R&D expenditures (from 0.40% to 0.60% of GDP);

– an 83.3% increase in the share of the digital economy (from 6% to 11% of GDP);

– the recovery of labor productivity to a level exceeding the baseline value;

– improvement in the energy efficiency of the economy;

– growth in investment in fixed capital and foreign direct investment inflows;

– expansion of the share of high-tech exports;

– an increase in the share of innovation-active enterprises to 20%.

Therefore, the data indicate the formation of prerequisites for the transition of the economy toward an innovation-digital development model, in which investments in science, digitalization, high-tech production, and improved resource efficiency play a key role. This trend provides an important foundation for ensuring long-term competitiveness and sustainable economic growth.

Economic modernization is one of the key factors in ensuring sustainable development and strengthening the national security of the state. It involves the renewal of the production base, the implementation of innovative technologies, the digitalization of economic processes, improvement

of energy efficiency, and development of human capital. Modernization transformations create conditions for increasing labor productivity, enhancing the competitiveness of the national economy, and strengthening its ability to adapt to external and internal challenges.

Economic modernization in contemporary conditions is one of the key factors ensuring the sustainable development of the state, since the renewal of the economic system creates the prerequisites for a harmonious combination of economic growth, social progress, and environmental responsibility. Sustainable development involves not only increasing production volumes or economic indicators but also the formation of such an economic model that meets the needs of the present generation without limiting the opportunities of future generations. In this context, modernization acts as a strategic tool for transitioning from a traditional resource-intensive economy to an innovative, efficient, and environmentally oriented development model.

Modern economic modernization involves the comprehensive renewal of production processes, technologies, management systems, and mechanisms for resource utilization. Its main objective is to increase economic productivity while simultaneously reducing negative environmental impacts and ensuring social stability. Therefore, modernization processes are closely linked to the concept of sustainable development, which is based on the principles of economic efficiency, environmental security, and social responsibility.

One of the defining directions of economic modernization is innovative development, which creates the foundation for long-term sustainable growth. The implementation of new technologies, the advancement of scientific research, support for innovative entrepreneurship, and the formation of a knowledge-based economy make it possible to improve resource efficiency and create products with high added value. Innovations contribute to the transition from an economic development model based on the consumption of natural resources to a model where knowledge, technologies, and human capital become the primary sources of competitive advantage.

An important element of modernization in the context of sustainable development is the digital transformation of the economy. The use of digital technologies, artificial intelligence, automated management systems, big data, and digital platforms makes it possible to optimize production processes, reduce costs, and improve resource efficiency. Digitalization creates opportunities for the transition toward a more flexible and adaptive economic system capable of rapidly responding to changes in the external environment and ensuring development stability.

Economic modernization also plays an important role in shaping an environmentally sustainable development model. Modern economic processes require a transition toward energy-efficient production, the use of renewable energy sources, the implementation of circular economy principles, and the reduction of the negative impact of industrial activities on the environment. Technological modernization of enterprises allows not only for improving economic efficiency but also for ensuring the rational use of natural resources and maintaining ecological balance.

An important aspect of sustainable development is the social component of economic modernization. Economic renewal should be accompanied by the development of human potential, the creation of new jobs, improvement of the quality of education, and the formation of modern professional competencies. Successful modernization is impossible without investment in human capital, since people are the primary factor in the creation and effective use of new technologies. Thus, modernization contributes not only to economic growth but also to improving the overall well-being of the population.

Economic modernization is of particular importance for ensuring the economic resilience of the state in the context of global crises and uncertainty. A modern economy must be capable of adapting to external challenges, maintaining production stability, and effectively utilizing available resources. Modernization processes form the foundation for increasing the competitiveness of the state, reducing dependence on external factors, and strengthening economic security.

For Ukraine, economic modernization is particularly relevant in the context of post-war recovery and integration into the European economic space. The reconstruction of the country should be based not only on rebuilding destroyed infrastructure but also on creating a modern economic system focused on innovation, digitalization, and sustainable development principles. The implementation of European approaches to the green economy, energy efficiency, and responsible production can become the foundation for a new stage of Ukraine's economic development.

Economic modernization also contributes to strengthening national security through the formation of a stable and independent economic system. An economically developed state has greater opportunities to ensure financial stability, maintain critical infrastructure, develop strategic industries, and effectively respond to external threats. Thus, sustainable development and national security are interconnected outcomes of economic modernization, as a strong and innovative economic system creates the foundation for state stability.

Therefore, economic modernization is not merely a process of technological renewal but a comprehensive transformation aimed at ensuring sustainable development of the state. It combines economic efficiency, innovation, social responsibility, and environmental security. Under modern conditions, a modernized economy is capable of ensuring long-term growth, increasing the competitiveness of the country, strengthening its resilience to crises, and creating conditions for a higher quality of life for future generations.

Under conditions of global instability, technological transformations, and military threats, modernization acquires strategic importance, as it ensures economic resilience, reduces dependence on external resources, and contributes to the formation of a high-tech structure of production and exports. Indicators of innovation activity, the level of digitalization, investment attractiveness, labor productivity, and energy efficiency serve as important criteria for assessing the effectiveness of modernization processes and the level of economic security of the state.

Table 1.14 – Relationship between Economic Modernization and Sustainable Development of the State

Direction of Economic Modernization	Content of Modernization Changes	Impact on Sustainable Development of the State
1	2	3
Innovative modernization	Development of scientific research, implementation of new technologies, support for innovative entrepreneurship, and formation of a knowledge-based economy	Ensures long-term economic growth, increases the country's competitiveness, and promotes the creation of products with high added value
Digital transformation of the economy	Use of artificial intelligence, big data, digital platforms, automated management systems, and electronic services	Improves resource efficiency, optimizes business processes, ensures management transparency, and increases the adaptability of the economic system
Technological modernization of production	Modernization of equipment, automation of production processes, and implementation of Industry 4.0 technologies	Contributes to higher labor productivity, cost reduction, increased production efficiency, and the formation of technological independence
Environmental modernization	Transition to energy-efficient technologies, development of renewable energy sources, and implementation of circular economy principles	Ensures rational use of natural resources, reduces negative environmental impacts, and supports ecological balance
Human capital development	Investments in education, professional training, development of digital competencies, and enhancement of the intellectual potential of the population	Creates the foundation for innovative development, improves the quality of labor resources, and contributes to social stability
Modernization of the management system	Implementation of modern management models, strategic planning, risk management systems, and digital decision-making tools	Increases the efficiency of public and corporate governance and ensures more rational use of resources
Development of a competitive business environment	Support for entrepreneurship, development of small and medium-sized enterprises, and attraction of investments	Creates new jobs, stimulates economic activity, and contributes to sustainable regional development

End of Table 1.14

1	2	3
Energy modernization	Improvement of energy efficiency, diversification of energy sources, and development of alternative energy	Reduces dependence on external resource suppliers and strengthens economic and national security
Infrastructure modernization	Renewal of transport, digital, production, and social infrastructure	Provides the foundation for economic development, integration into global markets, and improvement of the population's quality of life
European integration modernization	Harmonization of economic processes with EU standards, implementation of sustainable development principles, and development of a green economy	Increases investment attractiveness, promotes integration into the global economic space, and contributes to the formation of a sustainable economic model

The conducted analysis demonstrates that despite the negative impact of crisis phenomena and military challenges, the economy shows a tendency toward recovery and the accumulation of modernization potential. The growth of R&D expenditures, the increasing share of the digital economy, the restoration of investment activity, and the expansion of high-tech exports indicate the formation of prerequisites for the transition toward an innovation-oriented development model. At the same time, ensuring long-term sustainability requires further stimulation of innovation activity, attraction of investments, development of digital infrastructure, and support for technological modernization of enterprises.

Therefore, economic modernization acts not only as a tool for improving the efficiency of economic activities but also as an important indicator of the level of sustainable development and national security of the state. Its successful implementation ensures economic resilience, technological independence, and the long-term competitiveness of the country.

1.3. IMPACT OF ARTIFICIAL INTELLIGENCE ON ECONOMIC MODERNIZATION OPPORTUNITIES

Under current conditions of digital transformation of the economy, artificial intelligence (AI) is acquiring the status of a key driver of modernization processes, determining a new quality of economic growth. Its implementation covers almost all areas of economic activity – from industry and logistics to the financial sector and public administration. Therefore, studying the impact of AI on economic modernization opportunities is highly relevant in the context of global competition and accelerated digitalization.

The relevance of this issue is strengthened by the need to increase labor productivity, optimize costs, and ensure efficient resource utilization. AI enables the automation of routine processes, minimizes the human factor, and improves the accuracy of managerial and production decisions. For economies undergoing transformation or recovery processes, particularly Ukraine, this creates additional opportunities to accelerate modernization and enhance competitiveness.

The application of AI in supply chain management, logistics, and business analytics is becoming increasingly important. Intelligent systems for demand forecasting, route optimization, and automated resource management make it possible to significantly reduce costs and improve the efficiency of economic processes. This creates a new model of enterprise functioning based on data-driven approaches and algorithmic decision-making.

At the same time, the impact of AI on the economy is accompanied by a number of challenges, including labor market transformation, the need for new digital competencies, and the risks of technological inequality. This requires the adaptation of education systems, the development of innovation infrastructure, and the formation of appropriate public policies. Thus, AI acts not only as a tool for modernization but also as a factor driving profound structural changes in the economy.

Therefore, studying the impact of artificial intelligence on economic modernization is highly relevant, as it makes it possible to identify new development directions, improve the efficiency of economic systems, and establish long-term competitive advantages in the context of global digital transformation.

The advantages of applying artificial intelligence (AI) for economic modernization primarily lie in increasing the efficiency of all key economic processes. Through the automation of routine operations, AI significantly reduces time and resource costs, minimizes the impact of human factors, and improves the accuracy of task execution. This is particularly important for manufacturing, logistics, the financial sector, and public administration, where the speed and accuracy of decision-making are of critical importance.

Another important advantage is the enhancement of labor productivity and the optimization of resource utilization. Intelligent systems are capable of analyzing large volumes of data in real time, forecasting demand, optimizing production processes, and improving logistics routes. This enables enterprises to operate more efficiently, reduce losses, and increase the overall effectiveness of economic activities.

In the current context of digital transformation of the economy, artificial intelligence (AI) is becoming a key driver of modernization processes that determines a new quality of economic growth. Its implementation covers almost all areas of economic activity – from industry and logistics to the financial sector and public administration. Therefore, studying the impact of AI on the opportunities for economic modernization is highly relevant in the context of global competition and accelerated digitalization.

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At the same time, the impact of AI on the economy is accompanied by a number of challenges, including labor market transformation, the need for new digital competencies, and the risks of technological inequality. This requires adaptation of education systems, development of innovation infrastructure, and formation of appropriate public policies. Thus, AI acts not only as a tool for modernization but also as a factor of profound structural changes in the economy.

Therefore, studying the impact of artificial intelligence on economic modernization is highly relevant, as it makes it possible to identify new development directions, improve the efficiency of economic systems, and establish long-term competitive advantages in the context of global digital transformation.

The advantages of using artificial intelligence (AI) for economic modernization primarily lie in improving the efficiency of all key economic processes. Through the automation of routine operations, AI allows for significant reductions in time and resource costs, decreases the impact of human error, and improves the accuracy of task execution. This is particularly important for manufacturing, logistics, finance, and public administration, where the speed and accuracy of decision-making are of critical importance.

Another significant advantage is the increase in labor productivity and optimization of resource utilization. Intelligent systems are capable of analyzing large volumes of data in real time, forecasting demand, optimizing production processes, and improving logistics routes. This enables enterprises to operate more efficiently, reduce losses, and enhance the overall effectiveness of economic activities.

The third advantage is the improvement of managerial decision-making quality. AI provides analytical support based on data-driven approaches, reducing the risk of subjective errors and enabling more informed strategic decisions. This contributes to the development of innovative business models, increased enterprise competitiveness, and accelerated economic growth.

Particular attention should be paid to the role of AI in stimulating innovation and digital transformation of the economy. The use of AI contributes to the emergence of new products, services, and markets, as well as the development of startups and technology companies. This creates additional opportunities for economic growth and integration into global value chains [45].

Thus, the application of artificial intelligence (Table 1.15) is a powerful instrument for economic modernization that ensures increased efficiency, productivity, innovation capacity, and competitiveness at both national and international levels.

The analysis of the data presented in the table demonstrates that the application of artificial intelligence has a comprehensive and multidimensional impact on economic modernization. First of all, it should be noted that the most significant effect is productivity growth, which on average may increase by 15–40%. This means that enterprises implementing AI solutions are able to produce more goods or provide more services using the same amount of resources, which directly enhances their competitiveness.

An equally important effect is automation, which ensures a reduction in operating costs by 20–35%. This is achieved through the replacement of human labor in routine processes, which also decreases the probability of errors and improves the stability of business processes. In the long term, this contributes to the structural optimization of the cost component of the economy [46].

A particularly important role is played by big data analytics, which makes it possible to improve the accuracy of managerial and strategic decisions up to 70–90%. This indicates a transition from intuitive

Table 1.15 – Advantages of Using AI for Economic Modernization

No.	Advantage	Nature of Impact	Economic Effect
1	Process automation	Execution of routine operations without human involvement	Cost reduction, time savings
2	Productivity enhancement	Optimization of production and management processes	Growth in production and service volumes
3	Analytics and forecasting	Processing of large volumes of data in real time	More accurate planning and risk reduction
4	Resource optimization	Rational use of material and financial resources	Reduction of losses and increased efficiency
5	Improvement of managerial decisions	Decision-making support based on data and algorithms	Enhancement of strategic management quality
6	Innovation development	Creation of new products and business models	Formation of new markets and sources of revenue
7	Increased competitiveness	Faster adaptation to market changes	Strengthening positions at national and global levels

management to a data-driven approach, which is critically important for the modern economy characterized by a high level of uncertainty.

The impact of AI on risk management should also be emphasized. Through predictive models, companies and public institutions can identify potential crisis phenomena in advance, which makes it possible to reduce potential losses and increase the economic resilience of the system.

An important strategic effect of AI implementation is the stimulation of innovation development. Artificial intelligence not only optimizes existing processes but also creates new markets, products, and business models, ensuring long-term economic growth and structural modernization of the economy.

In general, it can be concluded that AI is not merely a technological tool but a systemic factor of economic transformation that simultaneously affects productivity, costs, innovation capacity, and the strategic resilience of economic systems.

CHAPTER 2.
CURRENT STATE OF AI UTILIZATION BASED ON ECONOMIC MODERNIZATION

2.1. ASSESSMENT OF AI UTILIZATION FOR THE MODERNIZATION OF UKRAINE'S ECONOMY

In modern conditions, artificial intelligence (AI) is becoming one of the key instruments of structural economic modernization, as it contributes to increasing labor productivity, optimizing management processes, developing innovative production systems, and creating new business models. For Ukraine, the relevance of using artificial intelligence technologies has significantly increased due to the full-scale war, the need to restore economic potential, the digital transformation of public administration, and integration into the European economic space.

The modernization of Ukraine's economy involves not only the renewal of the production base but also a transition toward a knowledge-based economy, in which innovations, digital competencies, and the ability to effectively use information resources become the main competitive advantages. AI represents one of the most promising technological directions, enabling a shift from traditional management models toward intelligent decision-making systems based on the analysis of large volumes of data.

Today, Ukraine is gradually developing its own artificial intelligence ecosystem. An important milestone was the approval of the Concept for the Development of Artificial Intelligence in Ukraine, which defines priority areas for AI application in the economy, public administration, defense, education, and science. Particular attention is paid to the development of digital infrastructure,

the training of specialists, the stimulation of innovation activity, and the creation of conditions for AI implementation in the business environment.

One of the most active areas of AI application in Ukraine is the automation of business processes and improvement of enterprise efficiency. Companies use machine learning algorithms for demand forecasting, inventory management, optimization of logistics operations, analysis of consumer behavior, and personalization of services. AI technologies are being actively implemented particularly in the fields of e-commerce, financial services, telecommunications, transport, and industry. For example, Ukrainian logistics companies use digital technologies and artificial intelligence solutions to optimize delivery routes, forecast network load, and automate customer service. The implementation of such solutions allows companies to reduce operating costs, accelerate managerial decision-making, and ensure greater business resilience under crisis conditions.

Significant AI potential is also evident in industry, where it serves as a foundation for the transition toward the Industry 4.0 concept. The use of intelligent systems enables enterprises to perform predictive equipment maintenance, monitor product quality in real time, optimize resource utilization, and reduce production losses. For Ukraine, which possesses considerable industrial potential, the implementation of such technologies is an important factor in restoring the competitiveness of the industrial sector.

Another important area is the use of AI in public administration and the development of digital services. Ukraine already has significant experience in the digitalization of public services through the Diia platform, which creates a foundation for further integration of intelligent technologies. In the future, AI can be used to automate administrative procedures, analyze socio-economic processes, forecast public needs, and improve the effectiveness of government policies.

An important aspect of economic modernization through artificial intelligence (AI) is its role in ensuring economic resilience and

Ukraine's post-war recovery. Intelligent technologies can contribute to more efficient allocation of investment resources, assessment of war-related damages, infrastructure recovery planning, and the development of regional development strategies. The use of AI-based analytical models enables decision-making not only on the basis of current data but also by considering predictive scenarios.

At the same time, the level of AI adoption in Ukraine remains uneven. The main barriers include the insufficient level of digital maturity of individual enterprises, limited financial resources for implementing innovations, a shortage of qualified specialists, data protection challenges, and the absence of a fully developed regulatory and legal framework governing the use of artificial intelligence. This particularly affects small and medium-sized enterprises, which often lack sufficient opportunities to invest in complex digital solutions. Thus, the use of artificial intelligence is becoming one of the key directions for modernizing Ukraine's economy, as it enables the digital transformation of enterprises, increases competitiveness, and facilitates the formation of new models of economic development. At the same time, effective AI integration requires comprehensive public policy, the development of digital infrastructure, support for innovative entrepreneurship, and the training of highly qualified specialists. It is precisely the combination of artificial intelligence technological capabilities with systemic reforms that can become an important factor in Ukraine's sustainable economic development in the face of global challenges.

One of the most promising areas of artificial intelligence application in the process of modernizing Ukraine's economy is the industrial sector. Industry constitutes a significant part of the country's economic potential; therefore, the implementation of intelligent technologies becomes an important factor in increasing enterprise competitiveness, optimizing production processes, and transitioning to the principles of Industry 4.0.

Under conditions of global digital transformation, Ukrainian industrial enterprises are gradually moving from traditional management

Table 2.1 – Main Directions of Artificial Intelligence Application in the Process of Modernizing Ukraine's Economy

Application Area	Directions of AI Application	Economic Effect
Industry	Predictive maintenance, production automation, quality control	Cost reduction, productivity improvement
Logistics	Route optimization, demand forecasting, inventory management	Reduction of delivery time, efficient use of resources
Business and trade	Customer analysis, personalization of offers, chatbots	Growth of sales and service quality
Public administration	Data analysis, digital services, process automation	Improvement of management efficiency
Financial sector	Risk assessment, fraud detection, forecasting	Enhancement of financial security
Economic recovery	Scenario modeling, needs assessment, investment planning	Acceleration of post-war reconstruction

models toward systems based on big data analysis, automation, and forecasting. Artificial intelligence is used for product quality control, prediction of equipment failures, optimization of production parameters, resource management, and improving the level of industrial safety.

One of the most promising areas for the application of artificial intelligence in the process of modernizing Ukraine's economy is the industrial sector. Industry forms a significant part of the country's economic potential; therefore, the implementation of intelligent technologies becomes an important factor in increasing enterprise competitiveness, optimizing production processes, and transitioning to Industry 4.0 principles.

Under conditions of global digital transformation, Ukrainian industrial enterprises are gradually moving from traditional management models toward systems based on big data analysis, automation, and forecasting. Artificial intelligence is used for product quality control, prediction of equipment failures, optimization of production parameters, resource management, and improvement of industrial safety levels.

According to the State Statistics Service of Ukraine, research into the use of information and communication technologies in enterprises covers such areas of digital transformation as the use of software, cloud services, data analysis, and artificial intelligence technologies. This indicates the gradual formation of a statistical basis for assessing the level of digital maturity of Ukrainian businesses.

Artificial intelligence technologies are being most actively implemented by large industrial companies that possess sufficient financial and technological potential. One example is the mining and metals group Metinvest, which develops digital solutions to optimize production processes. The company uses data analysis technologies, automated production process control, and elements of computer vision to improve the efficiency of its enterprises.

In metallurgical production, the application of AI enables forecasting of equipment technical conditions, timely detection of production deviations, and reduction of the risks of emergency situations. For example, machine learning algorithms can analyze data from production sensors and determine the probability of equipment failures before an actual shutdown occurs. This ensures the reduction of downtime and decreases repair costs.

An important area of AI application is also product quality control. Through computer vision technologies, enterprises can automatically analyze product characteristics, detect defects, and ensure more accurate control of production processes. For industrial enterprises, this is particularly relevant, as improving product quality is one of the key factors enabling Ukrainian manufacturers to enter international markets.

Significant potential for the use of artificial intelligence can also be observed in the energy sector. Ukrainian energy companies apply digital technologies to forecast electricity consumption, optimize network loads, and improve the efficiency of energy resource management. The use of machine learning algorithms makes it possible to consider a large number of factors and generate more accurate forecasts, which is especially important under conditions of instability in the energy system.

Another important area is the use of AI in the food industry and the agro-industrial complex. Ukrainian enterprises apply digital technologies for demand forecasting, production inventory management, raw material quality control, and logistics optimization. As a result, enterprises gain the opportunity to use resources more efficiently and respond more quickly to changes in the market environment.

The main examples of artificial intelligence application in Ukraine's industry are summarized in Table 2.2.

Thus, artificial intelligence is gradually becoming one of the key instruments for modernizing Ukraine's industry. Its application enables enterprises not only to automate individual operations but also to develop a new production management model based on data, forecasting, and innovation. At the same time, large-scale AI implementation requires the development of digital infrastructure, training of specialists, investment in technological modernization, and the formation of a favorable regulatory environment. A comprehensive approach to the digital transformation of industry can ensure the enhancement of Ukraine's economic competitiveness and its integration into the European innovation space.

Table 2.2 – Main Directions of Artificial Intelligence Application in the Process of Modernizing Ukraine's Economy

Industry	Example of AI Application	Expected Economic Effect
Metallurgy	production data analysis, computer vision, equipment failure prediction	reduction of downtime, decrease in production costs
Mechanical engineering	automation of quality control, robotization of production operations	increase in productivity and production accuracy
Energy sector	energy consumption forecasting and optimization of energy flows	improvement of resource utilization efficiency
Food industry	demand forecasting, product quality control	reduction of losses and production optimization
Industrial enterprise logistics	route optimization and inventory management	cost reduction and increase in operational speed

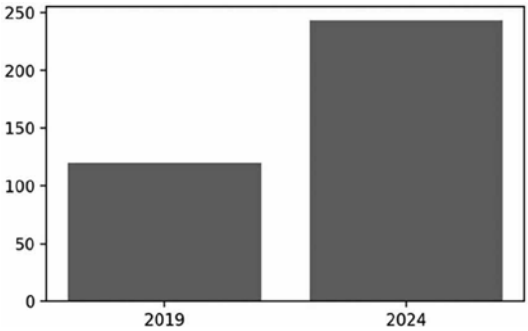

Figure 2.1 – Main Directions of Artificial Intelligence Application in Ukraine's Industry in 2019–2024 [49]

The indicators presented in Figure 2.3 demonstrate the positive dynamics of the development of the artificial intelligence sector in Ukraine. According to the AI Ecosystem of Ukraine study, the number of companies engaged in the development and implementation of artificial intelligence technologies increased from approximately 120 in 2019 to 243 in 2024, which means it more than doubled. This confirms the active development of the domestic AI ecosystem even under conditions of economic instability and martial law.

The growth in the number of AI companies is primarily driven by the acceleration of economic digital transformation processes, the development of information technologies, and increasing demand for intelligent digital solutions. Ukrainian enterprises are increasingly using machine learning algorithms, computer vision, natural language processing, and predictive analytics to automate production, logistics, financial, and management processes. This contributes to higher labor productivity, reduced operating costs, and improved quality of managerial decision-making.

An important factor in the development of the sector is Ukraine's strong human capital potential. In recent years, the number of specialists in artificial intelligence and machine learning has significantly increased, contributing to the creation of new innovative

enterprises and startups. In addition, a significant share of Ukrainian AI companies is focused on international markets, implementing projects for clients from the European Union, the United States, and Canada. This ensures investment inflows, the development of high-tech exports, and Ukraine's integration into the global digital space.

Despite positive trends, the development of enterprises operating in the field of artificial intelligence is accompanied by a number of challenges. The main ones include insufficient investment in research and development, limited access to financing for innovative projects, a shortage of highly qualified specialists in certain regions, as well as risks associated with military actions and business relocation. At the same time, state support for digitalization, the development of innovation infrastructure, and cooperation with international partners create favorable conditions for further growth of the AI sector [49–51].

Therefore, the presented dynamics indicate that artificial intelligence is gradually becoming one of the key drivers of Ukraine's economic modernization. The increase in the number of companies operating in the AI sector reflects the formation of a modern innovation ecosystem capable of ensuring technological modernization of industry, development of digital entrepreneurship, and enhancement of national economic competitiveness. Further expansion of artificial intelligence adoption will contribute to accelerating post-war recovery, implementing innovations in production, and strengthening Ukraine's position in the global high-technology market.

The metallurgical industry is one of the most technologically complex sectors of the economy, where production efficiency depends on the accuracy of managing raw materials, energy resources, temperature regimes, and the quality of finished products. Under modern conditions, artificial intelligence (AI) is becoming one of the key instruments for the digital transformation of metallurgy, as it enables the analysis of large volumes of production data, prediction of equipment failures, and optimization of technological processes.

One of the main areas of AI application in metallurgy is intelligent production automation. Machine learning algorithms analyze data from industrial equipment sensors, monitor melting temperatures, metal composition, and energy consumption, and assist operators in making optimal decisions. According to estimates by international analytical companies, the implementation of AI and industrial analytics can reduce production costs by 10–20% and energy consumption by 5–15%.

An important area is predictive maintenance of equipment. In metallurgical enterprises, downtime of blast furnaces, rolling mills, or electric furnaces can result in significant financial losses. AI-based systems predict potential failures by analyzing vibration, temperature, load, and other operational parameters. This makes it possible to reduce emergency equipment downtime by 20–50% and increase overall enterprise productivity.

Artificial intelligence is also actively used for quality control of metal products. Neural network-based computer vision technologies

Table 2.3 – Main Directions of AI Application in Metallurgy and Statistical Effects

AI Application Direction	Application Examples	Expected Economic Effect
Optimization of production processes	Analysis of melting parameters, blast furnace management, steel composition forecasting	Reduction of production costs by 10–20%
Predictive maintenance	Prediction of failures of furnaces, machines, and rolling lines	Reduction of equipment downtime by 20–50%
Product quality control	Computer vision, automatic defect detection	Reduction of defective products by 15–30%
Energy optimization	Analysis of gas, electricity, and heat consumption	Energy resource savings of 5–15%
Supply chain management	Demand forecasting, optimization of raw material inventories	Reduction of logistics costs by 10–15%
Environmental control	Monitoring of CO_2 emissions, optimization of resource use	Reduction of environmental impact and compliance with ESG standards

enable automatic detection of steel defects, cracks, coating irregularities, and other deviations. For example, large metallurgical companies implement AI-based quality control systems on rolling lines, ensuring product inspection accuracy of more than 95% and reducing the amount of defective production.

For the Ukrainian metallurgical industry, the use of AI is particularly important due to the need to modernize production, reduce energy consumption, and increase competitiveness in international markets. Companies such as Metinvest and ArcelorMittal Kryvyi Rih are developing digital solutions, automation of production processes, and the use of industrial analytics. In the future, AI will become an important factor in the transition of metallurgy toward the Industry 4.0 concept, which involves smart manufacturing, resource efficiency, and environmental sustainability.

Dynamics of digital technologies and AI implementation in metallurgy [52–51].

Artificial intelligence is becoming one of the key factors in the development of modern metallurgy, as it enables the transition

Table 2.4 – Level of AI

Year	Level of AI/digital Technology Implementation in Metallurgy*	Main Trends
2018	Approximately 15% of enterprises	Beginning of industrial analytics adoption
2020	Approximately 30%	Development of automated production control
2022	Approximately 45%	Active implementation of machine learning technologies
2024	More than 60%	Transition toward Smart Factory and Industry 4.0
2025–2026	70%+ (forecast)	Integration of generative AI and autonomous systems

**Estimated based on international studies of industrial digital transformation (McKinsey, Deloitte, World Economic Forum).*

from traditional production to smart industrial systems based on real-time data analysis. The use of AI contributes to increasing productivity, reducing costs, improving the quality of metal products, and enhancing the environmental sustainability of production processes.

For Ukraine, the integration of AI into the metallurgical industry is a strategic direction for the post-war modernization of the economy. Digitalization of metallurgical enterprises will enable the improvement of Ukrainian steel competitiveness in global markets, adaptation of production processes to European ESG requirements, and ensuring sustainable development of the industrial sector.

The Ukrainian metallurgical industry is gradually moving toward the Smart Factory model by applying artificial intelligence (AI), industrial analytics, computer vision, and automated production management systems. The most active example of digital transformation is the Metinvest Group (Table 2.5), which implements AI-based solutions in production processes, quality control, safety management, and data management.

1. Metinvest: one of the most digitally advanced examples of Ukrainian metallurgy

The Metinvest Group is one of the most representative examples of the use of artificial intelligence technologies in Ukraine's metallurgical sector. Through its own IT structure, Metinvest Digital, the company develops solutions based on computer vision and artificial intelligence. One of these solutions is the SPAIS (Smart Production AI System) platform, which uses image recognition algorithms to control production processes, ensure employee safety, and analyze technological operations.

The main areas of AI application within the group include:

– automatic monitoring of production areas using cameras;
– detection of hazardous situations;
– product quality analysis;
– automation of production data processing;
– support of management decisions based on Big Data analytics.

Table 2.5 – Examples of AI Application by Ukrainian Metallurgical Enterprises

Enterprise	AI Application Area	Practical Application	Result
Metinvest	Computer vision, data analytics, automation	Use of the SPAIS platform for object recognition, production process control, and safety monitoring	Improved quality control, automation of data collection and analysis
ArcelorMittal Kryvyi Rih	Production digitalization, automated control	Use of digital production process management systems, equipment monitoring, and environmental control	Optimization of production processes, increased efficiency of resource utilization
Interpipe	Industrial analytics, production automation	Digital production management systems, quality control of pipe products and railway wheels	Increased production stability and product quality
Zaporizhstal	Automation of technological processes	Use of information systems for production control and analysis of technological parameters	Reduction of human factor influence and improvement of management accuracy

According to the company's estimates, the use of digital technologies improves production transparency, reduces decision-making time, and creates the foundation for the transition toward Industry 4.0.

2. ArcelorMittal Kryvyi Rih: digital transformation of a large metallurgical complex

ArcelorMittal Kryvyi Rih is one of the largest enterprises in Ukraine's mining and metallurgical complex with a full production cycle, ranging from iron ore extraction to the production of finished metal products.

The main areas of digitalization include:

– automated control of technological processes;

– equipment monitoring systems;

– digital energy consumption management;

– environmental monitoring of production activities.

The use of AI in such systems enables the analysis of large volumes of production data and prediction of possible deviations in equipment operation. This corresponds to global predictive maintenance practices, where maintenance is performed not after equipment failure occurs, but based on forecasts of its technical condition.

3. Interpipe: digital production and quality control

Interpipe actively uses automated production management systems and digital technologies to increase competitiveness. A particularly important area is the quality control of pipe products and railway wheels, where the accuracy of production parameters is of critical importance.

AI-based solutions in these processes can provide:

– analysis of technological melting parameters;
– product defect detection and control;
– optimization of production modes;
– forecasting of maintenance requirements.

Mechanical engineering is one of the industries where artificial intelligence (AI) is being implemented most actively due to the high level of automation, the use of industrial robots, digital twins, and large volumes of production data. AI technologies enable enterprises to optimize design processes, improve the accuracy of component manufacturing, reduce production costs, and facilitate the transition toward the Smart Factory concept. According to the World Economic Forum, leading manufacturing enterprises implementing Industry 4.0

Table 2.6 – Overall Effect of AI Application in Ukraine's Metallurgy

Effect of AI Implementation	Expected Result
Automation of quality control	Reduction of defective products and improvement of production stability
Production data analysis	Faster managerial decision-making
Predictive maintenance	Reduction of emergency equipment downtime
Resource optimization	Reduction of energy and material costs
Safety improvement	Decrease in production risks

technologies demonstrate significant improvements in productivity, resilience, and environmental efficiency.

One of the key areas of AI application in mechanical engineering is predictive maintenance of equipment. Machine learning algorithms analyze data from industrial sensors and predict possible failures of machine tools, robotic systems, and production lines. This enables a transition from reactive repair approaches to proactive prevention of failures. Research in the field of AI-based predictive maintenance indicates that industrial equipment and sensor data are among the main areas of artificial intelligence application in manufacturing.

An important direction is computer vision and product quality control. In mechanical engineering, AI systems are used for automatic detection of component defects, control of geometric parameters, inspection of welded joints, and analysis of finished products. This is particularly relevant for the automotive industry, aerospace sector, and production of complex equipment, where even minor deviations can result in significant costs.

Artificial intelligence is also transforming design and production planning processes. Generative algorithms assist engineers in creating optimized component designs, conducting strength simulations, reducing material consumption, and shortening the development time of new products. Combined with digital twins, AI enables the simulation of equipment operation before the launch of actual production.

For Ukrainian mechanical engineering enterprises, the implementation of AI is an important direction of technological modernization and integration into the European industrial space. The use of AI contributes to increasing competitiveness, reducing energy consumption, automating production processes, and developing high-tech exports. In the future, mechanical engineering will move from traditional production models toward intelligent manufacturing systems, where decisions are made based on real-time data analysis.

The Global Lighthouse Network of the World Economic Forum included 153 leading manufacturing enterprises in 2023 that applied

Table 2.7 – Statistical Indicators of the Impact of Artificial Intelligence on Mechanical Engineering [55–60]

AI Application Direction	Practical Application in Mechanical Engineering	Statistical Effect
Predictive maintenance	Analysis of the condition of machine tools, robots, and production lines	Reduction of unplanned downtime by up to 30–50%
Optimization of production processes	AI-based analysis of production parameters, automatic equipment adjustment	Increase in productivity by 20–30%
Computer vision	Quality control of components, defect detection	Reduction of defect rates by 15–40%
Digital twins	Simulation of machine and production system operation	Reduction of product development time by up to 30%
Production robotization	Autonomous robots, automated assembly lines	Increase in operational efficiency by 20–35%
Energy optimization	Analysis of equipment energy consumption	Reduction of energy consumption by 10–20%
Generative AI in design	Creation of optimized component structures	Reduction of development cycle time by 30–50%

Table 2.8 – Dynamics of AI Implementation in the Manufacturing Sector [62–64]

Year	Level of AI Adoption in Manufacturing	Main Trends
2020	Approximately 6% of enterprises	Beginning of large-scale machine learning adoption
2022	10–15%	Development of automation and Industry 4.0 technologies
2023	More than 13% of manufacturing companies (in selected countries)	Active implementation of AI in production processes
2025	More than 20% (forecast)	Development of generative AI and digital twins
2026	Active scaling of Smart Factory solutions	Integration of AI, robotics, and data analytics

AI, robotics, cloud technologies, and Big Data solutions to improve productivity. By 2026, the network had expanded to 238 industrial facilities, demonstrating the accelerating adoption of intelligent technologies in global manufacturing.

AI implementation in Ukrainian mechanical engineering

In Ukraine, the implementation of artificial intelligence in mechanical engineering is at an active development stage. AI solutions are most

Table 2.9 – Examples of AI Application by Ukrainian Mechanical Engineering Enterprises [65–69]

Enterprise	Mechanical Engineering Sector	AI Application Areas	Expected Effect
Ukroboron-prom	Defense mechanical engineering	AI for data analysis, production automation, development, and modernization of military equipment	Increased speed of development, production accuracy, and management efficiency
Motor Sich	Aerospace engineering	Automated production control, digital modeling of components, analysis of technical parameters	Improvement of product quality and accuracy of technological processes
Progress	Aerospace engineering	CAD/CAM technologies, digital design, automation of engineering processes	Reduction of time required for engineering preparation of production
Corum Group	Mining machinery engineering	Digital equipment management systems, analysis of operational data	Increased equipment reliability and optimization of maintenance services
Interpipe	Heavy mechanical engineering, railway products	Production automation, data analysis, product quality control	Reduction of defective products and increase in productivity
Kremenchuk Railway Car Building Works	Transport mechanical engineering	Digital design, automated production control systems	Optimization of the production cycle and improvement of railway car quality

actively used by enterprises operating in defense mechanical engineering, transport engineering, industrial equipment manufacturing, and companies with developed digital production systems. The main areas of application include computer vision, equipment failure prediction, automation of production processes, big data analysis, and digital twins.

1. Defense mechanical engineering of Ukraine

Enterprises of Ukraine's defense-industrial complex are actively using artificial intelligence elements for the development and production of modern equipment. The main areas include big data analysis, automation of testing processes, computer modeling, and the creation of autonomous systems. Research by Ukrainian scholars indicates that AI is used at various stages of the defense product life cycle: from design and production to operation and modernization.

2. Metinvest and the mechanical engineering sector

Although the company belongs to the metallurgical sector, its structure includes enterprises with a mechanical engineering profile, particularly in the areas of repair, manufacturing of components, and industrial equipment production. The Group implements AI-based solutions for production planning, computer vision, quality control, and production data analysis. In particular, the company uses the SPAIS platform for computer vision, safety monitoring, and analytics, as well as the MIOSIAR system for automating document and data management processes.

3. Corum Group

Enterprises producing mining equipment use digital technologies to improve the efficiency of machinery operation. AI can be applied for analyzing equipment performance parameters, predicting component wear, and planning maintenance activities. This approach corresponds to the global trend of transitioning from scheduled repairs to predictive maintenance.

4. Aerospace engineering

Ukrainian aerospace enterprises use digital modeling, automated design systems, and production data analysis. The integration of AI

makes it possible to optimize component designs, reduce the number of testing procedures, and improve the accuracy of manufacturing complex components.

Ukrainian mechanical engineering enterprises are gradually moving from traditional production models toward the Industry 4.0 concept, where artificial intelligence becomes an important tool for enhancing competitiveness. The most promising areas include prediction of equipment technical conditions, automated quality control, digital design, and optimization of production processes. AI is particularly important for the post-war recovery of Ukraine's mechanical engineering sector, as it enables production modernization, integration of Ukrainian enterprises into European manufacturing chains, and the development of high-tech industries.

The use of artificial intelligence in the food industry is one of the key directions of digital transformation of modern production. AI technologies are applied for automation of production processes, product quality control, demand forecasting, logistics optimization, and inventory management. Through machine learning algorithms, enterprises can analyze large volumes of data in real time, which contributes to increased productivity, reduced production costs, and ensuring consistent quality of food products.

One of the leaders in artificial intelligence implementation is Nestlé, which uses AI for consumer demand forecasting, development of new products, recipe optimization, and supply chain management. In cooperation with IBM, the company applies generative artificial intelligence to create environmentally friendly packaging materials, contributing to the implementation of its sustainable development strategy. In addition, AI algorithms help the company analyze market trends more quickly and reduce the time required to launch new products on the market (Nestlé, 2025).

PepsiCo is also actively implementing artificial intelligence technologies. The company uses computer vision for automatic product quality control on production lines, as well as digital twins

of production facilities developed in cooperation with Siemens and NVIDIA. In 2026, PepsiCo announced the expansion of generative AI use in cooperation with Google Cloud to forecast demand, optimize production processes, and improve logistics efficiency. This enables the company to reduce production losses, decrease energy consumption, and enhance the effectiveness of managerial decision-making.

Companies such as Danone, Unilever, and Mondelez International are also actively integrating AI into their business processes. In particular, Danone uses artificial intelligence for demand forecasting and inventory management, which helps reduce the volume of unsold products. Unilever applies machine learning algorithms to analyze consumer behavior, optimize production processes, and improve logistics operations, while Mondelez International uses AI for digital production monitoring, predictive maintenance of equipment, and optimization of production lines.

In Ukraine, artificial intelligence technologies are gradually being implemented by large agricultural and food-processing companies, including MHP, Kernel, and Astarta-Kyiv. These companies use computer vision, machine learning, big data analytics, and forecasting systems to improve production efficiency, control product quality, and optimize logistics processes. Although the scale of AI adoption in Ukraine's food industry is still lower compared with global leaders, the spread of digital technologies creates favorable conditions for increasing enterprise competitiveness, reducing production costs, and ensuring sustainable development of the sector [70–72].

The presented indicators demonstrate that artificial intelligence has become an important tool for improving the efficiency of food industry enterprises. The largest international corporations, such as Nestlé [70] and PepsiCo [72], integrate AI not only into production operations but also into strategic management, marketing, logistics, and development planning. In particular, Nestlé applies digital systems across almost 90% of its production facilities, enabling real-time optimization of factory operations.

Table 2.10 – Indicators of Activity and Effects of AI Implementation in Food Industry Companies

Enterprise	Key Performance Indicators	Areas of AI Application	Quantitative Effect of AI Implementation
Nestlé	Operates in 185 countries worldwide, has 335 production facilities, sales volume in 2025 amounted to CHF 89.5 billion	AI-based demand analytics, digital product twins, production optimization, automation of marketing and sales processes	The connected digital management system covers almost 90% of factories; the AI virtual assistant automates up to 40% of routine sales tasks and provides time savings of 20–35%
PepsiCo	Revenue in 2024 amounted to approximately USD 92 billion; products are sold in more than 200 countries and territories	Digital production twins, computer vision, AI solutions for factory management and supply chain optimization	Initial AI-based digital twin projects increased production process efficiency by up to 20%, reduced capital expenditures (CAPEX) by 10–15%, and enabled detection of up to 90% of potential problems before physical modernization
Danone	One of the world's largest producers of dairy products, infant nutrition, and beverages	Machine learning for demand forecasting, inventory management, and supply chain optimization	AI improves sales forecasting accuracy and helps reduce product losses
Mondelez International	Owner of global biscuit and snack brands, operating in more than 150 countries	AI for product development, consumer analysis, recipe optimization, and production process improvement	AI reduces the time required to develop new products from months to weeks in certain processes
Unilever	International company producing food products and consumer goods	AI-based consumer behavior analytics, demand forecasting, logistics automation	Increased accuracy of supply planning and optimization of production costs

A particularly significant economic effect is demonstrated by the use of digital twins in production. The example of PepsiCo shows that AI-based modeling of production processes enables enterprises to increase production capacity by 20%, reduce investment costs by 10–15%, and predict potential problems before they occur. This indicates the transition of the food industry from traditional automation toward intelligent production management. Therefore, the implementation of artificial intelligence in the food industry provides not only cost reduction but also creates new competitive advantages for enterprises: faster response to changes in demand, reduction of production losses, improvement of product quality, and implementation of sustainable development principles.

Nestlé is one of the world's leading food industry companies that actively implements artificial intelligence (AI) technologies in production, management, and marketing processes. The company operates in more than 180 countries, employs over 270,000 people, and owns more than 300 production facilities. As part of its digital transformation strategy, Nestlé uses artificial intelligence to improve production efficiency, analyze consumer behavior, forecast demand, and develop innovative products.

One of the key areas of AI application at Nestlé is intelligent supply chain management and demand forecasting. Machine learning algorithms analyze large volumes of data on sales, seasonality, regional characteristics, and consumer trends. This enables the company to plan production more accurately, optimize inventory levels, and reduce the risk of overproduction. The use of AI-driven analytics also contributes to reducing food waste and improving the sustainability of production processes.

Nestlé has also gained extensive experience in the application of generative artificial intelligence and digital twins. The company uses AI platforms to simulate production processes, analyze equipment performance, and accelerate new product development. For example, digital tools enable faster testing of new recipes, assessment

of consumer preferences, and prediction of the market potential of products before they are introduced into production.

Another important area is the use of computer vision and automated quality control. AI systems analyze production parameters, verify product compliance with quality standards, detect packaging defects, and identify deviations in technological processes. This is particularly important for large food manufacturing enterprises, where even a slight improvement in inspection accuracy can significantly reduce raw material losses and enhance product safety.

Nestlé's experience demonstrates that artificial intelligence is not only an automation tool but also a strategic driver of competitiveness for food manufacturing enterprises. Through AI, the company combines improved economic efficiency with the principles of sustainable development by reducing resource consumption, optimizing production processes, and responding more rapidly to changing consumer needs. Nestlé's practices can serve as a valuable example for Ukrainian food industry enterprises seeking to implement digital technologies within the framework of industrial modernization and post-war economic recovery.

Nestlé's experience demonstrates that artificial intelligence has become one of the key drivers of digital transformation in the food industry. The adoption of AI enables the company to move beyond conventional automation toward intelligent management of production and business operations. By analyzing large volumes of data, Nestlé improves the accuracy of demand forecasting, optimizes production planning, and responds more rapidly to changing market conditions.

The implementation of artificial intelligence technologies at Nestlé spans a wide range of activities, from product quality control and production line management to new product development and the personalization of marketing strategies. The application of computer vision, machine learning, and digital twin technologies helps reduce production losses, improve resource efficiency, minimize equipment downtime, and ensure consistently high product quality. Moreover,

Table 2.11 – Main Areas of AI Application at Nestlé

Application Area	AI Technologies	Practical Outcome
Demand forecasting	Machine learning, Big Data analytics	More accurate production planning and inventory optimization
Quality control	Computer vision	Detection of product and packaging defects
New product development	Generative AI, data analytics	Reduced time required to develop new products
Production management	Digital twins, predictive maintenance	Reduced equipment downtime and improved operational efficiency
Marketing	AI-driven consumer analytics	Personalized customer offerings and enhanced customer engagement

Nestlé's experience illustrates that AI is not merely an operational tool but a strategic asset that supports innovation, sustainability, and long-term competitive advantage in the global food industry.

AI also plays a particularly important role in supporting the implementation of sustainable development principles. AI-based solutions help Nestlé reduce food waste, optimize energy and raw material consumption, and improve logistics processes. Thus, digital technologies serve not only as a means of increasing profitability but also as an important driver of the company's environmental and social responsibility.

Nestlé's experience demonstrates that the effective use of artificial intelligence requires a comprehensive approach combining technological innovation, workforce development, data management, and strategic planning. The company employs AI not as an isolated automation tool but as an integral component of its long-term business strategy aimed at enhancing competitiveness in the global marketplace.

For Ukrainian food industry enterprises, Nestlé's experience can serve as an important benchmark for digital modernization. The implementation of similar technologies will enable companies to increase production efficiency, improve product quality, optimize operating costs, and ensure the sustainable development of the industry under conditions of intensifying international competition.

2.2. EXPERIENCE OF DEVELOPED COUNTRIES IN ECONOMIC MODERNIZATION THROUGH THE USE OF ARTIFICIAL INTELLIGENCE

In recent years, the economic modernization of developed countries has become increasingly associated with the implementation of artificial intelligence (AI) technologies, which have emerged as one of the principal drivers of innovation, productivity growth, and the creation of new competitive advantages. AI is applied not only in the field of information technology but also across manufacturing, healthcare, financial services, transportation, energy, and public administration. The world's leading economies regard artificial intelligence as a strategic resource that facilitates the transition from traditional production models to a digital economy based on data, automation, and intelligent decision-making.

The United States is one of the global leaders in the development and application of AI, where artificial intelligence has become an important component of economic policy and technological leadership. American companies actively implement AI across manufacturing, finance, logistics, and service industries. Corporations such as Microsoft, Google, Amazon, and Tesla use artificial intelligence to automate production processes, analyze large-scale datasets, develop autonomous transportation systems, and optimize business models. According to analytical studies, the widespread adoption of AI is expected to generate significant productivity growth in the U.S. economy over the coming decades.

The United States of America is the global leader in the development and implementation of artificial intelligence (AI) technologies. It has established the world's largest innovation ecosystem, bringing together universities, research institutions, venture capital, technology corporations, and government agencies. Owing to substantial investments in research and development, American companies create foundational AI models that are widely used in business, healthcare,

defense, finance, transportation, and public administration. According to the Stanford AI Index, the United States has ranked first globally for several consecutive years in terms of private investment in AI, driving the rapid development of the digital economy.

A crucial role in AI advancement is played by leading American technology companies, including OpenAI, Google, Microsoft, NVIDIA, Amazon, and Meta. These corporations invest tens of billions of dollars in the development of large language models, generative AI, supercomputers, and specialized AI processors. For example, OpenAI developed the GPT family of models, Microsoft integrated them into Microsoft 365 Copilot, and NVIDIA has become the global leader in manufacturing graphics processing units (GPUs) for training neural networks. These investments are driving a new wave of digital transformation for enterprises worldwide.

One of the most successful examples of AI adoption is found in the U.S. financial sector. Banks, including JPMorgan Chase, employ machine learning algorithms for automated fraud detection, credit risk assessment, financial forecasting, and customer service automation. According to company reports, the implementation of AI has significantly reduced the time required to analyze legal documents while improving the efficiency of internal business processes, resulting in substantial cost savings and lower operational risks.

In the healthcare sector, the United States extensively applies artificial intelligence to disease diagnosis, medical image analysis, personalized medicine, and drug discovery. Organizations such as IBM, Mayo Clinic, and numerous biotechnology startups utilize deep learning algorithms for the early detection of oncological, cardiovascular, and neurological diseases. The use of AI significantly reduces diagnostic time, improves diagnostic accuracy, and supports healthcare professionals in making more informed clinical decisions.

The American manufacturing sector also makes extensive use of artificial intelligence technologies. Tesla, for example, applies computer vision and machine learning algorithms to develop

autonomous driving systems. Manufacturing enterprises employ AI for predictive maintenance, automated quality control, production process optimization, and cost reduction. By analyzing large volumes of production data, companies can significantly reduce equipment downtime, improve operational efficiency, and increase labor productivity [86–87].

Significant achievements in the United States can also be observed in the fields of e-commerce and logistics. Amazon uses artificial intelligence for demand forecasting, personalized product recommendations, automation of warehouse operations, and optimization of logistics routes. Robotic fulfillment centers enable the company to process millions of orders daily with high speed and minimal operational costs. Similar technologies are now being actively adopted by companies in many countries around the world [85].

A separate direction of AI development is its application in the public sector and defense industry. The U.S. Department of Defense implements large-scale programs for integrating artificial intelligence into satellite data analysis, cybersecurity, threat forecasting, support for military decision-making, and management of autonomous systems. In addition, the federal government actively funds fundamental research through agencies such as DARPA and the National Science Foundation, contributing to the emergence of new technological breakthroughs.

The experience of the United States demonstrates that successful AI development is based on a combination of government support, private investment, advanced scientific research, and close cooperation between universities and businesses. American case studies confirm that AI implementation contributes to productivity growth, increased enterprise competitiveness, development of an innovation-driven economy, and the creation of new high-technology jobs. Therefore, the U.S. experience is one of the most important benchmarks for countries seeking to modernize their economies through artificial intelligence technologies [88–90].

The data presented in the table indicate that the United States holds leading positions globally in terms of the scale of artificial intelligence implementation across various sectors of the economy. AI is most actively used in information technologies, finance, healthcare, e-commerce, logistics, and automotive manufacturing. A distinctive feature of the American model is the combination of fundamental scientific research with large-scale commercialization of innovations, which ensures the rapid adoption of advanced technologies into business operations.

The development of generative artificial intelligence is of particular importance, as it has become one of the key directions of digital transformation in business. Companies such as OpenAI and Microsoft have created universal tools that automate document preparation, information analysis, programming, marketing research, and customer communication. As a result, enterprises reduce the time spent on routine operations, increase labor productivity, and accelerate managerial decision-making processes.

The results of artificial intelligence application in the financial sector are equally significant. U.S. banking institutions use machine learning algorithms to assess credit risks, detect fraudulent activities, forecast financial indicators, and automate internal business processes. The use of AI enables a significant reduction in operational costs, improves the accuracy of large-scale data analysis, and ensures a higher level of security for financial transactions.

In the healthcare sector, artificial intelligence technologies contribute to improving the quality of medical services and increasing the efficiency of healthcare professionals. AI solutions are used for medical image analysis, automated generation of clinical documentation, early disease detection, and decision support for physicians. This helps reduce the administrative workload of medical personnel, improve diagnostic accuracy, and enhance patient treatment outcomes.

Significant economic effects are demonstrated by the use of artificial intelligence in e-commerce, logistics, and industry.

Companies such as Amazon and Tesla apply computer vision, predictive analytics, and machine learning algorithms to optimize production processes, automate warehouse operations, forecast demand, manage transportation systems, and develop autonomous technologies. This contributes to increasing enterprise productivity, reducing logistics costs, and improving the quality of customer service.

Overall, the experience of the United States confirms that the systematic implementation of artificial intelligence is one of the key factors in enhancing the competitiveness of the national economy. The combination of government support, substantial private investment, a developed innovation ecosystem, and close cooperation between businesses and research institutions ensures the sustainable leadership of the United States in the field of AI. This experience can be used by Ukraine to accelerate the digital transformation of enterprises, develop innovative entrepreneurship, and modernize the economy in line with current global trends (Table 2.12).

Germany provides an important example of AI implementation by integrating artificial intelligence within the framework of the "Industry 4.0" concept. German industrial enterprises use AI to create "smart factories", where production processes are controlled through sensors, robotic systems, and machine learning algorithms. Companies such as Siemens and Bosch apply artificial intelligence for predictive equipment maintenance, energy consumption optimization, and improving product quality. This approach enables higher industrial efficiency and helps maintain competitiveness in global markets.

Japan uses artificial intelligence as a tool for addressing demographic challenges and modernizing the manufacturing sector. The country actively develops robotics, automated production systems, and intelligent management solutions. Companies such as Toyota and FANUC use AI to optimize manufacturing processes, control product quality, and develop autonomous technologies. A distinctive feature of the Japanese model is the combination of artificial intelligence with robotics, which helps compensate for labor shortages and increase economic productivity.

Table 2.12 – Successful U.S. Projects Using Artificial Intelligence

Company / Project	Industry	AI Application	Main Results
OpenAI – ChatGPT (GPT)	Generative AI	Development of large language models for automation of work processes, education, programming, and business activities	More than 500 million weekly users in 2025–2026; widespread adoption in education and the corporate sector.
Amazon	E-commerce and logistics	Personalized recommendations, demand forecasting, warehouse optimization, and delivery route management	Reduced order fulfillment time, increased productivity of logistics centers, and improved quality of customer recommendations.
Tesla [99]	Automotive industry	Autopilot systems, computer vision, and road environment analysis	Continuous improvement of autonomous driving systems and automation of vehicle manufacturing processes.
JPMorgan Chase	Banking sector	Risk analysis, fraud detection, and automation of document processing	AI implementation generated approximately USD 2 billion in annual business value through improved process efficiency.
Kaiser Permanente	Healthcare	Generative AI for medical documentation and physician support	Large-scale implementation of AI assistants in 40 hospitals across eight U.S. states, reducing administrative workload for medical staff.
Common-Spirit Health	Healthcare	Automation of clinical processes and analysis of medical data	Approximately 250 AI solutions are used, generating more than USD 100 million in annual economic value and contributing to a reduction in sepsis-related mortality.
Microsoft – Microsoft Copilot	Software development	Generative AI for office applications and software development	Automation of document creation, data analysis, programming, and business process management in the corporate sector.
NVIDIA	High technologies	Development of graphics processing units (GPUs) and AI platforms	NVIDIA GPUs have become the global standard for training large artificial intelligence models and advancing generative AI technologies.

Japan is one of the world's leading countries in the development and practical application of artificial intelligence (AI). Due to its strong industrial base, high level of automation and robotics, and significant investments in research and development, the country actively integrates AI technologies into manufacturing, healthcare, transportation, public administration, and service sectors. The Japanese AI development model focuses not only on economic efficiency but also on addressing social challenges, particularly population aging and labor shortages.

One of the key areas of AI application in Japan is industry and manufacturing. Japanese corporations actively use intelligent systems to automate production processes, control product quality, predict equipment maintenance needs, and optimize supply chains. Companies such as Toyota Motor Corporation, Honda Motor Co., Ltd., and FANUC Corporation apply machine learning algorithms and robotic systems to increase production efficiency.

The development of artificial intelligence in Japan's automotive industry is particularly significant. Toyota Motor Corporation actively researches autonomous driving technologies, using AI to analyze road conditions, predict the behavior of other road users, and improve vehicle safety. Japanese manufacturers also apply artificial intelligence to develop next-generation electric vehicles, optimize battery systems, and advance the concept of "smart mobility."

An important area of AI application is robotics, where Japan has traditionally held leading positions. Due to the rapid aging of its population, the country is actively implementing robots with artificial intelligence capabilities to assist elderly people, support healthcare services, provide customer service, and improve industrial operations. For example, robots developed by SoftBank Robotics are used for communication, customer support, and performing social assistance functions.

Japan has also achieved significant results in the field of healthcare. Artificial intelligence is used for medical image analysis, early

disease detection, patient condition forecasting, and the development of personalized treatment approaches. Japanese medical institutions use AI systems to support physicians in diagnosing cancer, cardiovascular diseases, and other complex medical conditions. This is particularly important for a country with a high proportion of elderly citizens.

In agriculture, Japan applies artificial intelligence to develop "smart farming" solutions. Due to limited land resources and labor shortages, agricultural enterprises are implementing systems for automated yield monitoring, soil condition analysis, weather forecasting, and robotic crop management. AI technologies enable more efficient resource utilization and contribute to maintaining stable food production.

The Japanese government actively supports the development of artificial intelligence through national digital transformation strategies. In 2019, the AI Strategy Japan was introduced, focusing on the advancement of AI research, development of professional expertise, integration of technologies into industry and public administration, and strengthening international cooperation. Japan also collaborates with universities and the private sector to establish innovative artificial intelligence research centers.

Another important area is the use of AI in the financial sector and service industries. Japanese banks apply machine learning algorithms for risk analysis, fraud prevention, automation of customer consultations through chatbots, and forecasting financial transactions. In the retail sector, AI is used for personalized recommendations, consumer behavior analysis, and inventory management optimization.

Japan is also developing the application of artificial intelligence in transportation and urban infrastructure. Intelligent transportation systems help optimize traffic flows, predict congestion, manage energy consumption, and support the development of "smart cities." Such technologies are implemented within Smart City initiatives, where AI is used to improve the quality of life and efficiency of urban services.

Thus, Japan's experience demonstrates a comprehensive approach to the use of artificial intelligence as a tool for economic modernization

and social development. A distinctive feature of the Japanese model is the combination of high-tech manufacturing, robotics, government support, and a focus on addressing demographic challenges. The use of AI enables Japanese enterprises to increase competitiveness, optimize production processes, and create a foundation for the development of the future digital economy.

1. Toyota Motor Corporation – Artificial Intelligence in Manufacturing and Autonomous Mobility

Toyota Motor Corporation is one of the most prominent examples of AI application in Japan. The company implements machine learning algorithms to optimize production processes, control vehicle quality, predict equipment failures, and develop autonomous transportation technologies. AI systems analyze large volumes of manufacturing data, enabling the reduction of equipment downtime, improvement of production efficiency, and enhancement of product quality.

Figura 2.2 – Use of Artificial Intelligence in the Processes of Economic Modernization in Japan

Source: Developed by the author using artificial intelligence tools

One of Toyota's promising areas of development is the creation of "smart mobility" – transportation systems that use artificial intelligence to analyze the road environment, support drivers, and advance autonomous vehicle technologies. The company is also developing the Woven City concept – an experimental "smart city" where autonomous transportation, robotics, and AI-based solutions for urban infrastructure are being tested.

2. FANUC – Smart Factories and Industrial Robots

FANUC Corporation is a global leader in industrial robotics and manufacturing automation. The company uses artificial intelligence to create "Smart Factories", where robots can independently perform production operations, monitor product quality, and predict maintenance requirements.

The foundation of such systems is the FANUC FIELD platform, which integrates industrial robots, production equipment, and analytical

Figura 2.3 – Use of Artificial Intelligence in the Processes of Economic Modernization

Source: Developed by the author using artificial intelligence tools

systems through the use of Internet of Things (IoT) technologies and artificial intelligence. This enables enterprises to increase productivity, reduce costs, and transition toward the Industry 4.0 model.

3. SoftBank Robotics – Social Robots with Artificial Intelligence

SoftBank Robotics created one of the most well-known AI-powered robots – Pepper. This robot is capable of recognizing human emotions, maintaining dialogue, answering questions, and interacting with people.

Pepper was used in shopping centers, banks, hotels, and medical institutions in Japan as a customer support assistant. The project demonstrated the potential of artificial intelligence applications in the service sector, where communication and personalized interaction are essential.

4. Honda – Artificial Intelligence in Robotics

Honda Motor Co., Ltd. has been developing intelligent robotics for many years. The company's most famous project was the ASIMO robot, which became the foundation for further research in the field of autonomous robotics.

Current Honda research focuses on creating systems capable of assisting elderly people, performing complex physical tasks, and working alongside humans in industrial environments. The use of AI enables robots to adapt to changes in their surroundings.

5. AI in Japanese Healthcare

Japan actively applies artificial intelligence in healthcare due to the challenges associated with population aging. AI is used for medical image analysis, early disease detection, patient condition forecasting, and supporting medical decision-making.

Japanese healthcare institutions implement intelligent systems that help physicians analyze information faster and improve diagnostic accuracy. The use of robotic care systems for elderly people is particularly important.

6. AI in Japanese Agriculture

Due to labor shortages, Japan's agricultural sector is actively adopting artificial intelligence technologies. Machine learning systems

analyze plant conditions, soil quality, weather patterns, and predict crop yields.

Robotic farms use automated systems for planting, harvesting, and monitoring production processes. This helps improve agricultural efficiency and reduce dependence on human labor.

7. Mitsubishi Motors – Human–Robot Collaboration

Mitsubishi Motors Corporation is developing projects aimed at integrating robots into manufacturing processes. The company explores the use of humanoid robots in automotive production to perform complex operations and address workforce shortages.

This direction demonstrates the transition from simple automation toward "physical artificial intelligence," where robots can analyze situations, learn, and interact with humans.

Japan's experience demonstrates that artificial intelligence has become one of the key instruments for economic modernization. The greatest impact is observed in industry, robotics, healthcare, transportation, and the service sector. The Japanese model of AI development is based on the combination of high-tech manufacturing, government support, scientific research, and the practical implementation of innovations. The use of these technologies enables the country to compensate for labor shortages, increase the competitiveness of enterprises, and build the foundation for the digital economy of the future.

South Korea is actively developing the artificial intelligence economy through the support of high-tech industries, digital infrastructure, and innovative enterprises. Companies such as Samsung Electronics and LG Electronics apply AI technologies in electronics manufacturing, supply chain management, and the development of intelligent devices. The government implements AI development programs aimed at training specialists, supporting research activities, and creating a digital economic ecosystem.

China has also achieved significant results in the application of artificial intelligence, identifying AI as one of the key priorities of its long-term

economic development strategy. Chinese companies use artificial intelligence in manufacturing, e-commerce, finance, transportation, and urban infrastructure. Companies such as Alibaba Group and Tencent apply AI technologies to analyze consumer behavior, automate services, and develop digital platforms. Large-scale government investments in digital infrastructure contribute to the rapid expansion of AI solutions across various sectors of the economy.

South Korea is one of the most technologically advanced countries in the world, actively using artificial intelligence (AI) as a tool for economic development, digital transformation, and increasing the competitiveness of its industry. Due to its strong position in electronics, telecommunications, automotive manufacturing, and semiconductor production, the country has developed its own AI ecosystem that combines government programs, university research, and innovative projects of large corporations.

One of the main directions of AI development in South Korea (Fig. 2.4) is industry and the concept of Smart Factory (smart manufacturing). Korean enterprises are actively implementing machine learning systems, robotics, computer vision, and big data analytics to automate production processes. Companies such as Samsung Electronics, LG Electronics, and Hyundai Motor Company use AI to control product quality, predict equipment failures, and optimize production lines.

Samsung's experience in the field of artificial intelligence is particularly successful. The corporation applies AI technologies in the production of semiconductors, smartphones, and household appliances. Artificial intelligence algorithms analyze manufacturing data, detect product defects at early stages, and help optimize resource utilization. In addition, Samsung develops its own AI platforms for smartphones and digital devices, creating the concept of a "smart home," where technologies adapt to users' needs [100].

An important area is the development of artificial intelligence in the automotive industry. Hyundai Motor Group uses AI to create autonomous driving systems, analyze road conditions, and improve

Figure 2.4 – Use of Artificial Intelligence in the Processes of Economic Modernization in South Korea

Source: Developed by the author using artificial intelligence tools

traffic safety. As part of the development of future transportation, the company invests in autonomous vehicle technologies, robotics, and intelligent transportation systems [101]. The use of AI makes it possible to reduce the number of accidents, optimize traffic flows, and develop the concept of "smart mobility" [102].

South Korea is also actively developing the field of robotics, using artificial intelligence to automate manufacturing, healthcare, and social assistance. Robots equipped with AI systems are used in industrial enterprises, hospitals, and the service sector. Due to the challenges associated with an aging population, the country considers robots an important tool for supporting elderly people, providing patient care, and compensating for labor shortages.

In the healthcare sector, artificial intelligence is used for medical image analysis, disease diagnosis, and patient condition forecasting.

Figura 2.5 – Use of Artificial Intelligence in the Processes of Economic Modernization in South Korea

Source: Developed by the author using artificial intelligence tools

Korean hospitals are implementing AI systems to analyze X-ray images, computed tomography scans, and other medical data. This enables doctors to detect diseases faster, improve diagnostic accuracy, and provide more personalized treatment.

South Korea pays significant attention to the development of the semiconductor industry and AI infrastructure. The country is one of the world leaders in the production of microchips, which form the foundation of modern artificial intelligence systems. Companies such as Samsung Electronics and SK Hynix manufacture high-performance memory and components required for the operation of large AI models. This creates a strategic advantage for the country in the global competition for leadership in the field of artificial intelligence.

The South Korean government actively supports AI development through national digital transformation strategies. The country

implements programs aimed at developing the AI industry, financing research, establishing artificial intelligence centers, and supporting the training of specialists. Government policy is focused on making South Korea one of the global hubs for AI development and ensuring the competitiveness of the national economy.

An example of large-scale AI implementation is the development of Smart Cities. In South Korean cities, intelligent systems are used to manage transportation, energy consumption, security, and urban infrastructure. AI analyzes traffic flows, supports resource management, and improves the quality of public services provided to citizens.

Thus, South Korea's experience demonstrates that artificial intelligence is an important factor in economic modernization and industrial development. The country's success is ensured by the combination of government support, powerful technology corporations, scientific advancement, and large-scale implementation of digital technologies. The Korean model of AI adoption shows that investments in innovation, robotics, and digital infrastructure make it possible to increase enterprise productivity, strengthen economic competitiveness, and create new opportunities for sustainable development.

The United Kingdom considers artificial intelligence one of the key areas of innovation-driven development and improving economic competitiveness. The country actively develops AI startups, research centers, and cooperation programs between government institutions, universities, and businesses. AI is used in London's financial sector, healthcare, public services, and industry. Particular attention is paid to the responsible use of AI, data protection, and the development of an appropriate regulatory framework.

The experience of European Union countries demonstrates that successful economic modernization based on artificial intelligence requires not only technological investments but also the development of human capital. European countries are implementing digital transformation programs aimed at enhancing employees' digital competencies, supporting innovative enterprises, and creating a secure

and ethical environment for AI adoption. Particular attention is paid to integrating artificial intelligence with sustainable development principles, whereby digital technologies are used to reduce resource consumption, promote environmentally friendly production, and improve the efficiency of management processes.

Thus, the experience of developed countries indicates that artificial intelligence is becoming one of the key drivers of structural economic modernization. The most successful models of AI development are based on a combination of government support, investment in research and development, advanced digital infrastructure, and the active integration of AI technologies into business processes. For Ukraine, the application of international experience may become an important direction for post-war economic modernization, as the implementation of artificial intelligence will contribute to increasing productivity, developing innovative industries, attracting investment, and forming a competitive European-oriented economy.

Table 2.13 – Developed Countries in Economic Modernization through the Use of Artificial Intelligence [73–80]

Country	Main Areas of AI Application in the Economy	Examples of Enterprises / Sectors	Results of Economic Modernization
1	2	3	4
USA	Development of generative AI, production automation, big data analytics, autonomous systems, digital platforms	Microsoft – generative AI and cloud AI services; Google – machine learning and AI analytics; Tesla – autonomous transportation	Increased labor productivity, development of high-tech industries, formation of new business models
Germany	Industry 4.0 concept, smart factories, robotics, predictive maintenance of equipment	Siemens – digital twins and production automation; Bosch – AI applications in industry	Increased production efficiency, reduced equipment downtime, optimized resource utilization

End of Table 2.13

1	2	3	4
Japan	Robotics, automated production systems, AI in transportation and industry	Toyota – AI in automotive manufacturing; FANUC – industrial robots	Compensation for labor shortages, improved product quality, development of high-precision manufacturing
South Korea	AI in electronics manufacturing, digital platforms, intelligent devices	Samsung Electronics – AI in electronics production; LG Electronics – smart technologies	Increased industrial innovation, development of the digital economy, strengthening of technology exports
China	Large-scale AI implementation in industry, e-commerce, finance, transportation, and urban management	Alibaba Group – AI analytics and digital commerce; Tencent – AI services and digital platforms	Formation of a large-scale digital economy, business automation, development of innovative ecosystems
United Kingdom	AI startups, financial technologies, healthcare, digital public services	London financial sector, AI companies, university research centers	Increased competitiveness of the service sector, development of innovative entrepreneurship
France	AI research, industrial automation, defense technologies, digital services	Dassault Systèmes – digital modeling; industrial enterprises	Development of high-tech sectors, digital transformation of industry
Singapore	Government AI platforms, smart city solutions, digital governance, financial technologies	Banking sector, logistics, digital public services	Improved efficiency of public administration, attraction of investments, development of the digital economy

The experience of developed countries demonstrates that artificial intelligence has become one of the most important factors in the modernization of the contemporary economy. Its implementation enables the transition from traditional economic models to a digital economy based on the use of big data, automation, intelligent

analytics, and management decision-making based on predictive models. AI is gradually transforming from merely a technological tool into a strategic resource for the economic development of states.

The experience of the United States shows that the leading role in artificial intelligence development is driven by the combination of a strong private sector, scientific research, and venture capital investment. American technology companies actively use AI to develop cloud technologies, automate business processes, create new digital products, and increase labor productivity. This contributes to the formation of an innovation-driven economy, where knowledge, technologies, and the ability to rapidly adapt to changes become key competitive advantages.

Germany's model of economic modernization based on the concept of "Industry 4.0" demonstrates the importance of integrating artificial intelligence into the manufacturing sector. The use of smart factories, robotic systems, digital twins, and predictive maintenance technologies enables industrial enterprises to increase production efficiency, reduce costs, and ensure high product quality. This approach represents a successful combination of a traditional industrial base with advanced digital technologies.

Japan's experience demonstrates that artificial intelligence can serve as an effective tool for addressing socio-economic challenges, particularly labor shortages caused by population aging. The combination of AI and robotics enables the automation of complex production operations, supports the stability of industrial production, and increases enterprise competitiveness. The Japanese model proves that digital transformation should consider not only economic factors but also demographic challenges.

The experience of South Korea and China highlights the importance of government support in the development of artificial intelligence. The implementation of national strategies, investments in digital infrastructure, support for technology companies, and the development of education and workforce training systems have enabled

these countries to significantly strengthen their positions in the global digital economy. The integration of AI into industry, e-commerce, finance, and public administration has become an important factor in economic growth.

Along with the economic benefits of artificial intelligence adoption, developed countries pay significant attention to the ethical, legal, and secure use of AI technologies. The European approach is based on the principles of responsible technology implementation, personal data protection, algorithm transparency, and minimization of potential risks. This demonstrates that successful digital modernization requires not only technological solutions but also an effective regulatory framework.

An important outcome of artificial intelligence implementation is the enhancement of enterprise competitiveness and the formation of new business models. AI enables companies to optimize production processes, forecast market trends, personalize products, improve logistics, and use resources more efficiently. Therefore, leading countries around the world consider the development of artificial intelligence as a foundation for future economic leadership.

For Ukraine, the experience of developed countries is of particular importance in the context of post-war economic modernization. The use of artificial intelligence may become one of the key directions for industrial recovery, the development of innovative sectors, increasing enterprise productivity, and integrating the Ukrainian economy into the European digital space. Important conditions for successful AI adoption include the development of digital infrastructure, training of qualified specialists, support for scientific research, and the creation of a favorable investment environment.

The United States is one of the global leaders in using artificial intelligence as a tool for economic modernization. The American model is based on a combination of government support for research, the development of technology companies, significant investments in digital infrastructure, and the active integration of AI into business processes. According to the U.S. Census Bureau, in 2025–2026 approximately

17–20% of American enterprises used artificial intelligence in their operations, while among large companies with more than 250 employees, the level of AI adoption exceeded 37%.

Table 2.14 – Real Examples of AI Implementation by American Companies

Company	Industry	Areas of AI Application	Results and Statistics
Amazon [91]	E-commerce, logistics	AI for demand forecasting, warehouse management, logistics center automation, and personalized recommendations	AI-based recommendations generate a significant share of purchases on the platform; robotic warehouses help reduce order processing time and optimize operating costs
Tesla [92]	Automotive industry	Computer vision, autonomous driving, analysis of data collected from millions of vehicles	The Autopilot system is trained on data from billions of miles driven, enabling continuous improvement of autonomous driving algorithms
Microsoft [97]	IT, cloud technologies	Generative AI, Copilot, automation of office processes, and data analytics	Corporate users report time savings in analytical, programming, and administrative tasks; enterprises use AI as a key element of digital transformation
Google	Information technology, advertising, cloud services	Machine learning, user behavior prediction, AI-powered search, and advertising optimization	AI forms the foundation of the company's search systems, advertising algorithms, and cloud services
JPMorgan Chase	Financial sector	AI for risk analysis, fraud detection, and process automation	AI is used to analyze millions of financial transactions and improve the security and efficiency of banking services
Walmart	Retail trade	AI for inventory management, demand forecasting, and logistics optimization	The use of AI improves sales forecasting accuracy and increases the efficiency of supply chain management

1. Amazon: artificial intelligence in digital commerce and logistics

Amazon's experience demonstrates how AI can modernize the fields of trade and logistics. The company uses machine learning algorithms for demand forecasting, automation of warehouse operations, and the creation of personalized customer offers. Through AI, Amazon optimizes delivery routes, inventory management, and the operation of robotic warehouse systems, which allows the company to reduce operating costs and improve the speed of customer service.

2. Tesla: AI as the foundation of innovative industry

Tesla represents an example of the transition of the automotive industry toward the "smart manufacturing" model. The company uses artificial intelligence in autonomous driving systems, production quality control, and vehicle data analysis. Millions of data points collected from vehicles are used for continuous improvement of machine learning algorithms. This approach enables the creation of a new model of the automotive industry, where software becomes one of the main sources of competitive advantage.

3. Microsoft: AI as a tool for improving business productivity

Microsoft actively integrates generative artificial intelligence into the corporate environment through Copilot tools and cloud-based AI solutions. Companies use AI to automate document preparation, analyze information, support programming, and improve management decision-making. According to corporate studies, users of AI-based tools report significant reductions in working time and increased productivity in performing knowledge-intensive tasks.

4. Financial Sector: The Use of AI for Risk Management

American banks actively apply artificial intelligence to modernize the financial system. AI is used for credit risk assessment, fraud detection, automation of customer service, and forecasting market trends. This enables financial institutions to make decisions faster, reduce operating costs, and improve the security of financial operations.

5. Overall Economic Impact of AI Implementation in the United States

The experience of the United States demonstrates that artificial intelligence is becoming an important factor in increasing economic productivity. According to research estimates, AI is most actively adopted by large enterprises and companies operating in the information technology, financial, and professional services sectors. In large companies, the level of AI adoption significantly exceeds the average rate across the economy.

Thus, the U.S. experience demonstrates that artificial intelligence is not merely an automation technology but a comprehensive tool for economic modernization. Real-world cases of Amazon, Tesla, Microsoft, Google, and financial corporations confirm that AI contributes to increased productivity, optimization of business processes, development of new products, and the formation of competitive advantages. For Ukraine, the American model can serve as a benchmark in the process of digital transformation and post-war economic modernization.

Therefore, international experience proves that artificial intelligence is not just a separate technology but a comprehensive factor of structural economic modernization. Countries that actively invest in AI development gain significant advantages in productivity, innovation capacity, and global competitiveness. For Ukraine, the adaptation of best international practices in the use of artificial intelligence can become an important element in building a modern, resilient, and innovative economy.

2.3. JUSTIFICATION OF THE FEASIBILITY OF USING ARTIFICIAL INTELLIGENCE UNDER CONDITIONS OF ECONOMIC MODERNIZATION

Economic modernization under current conditions involves a transition from a traditional development model to an innovative, digital, and high-tech economic system. One of the key instruments of this transition is artificial intelligence (AI), which ensures increased production efficiency, optimization of management processes, and the creation of new opportunities for economic growth. The use of AI is becoming a necessary condition for the formation of a competitive economy capable of adapting to global challenges.

The feasibility of AI implementation is determined by its ability to process large volumes of information and support informed managerial decision-making. In the modern economy, data has become one of the most important resources for development, while artificial intelligence enables the analysis of market trends, demand forecasting, risk assessment, and the development of effective enterprise development strategies. This contributes to improving management quality and reducing uncertainty in the business environment.

An important area of AI application is increasing labor productivity and automating business processes. Intelligent systems can perform repetitive operations, monitor production processes, optimize logistics, and improve resource management. As a result, enterprises gain the opportunity to reduce costs, improve product quality, and focus human potential on creative and strategic tasks.

In industry, the application of AI is an important factor in the transition toward the Industry 4.0 concept. The use of machine learning, robotic systems, predictive analytics, and digital twins enables the creation of more flexible production systems. For the Ukrainian economy, which requires large-scale post-war modernization, the implementation of such technologies can become the foundation for restoring industrial potential and increasing enterprise efficiency.

The concept of Industry 4.0 represents a modern model of industrial development based on the integration of digital technologies, automation, big data analysis, and intelligent management of production processes. One of the key technological components of this concept is artificial intelligence (AI), which enables production systems to independently analyze information, predict changes, and make optimal decisions. The use of AI transforms traditional enterprises into flexible, adaptive, and highly efficient digital production systems.

The main role of artificial intelligence in Industry 4.0 lies in processing large volumes of data generated by industrial equipment, sensors, and enterprise information systems. Through machine learning algorithms, industrial companies can analyze production indicators in real time, identify hidden patterns, and predict potential problems. This enables a transition from traditional production management to a data-driven management model.

One of the most widespread applications of AI in industry is predictive maintenance. Intelligent systems analyze equipment operation, determine the risk of failures, and enable maintenance to be carried out before critical breakdowns occur. According to international research estimates, the use of predictive analytics can reduce equipment downtime by 20–50% and decrease maintenance costs.

An important area of AI integration into Industry 4.0 is the robotization of production processes. Modern industrial robots are capable not only of performing programmed operations but also of adapting to changes in the production environment through artificial intelligence algorithms. This ensures increased accuracy, speed, and safety of production, while also enabling enterprises to manufacture products tailored to individual consumer needs.

Artificial intelligence plays an important role in the creation of digital twins – virtual models of real production facilities, equipment, or entire enterprises. With the help of AI, digital twins can simulate various production scenarios, predict the outcomes

of managerial decisions, and optimize resource utilization. This allows enterprises to reduce costs, improve product quality, and accelerate the implementation of innovations.

AI is particularly important for supply chain management. Intelligent systems analyze demand, forecast inventory requirements, optimize delivery routes, and help enterprises respond to changes in market conditions. Under conditions of global instability, the use of AI enables companies to increase resilience and ensure the continuity of production processes.

For Ukraine, the development of Industry 4.0 based on AI technologies is of strategic importance in the modernization and post-war reconstruction of the industrial sector. Ukrainian enterprises have the opportunity not only to restore outdated production capacities but also to transition toward modern digital management models. The implementation of AI in mechanical engineering, metallurgy, energy, agriculture, and logistics can become a foundation for increasing the competitiveness of the national economy.

An example of applying Industry 4.0 principles is the development of Smart Factories, where equipment, information systems, and employees interact through digital platforms. AI enables automated quality control, optimization of production parameters, and rapid response to changes in market demand. Such enterprises are characterized by higher productivity, reduced levels of waste, and greater adaptability to market requirements.

The implementation of AI within the framework of Industry 4.0 also changes the requirements for human capital. Future employees must possess digital competencies, data analysis skills, an understanding of automated systems, and knowledge of innovation management principles. Therefore, industrial modernization requires the simultaneous development of education, science, and a system or training highly qualified specialists.

Thus, artificial intelligence is one of the key drivers of implementing the Industry 4.0 concept. It enables the transition from traditional

production to intelligent, autonomous, and flexible industrial systems. The use of AI contributes to increasing productivity, reducing costs, promoting innovation, and forming a competitive economy. For Ukraine, the integration of AI into industry is an important direction of digital transformation and a foundation for future economic recovery.

The Industry 4.0 concept involves a transition from traditional production to digital, automated, and intelligent manufacturing systems. Artificial intelligence is one of the key elements of this transformation, as it enables enterprises to analyze large volumes of data, predict changes, automate operations, and make effective management decisions. The use of AI allows the formation of "smart enterprises," where equipment, software systems, and employees interact within a unified digital environment.

One of the main areas of AI application is intelligent production automation. Unlike traditional automation, modern AI-based systems are capable of independently analyzing production parameters and adapting processes to changing conditions. Robotic systems with artificial intelligence capabilities are used for product assembly, sorting, packaging, and performing hazardous operations. This contributes to increased labor productivity, cost reduction, and improved production quality.

An important area is predictive maintenance. Through the integration of artificial intelligence, Internet of Things (IoT) sensor systems, and data analytics, enterprises can determine the technical condition of equipment in real time. This makes it possible to predict potential failures and perform maintenance before emergency situations occur. As a result, downtime of production lines is reduced, and the efficiency of using fixed assets is improved.

The use of digital twins (Digital Twins) has significant potential. They create a virtual replica of a real object, production system, or enterprise, enabling the modeling of various development scenarios and assessment of the consequences of managerial decisions.

Table 2.15 – Main Directions of Artificial Intelligence Application within the Industry 4.0 Concept

№	Direction of AI Application in Industry 4.0	Main Technologies	Practical Application in Enterprises	Economic Effect
1	2	3	4	5
1	Intelligent production automation	Machine learning, industrial robots, robotic systems	Automation of production operations, process control, optimization of equipment performance	Increased productivity, reduced costs, fewer errors
2	Predictive Maintenance	AI analytics, IoT sensors, Big Data	Monitoring equipment conditions, predicting failures before accidents occur	Reduction of downtime by 20–50%, lower maintenance and repair costs
3	Digital Twins	Artificial intelligence, modeling, cloud technologies	Creation of virtual models of enterprises, equipment, and production lines	Production optimization, testing solutions without additional costs
4	Product quality control	Computer vision, neural networks	Automatic detection of product defects and quality standard control	Improved product quality, reduction of defective products
5	Supply Chain Optimization	Predictive analytics, optimization algorithms	Inventory management, demand forecasting, optimization of delivery routes	Reduction of logistics costs, increased business resilience
6	Smart energy management and resource efficiency	AI monitoring, intelligent management systems	Analysis of energy consumption, optimization of resource utilization	Reduced energy consumption, support for sustainable development

End of Table 2.15

1	2	3	4	5
7	Production personalization (Mass Customization)	Generative AI, customer data analytics	Manufacturing products according to individual consumer needs	Increased competitiveness and customer satisfaction
8	Intelligent enterprise management	AI-powered ERP systems, business analytics	Automation of managerial decision-making, risk analysis	Improved management efficiency and faster response to changes
9	Cybersecurity of industrial systems	AI threat monitoring, machine learning	Detection of cyberattacks, protection of industrial networks and data	Increased security of digital infrastructure
10	Human capital development	AI-based education, digital platforms, automated learning	Training employees to work with digital technologies	Formation of new competencies and innovation potential

With the support of AI, digital twins can optimize production processes, reduce resource consumption, and accelerate the implementation of innovations.

One of the most widespread areas is product quality control using computer vision. Intelligent systems are capable of automatically analyzing product images, detecting defects, and monitoring compliance with established standards. This is particularly important for mechanical engineering, metallurgy, the food industry, and pharmaceuticals, where product quality directly affects the competitiveness of enterprises.

Artificial intelligence also plays an important role in supply chain management. AI algorithms enable demand forecasting, optimization of inventory levels, identification of the most efficient delivery routes, and rapid response to changes in market conditions. Under conditions of global instability and disruptions in logistics networks, such technologies

ensure greater resilience of enterprises. An additional area is smart energy resource management. AI systems analyze electricity consumption, forecast production needs, and automatically optimize resource utilization. This contributes to cost reduction, improved energy efficiency, and the implementation of sustainable development principles. For Ukrainian enterprises, this area is particularly relevant due to the need to achieve energy independence and modernize production processes.

The use of AI promotes the development of personalized production, where enterprises can quickly adapt products to individual consumer needs. Generative AI and customer behavior analytics make it possible to forecast market demands and create new products. This approach enables enterprises to build competitive advantages in the global environment.

An important component of Industry 4.0 is intelligent enterprise management. The integration of AI with ERP systems and business

Figure 2.6 – Directions of Artificial Intelligence Application within the Industry 4.0 Concept

Source: Developed by the author using artificial intelligence tools

analytics platforms allows managers to obtain up-to-date information for strategic planning, risk assessment, and managerial decision-making. This improves management efficiency and ensures more flexible responses to changes in the external environment.

Thus, artificial intelligence is a system-forming technology of the Industry 4.0 concept. Its implementation ensures the digital transformation of enterprises, increased productivity, reduced costs, and the development of innovative business models. For Ukraine, the use of AI in industry is an important direction for economic modernization, restoration of production potential, and integration into the European digital space.

Artificial intelligence also plays an important role in the development of the innovation economy and the creation of new types of economic activity. The formation of the AI market contributes to the emergence of high-tech companies, the development of digital professions, attraction of investments, and integration of countries into the global technological space. Therefore, the use of AI is becoming not only a technological process but also a strategic direction of state economic policy.

The relevance of AI implementation is also associated with the need to increase the competitiveness of enterprises in international markets. Companies using intelligent technologies gain advantages through faster decision-making, product personalization, more effective marketing, and improved customer interaction. In the global economy, the digital maturity of an enterprise is becoming one of the key factors determining its success.

Artificial intelligence is of particular importance for ensuring sustainable economic development. Intelligent systems can contribute to more efficient use of energy resources, reduction of industrial waste, optimization of transport flows, and the development of a green economy. The combination of AI with ESG principles (environmental, social, and corporate governance) enables enterprises to develop long-term sustainable development strategies.

Under conditions of economic modernization, the use of AI contributes to the development of human capital. Despite the automation of certain

processes, artificial intelligence creates demand for new competencies, including data analysis, digital management, programming, cybersecurity, and innovation management. Therefore, an important task for the state and educational institutions is to train specialists capable of effectively operating in the digital economy.

For Ukraine, the implementation of AI is of strategic importance in the process of economic recovery and European integration. The use of modern technologies can accelerate the digital transformation of public administration, industry, the agricultural sector, the financial system, and the service sector. AI can become one of the key instruments for overcoming structural economic challenges and forming a new development model.

Therefore, the use of artificial intelligence in the context of economic modernization is an economically justified and strategically necessary direction of development. AI ensures increased efficiency of enterprises, stimulates innovation, supports sustainable development, and contributes to the formation of a competitive economy. Its integration into production and management processes is an important prerequisite for successful digital transformation and long-term economic growth.

The implementation of artificial intelligence is of strategic importance for Ukraine in the context of economic recovery, as it enables a transition from the model of restoring destroyed capacities to the creation of a modern innovation-based economy. The use of AI ensures not only the reconstruction of individual sectors but also the formation of a new technological foundation for the country's development in accordance with European standards.

One of the main areas of AI application is improving enterprise efficiency. Ukrainian businesses are gradually implementing intelligent systems for demand forecasting, production automation, human resource management, quality control, and logistics optimization. This enables enterprises to reduce costs, adapt more quickly to market changes, and increase their competitiveness in international markets.

Table 2.16 – The Impact of Artificial Intelligence Implementation on the Directions of Economic Modernization of Ukraine

Direction of AI Application	Statistical Indicators / Estimates	Significance for Economic Recovery and European Integration
Business digitalization	According to research, more than 70% of Ukrainian companies actively use or plan to implement digital technologies in business processes	AI accelerates the transition of enterprises toward the European model of the digital economy, increasing transparency and management efficiency
Development of the AI market	The global AI market is projected to exceed USD 800 billion by 2030 (according to estimates of international analytical companies)	Ukraine has the opportunity to integrate into the global technological space through the development of its own AI solutions
Production automation	The use of AI and robotics can increase labor productivity in industry by 20–40%, depending on the sector	Supports the recovery of the industrial sector after destruction and contributes to the creation of competitive production facilities
Economic impact of digital transformation	According to international experts, digitalization can provide additional GDP growth of 2–4% annually in the long term	Creates conditions for accelerating Ukraine's economic development and convergence with EU standards
Use of AI in public administration	Ukraine belongs to the group of countries with a high level of e-government development	AI enables automation of public services, data analysis, and improvement of governance efficiency
Agricultural sector	The use of AI solutions in precision farming can reduce resource costs by 10–30% and increase productivity	Supports modernization of one of Ukraine's key economic sectors and strengthens export competitiveness
Logistics and transport	Intelligent route optimization systems can reduce transportation costs by 15–25%	Important for the restoration of transport infrastructure and integration of Ukraine into European logistics networks
Human capital development	By 2030, a significant share of professions will be transformed due to automation and the use of AI	Creates demand for new digital competencies and modernization of the education system in accordance with EU requirements

AI is particularly important for the post-war recovery of Ukrainian industry. Ukraine requires not merely the restoration of outdated production models but a transition toward technology-driven manufacturing based on Industry 4.0 principles. The use of robotic systems, digital twins, and predictive analytics will allow enterprises to modernize and integrate into European production chains.

In the context of European integration, AI serves as an important tool for Ukraine's adaptation to the digital policies of the European Union. The EU is actively developing areas related to artificial intelligence, digital platforms, cybersecurity, and data governance. Therefore, the implementation of similar technologies in Ukraine will contribute to the harmonization of the economic environment and the attraction of foreign investment. Significant potential for the use of AI is observed in the field of public administration. Intelligent systems can provide analysis of large volumes of information, forecasting of economic processes, monitoring of the use of public resources, and improvement of the quality of administrative services. This contributes to the formation of a transparent and efficient public administration system, which is an important condition for integration into the European Union [104].

Therefore, the implementation of artificial intelligence is one of the key factors in the modernization of Ukraine's economy. Its use ensures increased productivity, the development of innovations, digital transformation of enterprises, and the approximation of Ukraine's economic system to the European development model. AI can become one of the main drivers of post-war recovery and the long-term competitiveness of the state.

During the period 2022–2025, Ukraine experienced an acceleration in the adoption of artificial intelligence as an integral component of the digital transformation of the economy. While in 2022 the use of AI was mainly experimental, by 2025 artificial intelligence technologies had become an element of strategic enterprise management [105].

The most significant growth occurred in the areas of business process automation and the use of analytical systems. Enterprises

apply AI technologies for demand forecasting, inventory management, logistics optimization, consumer behavior analysis, and improving production efficiency.

An important factor in this development has been the increase in investment in digital technologies. Despite wartime risks, Ukrainian

Table 2.17 – Dynamics of Artificial Intelligence Development and Implementation in Ukraine's Economy (2022–2025) [110–118]

Indicator	2022	2023	2024	2025	Dynamics over 4 Years
Share of enterprises using or testing AI solutions	10%	18%	28%	40%	+30 percentage points
Number of Ukrainian companies implementing AI solutions (estimate)	300	600	1,000	1,500	Fivefold growth
Investments in business digitalization and AI solutions	USD 0.5 billion	USD 0.8 billion	USD 1.2 billion	USD 1.8 billion	+260%
Level of enterprise use of cloud and analytical technologies	25%	35%	45%	55%	+30 percentage points
Share of companies using business process automation	22%	32%	45%	60%	+38 percentage points
Number of AI/IT companies and startups in Ukraine	250	350	500	650	+160%
Use of AI in the public sector (digital services, analytics)	Low level	Initial implementation	Active scaling	Integration into public processes	Significant growth
Export of Ukraine's IT services	USD 7.3 billion	USD 8.0 billion	USD 6.9 billion	Approximately USD 7 billion	Stabilization after wartime decline

businesses are gradually moving toward an innovation-oriented development model, where AI is considered a tool for enhancing competitiveness and resilience.

Thus, the dynamics of 2022–2025 indicate that artificial intelligence is becoming one of the key factors in the modernization of the Ukrainian economy. Its application contributes to enterprise recovery, the development of digital infrastructure, attraction of investments, and integration of Ukraine into the European digital space.

The development of artificial intelligence (AI) in Ukraine in recent years demonstrates steady positive dynamics and the gradual formation of a national AI ecosystem. The implementation of AI has become one of the key directions of economic digital transformation, as these technologies enable the automation of business processes, increase enterprise productivity, promote innovation, and create new high-skilled employment opportunities. The development of AI has acquired particular importance in the context of Ukraine's economic recovery needs and integration into the European Union's digital environment.

The first important indicator of AI development is the growth in the number of companies operating in the field of artificial intelligence. According to studies of the Ukrainian AI ecosystem, Ukraine has developed a significant sector of companies engaged in the development of AI solutions, machine learning, data analytics, computer vision, and automated systems. The number of such companies increased from approximately 100 in 2020 to more than 240 in 2024–2025, indicating more than a twofold increase in the potential of the Ukrainian AI market.

An important factor in the development of the sector is the formation of human resource potential. Ukraine has a strong IT industry, which has become the foundation for the development of artificial intelligence. The number of specialists working with AI and machine learning technologies has increased significantly in recent years. According to expert estimates, the number of AI/ML specialists grew from approximately 1,000 people in 2020 to more than 5,000

in 2024, creating a foundation for the development of an innovation-oriented economy.

One of the indicators of AI adoption is the active use of generative AI tools by the population and businesses. Following the emergence of accessible artificial intelligence-based platforms, Ukrainian users began applying them for document preparation, information analysis, content creation, education, and professional activities. According to the Ministry of Digital Transformation of Ukraine, by 2025 a significant share of the adult population had already used AI tools in their daily activities.

Ukrainian businesses play a significant role in the development of AI. Enterprises are gradually implementing intelligent solutions to optimize management, forecast demand, automate production, control quality, and improve customer interaction. The highest level of activity is demonstrated by IT companies, banks, logistics enterprises, retail chains, and industrial enterprises, which use AI as a tool for enhancing competitiveness.

An important direction of development is the use of AI in industry in accordance with the principles of Industry 4.0. Ukrainian enterprises apply predictive analytics technologies, automated quality control systems, robotics, and digital twins. The implementation of such solutions enables the reduction of production costs, more efficient use of resources, and modernization of the industrial sector in accordance with European standards.

The defense and technology sector has also had a significant impact on the development of AI in Ukraine. Under wartime conditions, Ukrainian companies actively develop and implement AI solutions for analyzing large volumes of information, cybersecurity, autonomous systems, satellite data processing, and improving the efficiency of managing complex processes. This area has become one of the factors accelerating the development of Ukrainian technology startups. Government policy also contributes to the development of artificial intelligence. In 2020, Ukraine adopted the Concept

for the Development of Artificial Intelligence, which identified the main directions for the use of AI in the economy, education, science, public administration, and security. The further development of digital services, particularly the Diia platform, creates a foundation for the integration of AI technologies into public administration. An important indicator is Ukraine's integration into the international digital space. The Ukrainian AI ecosystem is gradually becoming part of global technological processes through cooperation with international companies, participation in research projects, and the development of IT exports. This creates opportunities for attracting investments, developing innovative enterprises, and forming Ukraine's competitive advantages in the field of the digital economy [118–121]. Thus, the statistical dynamics of artificial intelligence development in Ukraine during 2020–2025 indicate the gradual formation of a strong technological ecosystem. The growth in the number of AI companies, the increasing number of specialists, and the expanding use of AI solutions in business and the public sector demonstrate the strategic role of artificial intelligence in economic modernization. In the future, AI may become one of the key factors in Ukraine's post-war recovery, increasing enterprise productivity, and accelerating European integration.

CHAPTER 3.
PROSPECTS FOR THE USE OF ARTIFICIAL INTELLIGENCE IN THE CONTEXT OF GLOBAL CHANGES

3.1. DEVELOPMENT OF ARTIFICIAL INTELLIGENCE CONSIDERING STRATEGIC CHALLENGES

In the current conditions of global economic transformation, increasing digital competition, and growing uncertainty, artificial intelligence (AI) is becoming one of the key strategic resources for the development of states, businesses, and society. The rapid expansion of machine learning technologies, generative AI, big data analytics, and automated decision-making systems creates new opportunities for increasing productivity, innovation, and the competitiveness of economic systems. At the same time, the large-scale implementation of AI is accompanied by a number of strategic challenges related to labor market transformation, cybersecurity issues, ethical data use, digital inequality, and the need to develop effective regulatory policies.

The development of AI in the 21st century is taking place under the simultaneous influence of economic, technological, social, and geopolitical factors. Global crises, military conflicts, changes in international competition models, and the need to transition toward sustainable development encourage states and enterprises to seek new instruments for adaptation. Therefore, artificial intelligence is considered not only as a technological innovation but also as a strategic mechanism for ensuring resilience, forecasting risks, and optimizing management processes.

The issue of AI development is becoming particularly relevant for economies undergoing modernization and integration into the global

digital space. The use of intelligent technologies makes it possible to increase production efficiency, improve logistics systems, automate business processes, enhance the quality of public administration, and create new high-tech industries. For Ukraine, AI development is one of the important directions of post-war recovery, as it can contribute to accelerating digital transformation, restoring industrial potential, and increasing competitiveness in international markets.

At the same time, the strategic development of AI requires consideration of potential risks. The automation of certain types of activities may lead to changes in the employment structure and the need to develop new professional competencies. The growing volume of personal and corporate data usage highlights the importance of information security and privacy protection. Furthermore, the spread of generative AI creates new challenges in ensuring information reliability, combating disinformation, and promoting the responsible use of digital technologies.

A strategic approach to AI development involves the formation of a comprehensive policy that combines technological innovation, investment in human capital, the development of digital infrastructure, and the creation of an effective regulatory and legal environment. The success of countries in the field of AI will be determined not only by the level of technological advancement but also by their ability to integrate artificial intelligence into socio-economic processes in a way that ensures long-term growth, resilience, and public benefit.

Therefore, the development of artificial intelligence considering strategic challenges is one of the defining directions in the formation of a new model of economic development. AI is gradually moving from the status of a separate technological tool to the role of a strategic factor in the transformation of the economy, governance, and international competitiveness. In the long term, the key task will be to ensure a balance between the innovative potential of AI and responsible governance.

The current stage of digital transformation is characterized by a gradual transition from traditional information systems,

which primarily performed functions of data collection, storage, and processing, to autonomous intelligent platforms capable of independently analyzing information, learning, and making managerial decisions. This transformation is the result of the development of artificial intelligence technologies, machine learning, big data, cloud computing, and the Internet of Things. While traditional information systems operated according to predefined algorithms, modern AI platforms are gaining the ability to adapt to changes in the environment and predict future events.

Traditional information systems have long been the foundation for managing enterprises and organizations. They enabled the automation of accounting, document management, financial analysis, human resource management, and production processes. However, such systems had a significant limitation – they depended on human involvement in decision-making and could operate only within predefined scenarios. Under conditions of rapid economic change, increasing volumes of information, and the need for prompt responses, this approach became insufficient.

The emergence of artificial intelligence technologies has changed the principles of digital system functioning. Autonomous intelligent platforms do not merely process information but perform in-depth analysis, identify hidden patterns, and generate recommendations for users. Through machine learning algorithms, such systems are able to improve their own models based on accumulated experience, ensuring more accurate forecasting and more effective management of complex processes.

A distinctive feature of autonomous intelligent platforms is their ability to operate in real time and integrate information from various sources. For example, in the business sector, they can simultaneously analyze data on consumer demand, production conditions, logistics processes, financial indicators, and external market factors. This enables enterprises to respond more quickly to changes in the competitive environment, optimize resource utilization, and develop more informed strategic decisions.

An important direction in the development of autonomous platforms is their application in industry within the framework of the "Industry 4.0" concept. Intelligent production systems combine robotic equipment, sensor technologies, and AI algorithms to automatically control product quality, predict maintenance needs, and optimize production operations. As a result, enterprises gain the ability to increase productivity, reduce costs, and ensure greater flexibility of production processes.

In the field of management, autonomous intelligent platforms are gradually transforming the role of managers and analysts. They do not replace human strategic thinking but become a powerful tool for supporting decision-making. The use of AI analytics makes it possible to assess risks, model various development scenarios, and generate long-term forecasts. This becomes particularly important in conditions of crises, global competition, and high uncertainty in the economic environment.

Along with their advantages, the transition to autonomous intelligent platforms creates new strategic challenges. These include issues related to data protection, cybersecurity, algorithm transparency, and responsibility for decisions made with the involvement of artificial intelligence. There is a need to develop new principles of digital system governance that combine the technological capabilities of AI with ethical and legal standards.

For Ukraine, the transition to autonomous intelligent platforms is of particular importance in the context of economic modernization and post-war recovery. The use of such technologies can contribute to increasing industrial efficiency, developing innovative entrepreneurship, digitalizing public administration, and strengthening the competitive positions of Ukrainian companies in international markets. The integration of AI into business processes will not only optimize current operations but also create new models of economic development.

Thus, the transition from traditional information systems to autonomous intelligent platforms is a natural stage of digital evolution. It reflects a change in the role of information technologies –

from tool for automating individual operations to a strategic mechanism for managing the development of organizations and economic systems. In the future, the ability to effectively integrate artificial intelligence into decision-making processes will become one of the key factors determining the competitiveness of states and enterprises.

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Thus, the transition from traditional information systems to autonomous intelligent platforms is a natural stage of digital evolution. It reflects a change in the role of information technologies – from a tool for automating individual operations to a strategic mechanism for managing the development of organizations and economic systems. In the future, the ability to effectively integrate artificial intelligence into decision-making processes will become one of the key factors determining the competitiveness of states and enterprises.

Artificial intelligence is the result of a long-term development of scientific and technological ideas that emerged long before the appearance of modern digital systems. The history of AI is associated with the search for ways to reproduce human intellectual abilities through technical devices. From the first mathematical models of thinking to modern autonomous intelligent platforms, the development of AI has gone through several stages, each of which defined a new level of interaction between humans and technologies.

The first theoretical foundations of artificial intelligence were formed in the 1940s–1950s alongside the development of computing technologies. An important role in this process was played by the research of the British mathematician Alan Turing, who in 1950 proposed the idea of testing a machine's ability to demonstrate

intelligent behavior, known as the Turing Test. His works laid the foundation for further research in the field of machine reasoning and automated decision-making.

The official establishment of artificial intelligence as a research field took place in 1956 during the Dartmouth Conference (USA), where the term "artificial intelligence" was first introduced. The conference participants defined AI as a research area aimed at creating machines capable of performing tasks that traditionally require human intelligence, including learning, information recognition, logical reasoning, and problem-solving.

During the 1960s–1970s, AI development focused on creating expert systems and symbolic programming algorithms. Researchers attempted to describe human thinking processes through a set of rules and logical operations. During this period, the first programs were developed that could solve mathematical problems, play chess, and perform limited speech recognition. However, the limitations of computing capabilities and the complexity of modeling the real world led to the first periods of declining interest in AI, known as "AI winters."

A new stage of AI development began in the 1980s with the spread of expert systems in business and industry. Companies started using computer-based systems to support management decisions, diagnose equipment, analyze financial information, and optimize production processes. It was during this period that AI began to be perceived as a practical tool for improving the efficiency of economic activities.

In the 1990s–2000s, AI development became closely associated with the emergence of large datasets and the increasing power of computer systems. Instead of programming rigid rules, researchers increasingly focused on machine learning methods, where algorithms gained the ability to independently identify patterns within large volumes of information. A significant achievement was the application of neural networks for image recognition, text analysis, and forecasting of various processes.

Starting from the 2010s, artificial intelligence entered a period of rapid development due to the combination of big data, cloud technologies, and deep learning. It was during this period that AI began to be actively applied in medicine, industry, transportation, finance, marketing, and public administration. Algorithms became capable of analyzing complex information flows, recognizing images, translating languages, and predicting consumer behavior.

A particularly significant stage was the emergence of generative artificial intelligence in the 2020s. New-generation systems gained the ability to create texts, images, software code, models, and analytical solutions. Platforms based on large language models demonstrated a transition from the use of AI as an auxiliary tool to autonomous intelligent systems capable of interacting with humans, analyzing context, and performing complex comprehensive tasks [121].

Today, artificial intelligence is considered not only as an automation technology but also as a strategic factor of economic development. Leading countries are developing national AI strategies aimed at increasing economic competitiveness, fostering innovation, and ensuring technological leadership. At the same time, the current stage of AI development requires addressing important issues related to ethics, data security, regulation, and the responsible use of intelligent technologies [122].

Thus, the history of artificial intelligence technologies demonstrates a gradual transition from simple algorithmic systems to autonomous platforms capable of learning, analyzing, and making decisions. The evolution of AI reflects the general trend of digital transformation of society, in which intelligent technologies are becoming a key instrument for the modernization of the economy, governance, and social development.

The historical development of artificial intelligence took place gradually, passing through several qualitatively different stages – from the formation of theoretical ideas about the possibility of creating "intelligent machines" to the emergence of autonomous intelligent

Table 3.1 – Main Stages of Artificial Intelligence Technology Development [125–130]

Period	Stage of Development	Main Characteristics
1940s–1950s	Formation of the theoretical foundations of AI	Development of computing machines, ideas of machine thinking, the Turing Test
1956	Official emergence of the AI field	The Dartmouth Conference, introduction of the term "Artificial Intelligence"
1960s–1970s	Symbolic AI	Logical systems, the first problem-solving programs
1980s	Expert systems	Application of AI in business, medicine, and industry
1990s–2000s	Machine learning	Big data analysis, statistical algorithms
2010–2020	Deep learning	Neural networks, computer vision, automatic recognition
2020s	Generative AI	Creation of texts, images, code, autonomous AI platforms

platforms that are currently capable of independently analyzing information, learning, and generating new solutions. Each stage of AI development was associated with advances in computer science, the growth of available data volumes, and increasing computational capabilities.

The first stage (1940s–1950s) – the formation of the theoretical foundations of artificial intelligence. This period was characterized by the emergence of the first electronic computers and the development of scientific concepts regarding the possibility of modeling human intelligence. Researchers focused primarily on the question of whether machines could perform tasks traditionally considered exclusive to humans – logical reasoning, learning, information analysis, and decision-making. A significant contribution to the development of this field was made by Alan Turing, who proposed the concept of testing machine intelligent behavior. This period laid the foundation for the future science of artificial intelligence.

The second stage (1956) – the official emergence of the artificial intelligence field. A key event was the Dartmouth Conference

of 1956, where researchers first introduced the concept of "Artificial Intelligence." Participants of the conference proposed the idea that every aspect of human intelligence could be described precisely enough for a machine to reproduce it. At this stage, the main areas of AI research were formed: automated problem-solving, machine learning, speech recognition, and information retrieval. Although the capabilities of early systems were limited, this period defined the further development of AI as an independent scientific discipline.

The third stage (1960s–1970s) – development of symbolic artificial intelligence. During this period, researchers mainly used an approach based on rules and logical operations. It was believed that human thinking could be represented as a system of formal rules that could be executed by a computer. The first programs for playing chess, mathematical theorem proving, and natural language processing were developed. However, such systems had significant limitations, as they could operate only within narrowly defined areas and were unable to adapt

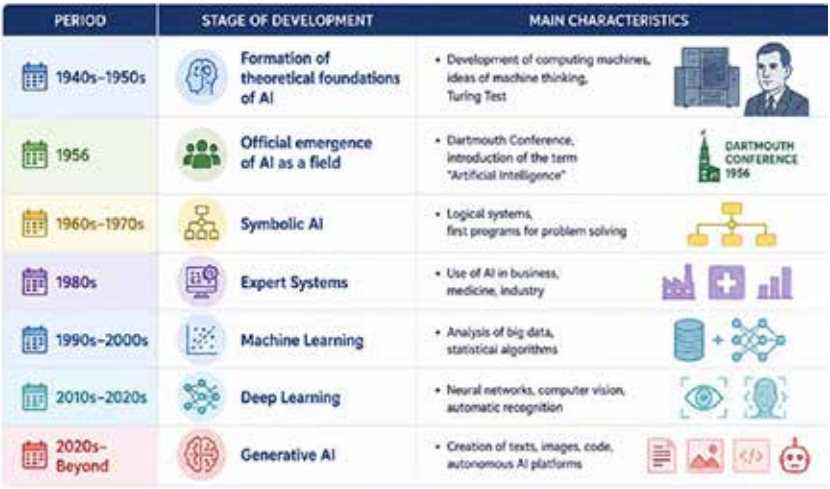

Figure 3.1 – Evolution of Artificial Intelligence Technology Development

to new conditions. This led to a decline in expectations regarding AI capabilities and contributed to the emergence of the first "AI winter."

The fourth stage (1980s) – expansion of expert systems. At this stage, artificial intelligence began to move actively from the scientific field into practical applications. Expert systems became one of the first examples of the commercial use of AI. They accumulated the knowledge of specialists in specific fields and used it to support decision-making processes. Such systems were applied in medicine for disease diagnosis, in industry for equipment monitoring, and in finance for risk assessment. This period shaped the understanding of AI as a tool for improving management efficiency.

The fifth stage (1990s–2000s) – transition to machine learning. Rule-based systems were gradually replaced by machine learning algorithms. Their main feature was that computers gained the ability to independently identify patterns in large datasets without the need for detailed programming of every action. The development of the Internet, the accumulation of digital information, and the growth of computing power created favorable conditions for the active use of AI in business, marketing, finance, logistics, and management.

The sixth stage (2010–2020) – development of deep learning and neural networks. This period became a turning point in AI development due to the emergence of Deep Learning technologies. Multi-layer neural networks enabled computers to perform complex tasks such as image recognition, video analysis, language translation, and consumer behavior prediction. Thanks to deep learning, artificial intelligence began to be widely applied in autonomous transportation, medicine, industrial automation, and cybersecurity systems.

The seventh stage (2020s) – generative artificial intelligence and autonomous platforms. The current stage is characterized by a transition from analytical AI to generative systems capable of creating new content: texts, images, software code, audio, and video materials. Large language models have become the foundation of a new generation of intelligent platforms that can conduct dialogue, analyze

complex queries, and assist in managerial decision-making. Generative AI is being actively integrated into business processes, education, science, public administration, and industry.

Thus, the evolution of artificial intelligence demonstrates a gradual transition from simple programmable systems to complex autonomous platforms capable of adapting to changes and performing tasks that previously required human involvement. The modern development of AI defines a new stage of digital transformation, in which intelligent technologies become one of the key factors of economic growth, innovation development, and increasing the competitiveness of countries and enterprises.

Table 3.2 – Forecast Indicators of the Pessimistic Scenario for AI Development in Ukraine (2026–2030)

Indicator	Current Situation	Pessimistic Forecast for 2030	Possible Consequences
Investments in civilian AI technologies	Limited due to wartime risks	Reduction in the growth rate by 20–30%	Slowing down the digital modernization of businesses
Economic recovery expenditures	More than USD 500 billion in estimated needs	Increase in recovery needs due to the continuation of the war	Lack of resources for innovation development
Share of enterprises using AI	Gradual adoption	Slow growth to 20–30% of enterprises	Lagging behind EU countries
Digital skills shortage	Lack of AI specialists	Increase due to migration of professionals	Dependence on foreign technologies
Cybersecurity threat level	High due to the war	Further growth of AI-based attacks	Risks for government systems and businesses
Use of AI in disinformation	Active application of generative technologies	Increase in the number of AI-generated fakes	Declining trust in information
Technological dependence	A significant share of solutions is imported	Strengthening dependence on global platforms	Limitations on technological sovereignty

The pessimistic scenario of artificial intelligence development under wartime conditions assumes a situation in which the prolonged persistence of military instability, the destruction of economic potential, limited investment opportunities, and the escalation of cyber threats may slow down the development of civilian AI applications. For Ukraine, this scenario is not associated with abandoning technological development, but rather with the risk that a significant share of resources will be directed toward defense needs, while the modernization of the economy, education, and industry will proceed at a slower pace. According to assessments by the World Bank, the European Commission, the United Nations, and the Government of Ukraine, the country's recovery needs are already estimated at hundreds of billions of US dollars, creating additional pressure on national economic resources.

In the pessimistic scenario, the main risk factor is the continuation of the war and the preservation of a high level of destruction of critical infrastructure. According to the updated RDNA assessment, as of the end of 2025, direct damages in Ukraine were estimated at approximately USD 195 billion, while total recovery and reconstruction needs were estimated at nearly USD 588 billion over the next decade. The most affected sectors include housing, transport, energy, and industrial infrastructure. Under such conditions, AI implementation may become concentrated primarily in the areas of defense and security rather than in industrial modernization.

Main Areas of Negative Impact of the War on AI Development

1. Reduction of resources for digital transformation. In the event of continued military operations, the state and businesses will be forced to concentrate financial resources on defense, the restoration of critical infrastructure, and social needs. This may lead to a reduction in investments in artificial intelligence research, the development of AI startups, and the implementation of intelligent systems in industry.

2. Increasing technological gap. Leading countries around the world continue to actively invest in artificial intelligence,

developing their own technological ecosystems. Under the pessimistic scenario, Ukraine may remain primarily a user of ready-made AI solutions rather than a developer of its own technologies. This creates the risk of dependence on foreign platforms, software, and computing resources.

3. Loss of human capital. One of the greatest risks is the migration of highly qualified specialists in IT, science, and engineering. If the outflow of professionals continues, Ukraine may face a shortage of experts needed for the development of artificial intelligence, the digital economy, and innovative entrepreneurship.

4. Growth of AI use in military and information conflicts. The war stimulates the development of autonomous systems, data analysis technologies, and unmanned platforms. At the same time, the risks of using AI for cyberattacks, the creation of disinformation campaigns, and psychological influence are increasing. Research on generative AI also highlights the risks of information distortion and manipulation in the context of warfare.

5. Slowing down enterprise modernization. Under the negative scenario, enterprises, especially small and medium-sized businesses, may postpone the implementation of AI solutions due to limited funding, high risks, and uncertainty. This may result in a decline in the competitiveness of Ukrainian businesses in international markets.

The pessimistic scenario of AI development under wartime conditions is characterized by the risk of a situation in which Ukraine's technological potential will be used primarily to address short-term security challenges, while the long-term digital modernization of the economy will be postponed. The main threats include insufficient research funding, loss of human capital, technological dependence, and increasing information risks. At the same time, even under a negative scenario, the war may become a factor accelerating certain areas of AI development, particularly defense technologies, data analytics, autonomous systems, and cybersecurity. The task of public policy should be to transform these developments into a foundation for future economic modernization.

The following section presents a pessimistic scenario forecast for the development of artificial intelligence (AI) in Ukraine until 2030, taking into account wartime risks, economic constraints, shortage of qualified specialists, and technological dependence. The forecast is scenario-based rather than an official prediction. Ukraine is simultaneously developing an AI strategy until 2030; however, key risks remain related to infrastructure limitations, data security, and the consequences of the war.

The graph of the pessimistic forecast of artificial intelligence development in Ukraine for 2025–2030 demonstrates gradual but slow growth in the level of AI technology adoption in the economy

Table 3.3 – Pessimistic Forecast of Artificial Intelligence Development in Ukraine (2025–2030)

Year	Expected Situation	Main Negative Factors	Approximate Level of AI Development
2025	Initial stage of large-scale AI implementation in business and the public sector	War, lack of investment, dependence on foreign platforms	30%
2026	AI is mainly used by large companies and government institutions	Infrastructure destruction, shortage of computing capacity, outflow of IT specialists	35%
2027	Slow expansion of AI in industry, education, and healthcare	Insufficient funding for modernization, weak integration of enterprises	40%
2028	Ukraine mainly uses ready-made foreign AI solutions	Technological dependence on the USA and EU, lack of domestic AI models	45%
2029	Formation of an uneven digital economy	Some enterprises are unable to transition to automation	50%
2030	AI becomes an important tool only for certain sectors	Lagging behind leading countries, shortage of investment and qualified personnel	55%

and social processes. According to this scenario, in 2025 the level of AI development is estimated at approximately 30%, reflecting the use of technologies mainly by large enterprises, IT companies, state digital services, and the defense sector.

In the following years, the indicator is expected to gradually increase to 55% by 2030; however, the pace of development remains limited due to the long-term consequences of the war, insufficient investment in technological modernization, a shortage of qualified specialists, and dependence on foreign AI solutions. This dynamic indicates that Ukraine retains significant potential for artificial intelligence development, but under unfavorable conditions it may fail to ensure a rapid transition toward an innovation-driven economy, creating a risk of technological lag behind the world's leading countries.

The graph illustrates the possible trajectory of slow development and implementation of artificial intelligence technologies in Ukraine under unfavorable conditions. The analysis is based on a conditional AI development index, where 100% represents the complete technological integration of AI into the economy, public administration, industry, and social processes.

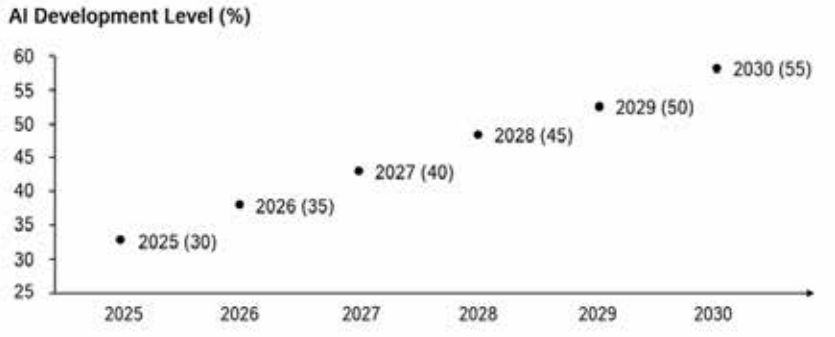

Figure 3.2 – Pessimistic Scenario of Artificial Intelligence Development in Ukraine (2025–2030)

In 2025, the level of AI development is estimated at approximately 30%. This corresponds to a situation where artificial intelligence technologies are already actively used by individual companies, the IT sector, financial institutions, the defense sector, and state digital services. However, broad implementation in industry, small businesses, and regional economies remains limited due to the consequences of the war and insufficient investment.

In 2026, a slight increase to 35% is projected. The main limiting factors are the continuation of military risks, damage to energy and digital infrastructure, as well as a shortage of highly qualified specialists. AI development occurs mainly in areas where there is a strategic necessity, including defense, cybersecurity, logistics, and the financial sector.

In 2027, the indicator may reach approximately 40%. Even under conditions of gradual economic recovery, the pace of digital transformation remains insufficient. Large enterprises begin to actively implement forecasting systems, production automation, and data analytics technologies, while a significant share of small and medium-sized enterprises lacks the financial capacity to integrate AI solutions.

In 2028, the projected level reaches approximately 45%. During this period, Ukraine may face the problem of technological dependence: instead of developing its own competitive AI solutions, enterprises mainly rely on foreign platforms. This limits the development of the national technological ecosystem and reduces the economic benefits generated by AI implementation.

In 2029, the level of AI development reaches approximately 50%. A gradual increase in the number of enterprises using business process automation, digital twins, robotic systems, and big data analytics is expected. However, the gap between technologically advanced companies and traditional enterprises remains significant.

In 2030, the pessimistic scenario assumes that Ukraine will reach only 55% of its potential AI development level. This means that Ukraine will have individual successful AI implementation centers

but will not achieve comprehensive integration of artificial intelligence into all areas of the economy. The country risks remaining primarily a consumer of ready-made technologies rather than a developer of its own AI solutions.

The graph line demonstrates gradual but slow growth, reflecting a situation where AI development continues but progresses at a lower pace compared with leading countries worldwide. The main reasons for this scenario include:

– prolonged consequences of the war and limitations on public funding;

– insufficient investment in AI research and development;

– outflow of highly qualified specialists;

– dependence on foreign technological platforms;

– uneven digitalization of enterprises.

The graph of the positive forecast for artificial intelligence development in Ukraine in 2025–2030 demonstrates accelerated growth in the level of AI technology integration into all sectors of the economy. Under this scenario, the level of AI development increases from approximately 35% in 2025 to 85% in 2030, indicating Ukraine's transition from the stage of using individual digital solutions to the formation of a fully developed innovation ecosystem. The main drivers of this development include the completion of the active phase of war-related risks, attraction of international investments, integration of Ukraine into the European Union's digital space, development of domestic technology companies, and training of specialists in the field of artificial intelligence. The graph of the positive forecast for the development of artificial intelligence in Ukraine in 2025–2030 demonstrates accelerated growth in the level of AI technology integration across all sectors of the economy. Under this scenario, the level of AI development increases from approximately 35% in 2025 to 85% in 2030, indicating Ukraine's transition from the stage of implementing individual digital solutions to the formation of a comprehensive innovation ecosystem. The main factors driving

Table 3.4 – Positive Forecast of Artificial Intelligence Development in Ukraine (2025–2030)

Year	Expected Situation	Main Development Factors	Estimated Level of AI Development
2025	Increased use of AI in business, public administration, defense, and education	Development of digital services, support from international partners, growing demand for automation	35%
2026	Expansion of AI implementation in industry, logistics, finance, and healthcare	Investments in digital infrastructure, training of specialists, development of startups	45%
2027	Formation of the Ukrainian AI ecosystem	Creation of research centers, cooperation with the EU, use of AI for economic recovery	55%
2028	Large-scale integration of AI into production processes and enterprise management	Automation, robotization, development of proprietary technological solutions	65%
2029	Transition to an innovative economic model based on AI	Growth of investments, development of Ukrainian AI companies, export of digital products	75%
2030	AI becomes one of the key factors of Ukraine's competitiveness	Full integration of AI into business, public administration, education, and industry	85%

this development include the completion of the active phase of war-related risks, attraction of international investments, integration of Ukraine into the European Union's digital space, development of domestic technology companies, and training of specialists in the field of artificial intelligence.

In 2025–2027, active implementation of AI is expected in strategic sectors such as industry, defense, logistics, agriculture, finance, and public administration. During 2028–2030, artificial intelligence

Table 3.5 – Comparison of Positive and Pessimistic Forecasts for the Development of Artificial Intelligence in Ukraine (2025–2030)

Year	Positive Scenario, %	Pessimistic Scenario, %
2025	35	30
2026	45	35
2027	55	40
2028	65	45
2029	75	50
2030	85	55

becomes one of the key factors in economic modernization, increasing enterprise productivity, and creating competitive advantages for Ukraine in international markets. The implementation of this scenario will allow Ukraine to move from the role of a consumer of ready-made technologies to that of an active participant in the global AI solutions market.

The graph presents two possible scenarios for the development of artificial intelligence in Ukraine up to 2030. The positive scenario is characterized by faster growth in the level of AI implementation – from 35% in 2025 to 85% in 2030. This trajectory assumes the gradual completion of the active phase of the war, economic recovery, increased international support, attraction of investments in digital technologies, development of Ukrainian IT companies, and active integration of Ukraine into the European digital space.

The pessimistic scenario demonstrates slower growth – from 30% in 2025 to 55% in 2030. Such development may occur under conditions of prolonged war-related risks, insufficient innovation financing, infrastructure destruction, outflow of qualified specialists, and continued dependence on foreign technology platforms. In this case, AI development is expected to remain concentrated mainly in large companies, the defense sector, and selected government projects.

The main difference (Table 3.6) between the positive and pessimistic forecasts lies in the speed of Ukraine's recovery and the ability of the economy to utilize the potential of artificial intelligence.

Table 3.6 – Differences Between Positive and Pessimistic Forecasts for AI Development

Criterion	Positive Forecast	Pessimistic Forecast
War	Completion of the active phase of the war in 2025–2026 and the beginning of large-scale reconstruction	Prolonged war period or slow post-war recovery
Investment in AI	Significant attraction of foreign and domestic investments	Limited funding due to economic instability
Digital infrastructure	Modernization of networks, development of data centers and cloud technologies	Slow recovery of damaged infrastructure
Enterprises	Large-scale implementation of AI in manufacturing, logistics, and management	AI adoption mainly by large companies
Human capital	Training of specialists and return of part of IT professionals	Continued outflow of qualified personnel
Domestic AI solutions	Development of Ukrainian startups and technological products	Predominant use of foreign platforms
Economic impact	Increased productivity, creation of new jobs, and modernization of the economy	Slow digital transformation and risk of technological lag
AI development level in 2030	≈85%	≈55%

In the positive scenario, the completion of the active phase of the war creates conditions for large-scale modernization of enterprises, attraction of investments, and implementation of AI as a strategic development tool. Ukraine gradually moves from the use of individual digital services to comprehensive automation of business processes, robotics, and data-driven management.

In the pessimistic scenario, even with gradual AI development, its implementation remains limited due to economic and security factors. Ukraine mainly relies on ready-made foreign technologies, while the potential of AI for modernizing industry, small businesses, and public administration is only partially realized.

The positive scenario assumes that AI will become one of the key factors of Ukraine's post-war recovery and competitiveness, whereas

the pessimistic scenario implies gradual development without fully utilizing the country's innovation potential. The difference between these scenarios in 2030 is approximately 30 percentage points, demonstrating the importance of government policy, investment, education, and international cooperation in the field of artificial intelligence.

The positive scenario for AI development in Ukraine is based on the assumption that after the completion of the active phase of the war, the country will become one of the largest European platforms for technological modernization. The significant scale of future reconstruction creates opportunities for attracting foreign capital into digital infrastructure, production automation, and the development of AI-based solutions. According to estimates by the World Bank, the European Commission, the United Nations, and the Government of Ukraine, the total cost of Ukraine's reconstruction needs amounts to approximately USD 524 billion over the next decade (assessment as of the end of 2024), while the updated 2025 estimate increases this figure to nearly USD 588 billion.

In 2024–2025, Ukraine's recovery needs were estimated by international partners at USD 524–588 billion. These funds are required to reconstruct destroyed infrastructure, housing, energy facilities, industrial enterprises, the transport system, and the social sector. Under the positive scenario, by 2030, the reconstruction process is viewed not merely as the restoration of lost assets but as an opportunity for comprehensive economic modernization. An investment potential of more than USD 600 billion is expected to be generated, part of which will be directed toward digital transformation, the development of artificial intelligence, automation, and the creation of modern technological infrastructure.

The current stage, digital components account for a relatively small share of Ukraine's recovery programs – approximately 5–10%. These primarily include individual projects focused on the digitalization of public services, the development of e-government, telecommunications

Table 3.7 – Main Statistical Indicators of the Positive Scenario for AI Development in Ukraine with the Support of Foreign Investors

Indicator	Baseline Status (2024–2025)	Positive Forecast for 2030
Ukraine's required recovery needs	USD 524–588 billion	Over USD 600 billion in investment potential
Share of digital and technological projects in reconstruction	5–10% (individual programs)	20–25% of all modernization investments
Investment in AI, automation, and digitalization	Approximately USD 0.5–1 billion per year (estimate)	USD 3–5 billion annually
Ukraine's IT exports	Approximately USD 7 billion per year	USD 12–15 billion
Number of enterprises using AI	10–15% of large companies	50–70% of medium-sized and large enterprises
Share of automated production processes	20–30% in leading companies	60–70% in industry
Number of AI startups	Hundreds of technology teams	1,000+ companies and startups
Level of AI development in the economy	30–35%	85%

infrastructure, and the implementation of digital solutions in business. Under the positive forecast, by 2030, digitalization will become one of the key areas of economic reconstruction. It is expected that 20–25% of all modernization investments will be related to digital technologies, including artificial intelligence, robotics, automated management systems, and digital platforms.

In 2024–2025, Ukrainian businesses are only beginning to actively scale up the implementation of AI solutions. The main areas of application include the financial sector, logistics, marketing, data analysis, customer service management, and the optimization of production processes. The volume of such investments is estimated at approximately USD 0.5–1 billion per year. Under favorable conditions, by 2030, following the end of the active phase of the war and increased inflows

of international capital, investments in AI and digital transformation could rise to USD 3–5 billion annually. This would contribute to the emergence of new technology sectors and accelerate industrial modernization.

Ukraine's IT sector remains one of the most resilient segments of the economy even under wartime conditions. In 2024–2025, the volume of IT service exports amounts to approximately USD 7 billion per year, generating significant foreign-currency revenues and supporting the country's competitiveness in the global market. Under the positive scenario, by 2030, Ukraine could move from a model primarily based on the export of IT services toward the development of its own AI-based technology products. IT exports are expected to increase to USD 12–15 billion, driven by the development of startups, cooperation with international technology companies, and the expansion of the digital services market.

During the 2024–2025 baseline period, artificial intelligence is primarily used by large companies with sufficient financial and technological resources. These include banks, telecommunications companies, logistics operators, and industrial enterprises. Their share is estimated at approximately 10–15% of large enterprises. By 2030, a significant expansion of AI adoption across the business sector is expected: approximately 50–70% of medium-sized and large enterprises may use artificial intelligence technologies for demand forecasting, resource management, risk analysis, operational automation, and managerial decision-making.

In 2024–2025, the level of automation in Ukrainian industry remains uneven. The most technologically advanced enterprises use robotic production lines, digital quality-control systems, ERP systems, and elements of the Industrial Internet of Things (IIoT). The overall share of automated processes is estimated at 20–30%. Under the positive scenario, by 2030, investment in production modernization could increase this indicator to 60–70%. This would help increase labor productivity, reduce production costs, and integrate Ukrainian enterprises into European production value chains.

At the current stage, Ukraine has significant potential in the field of technological entrepreneurship due to its highly skilled IT workforce. However, the number of companies specializing specifically in artificial intelligence remains relatively limited. These include hundreds of technology teams operating in areas such as finance, defense, cybersecurity, healthcare, and data analytics. Under the positive forecast, by 2030, Ukraine could develop a strong ecosystem of AI startups comprising more than 1,000 companies and technology projects. This would contribute to the creation of new jobs, the attraction of venture capital investment, and the development of an innovation-driven economy.

In 2024–2025, the level of AI integration into Ukraine's economic processes is estimated at approximately 30–35%, as these technologies are primarily used by individual industries and large enterprises. The main barriers remain insufficient investment, a shortage of qualified specialists, high implementation costs, and the consequences of the war. Under the positive scenario, by 2030, the level of AI development in the economy could reach 85%. This would mean that the majority of enterprises would use artificial intelligence for strategic management, operational automation, forecasting market changes, and improving competitiveness.

The positive scenario for the development of artificial intelligence in Ukraine by 2030 envisages a transition from a post-war recovery model toward the formation of a digital innovation-driven economy. The main conditions for implementing this scenario include the end of the war, the attraction of international investment, support from the European Union, the development of education, and the training of specialists in digital technologies. As a result of the active use of AI, Ukraine could increase enterprise productivity, create new technology sectors, strengthen its export potential, and integrate into global innovation value chains. Artificial intelligence will become not only a tool for digitalization but also one of the key factors of the country's economic recovery and long-term development.

Table 3.8 – Examples of Foreign Investment Support for Digital Development [131–149]

Investor	Volume of Support	Significance for AI Development
European Union	Tens of billions of euros in support programs for Ukraine	Digital transformation and integration into the EU Single Digital Market
World Bank, EBRD, IFC	Hundreds of millions of US dollars for digital infrastructure	Modernization of telecommunications and technological systems
IFC and EBRD	USD 435 million in investment in a Ukrainian telecommunications company in 2024	Development of digital infrastructure required for AI services
International technology companies	Strategic partnerships	Technology transfer, cloud solutions, and cybersecurity

The European Union is one of Ukraine's key partners in the areas of digitalization, innovation, and post-war recovery. EU support is aimed not only at financing reconstruction but also at creating a modern digital economy, developing artificial intelligence, strengthening cybersecurity, expanding digital public services, and integrating Ukraine into the European Single Digital Market.

The main areas of EU assistance include the Digital Europe Programme, Horizon Europe, EU4Digital, as well as financial support provided through the Ukraine Facility. These programs provide funding for digital infrastructure, the development of innovative enterprises, AI research, startup support, and the training of qualified specialists. Under the Digital Europe Programme, Ukraine has gained the opportunity to participate in European projects related to high-performance computing, artificial intelligence, cybersecurity, and digital skills. The objective of the program is to create a common digital space for the EU and its partner countries [131].

An important area of EU support is the Horizon Europe programme, which supports scientific research and innovation. Ukrainian

universities, research institutions, and technology companies can receive grants for the development of AI solutions, digital platforms, robotics, and Industry 4.0 technologies [132]. Within the framework of the Ukraine Facility (2024–2027), the EU has provided substantial financial support to Ukraine for economic reforms and recovery. A significant portion of these funds is directed toward the digital transformation of the state, industrial modernization, and the creation of favorable conditions for attracting innovative investment [133].

Impact of EU programmes:

– accelerating Ukraine's digital integration into the European digital space;

– supporting the development of Ukrainian AI startups;

– modernizing public digital services;

– supporting enterprises in the implementation of automation technologies;

– creating favorable conditions for attracting foreign technology companies.

The World Bank, the European Bank for Reconstruction and Development (EBRD), and the International Finance Corporation (IFC) play an important role in supporting Ukraine's economic recovery. Their activities focus on financing critical infrastructure, supporting businesses, digitalizing public administration, and developing innovative enterprises.

The World Bank implements programs in Ukraine aimed at strengthening economic resilience, improving public administration, and restoring infrastructure. One of the key areas is the digitalization of public services, the development of e-government, and improving the efficiency of public administration. Through its financial support programs, the World Bank helps Ukraine to:

– modernize government information systems;

– develop digital services for citizens;

– support governance reforms;

– implement technological solutions in reconstruction projects.

The World Bank contributes to the development of a digital state, the reduction of administrative costs, and greater transparency in public administration.

The EBRD is one of the largest institutional investors in Ukraine. The Bank supports the private sector, industrial enterprises, energy, transport, logistics, and digital transformation.

Key areas of support include:

– financing technological modernization of enterprises;
– supporting small and medium-sized businesses;
– developing innovative companies;
– implementing digital management systems.

An example of the EBRD's impact is its support for enterprises implementing automation, energy-efficient technologies, and digital production management systems. The EBRD contributes to the transition of Ukrainian businesses from traditional production models toward Industry 4.0.

The IFC supports the development of Ukraine's private sector through investments, loans, and advisory programs. The organization actively works with technology companies, banks, agribusinesses, and industrial enterprises.

Key areas of support include:

– digitalization of business processes;
– development of financial technologies (FinTech);
– support for innovative companies;
– attracting private investment.

The IFC helps enterprises implement:

– data analytics systems;
– automated production processes;
– digital management platforms;
– modern financial technologies.

The IFC stimulates the development of private businesses and creates favorable conditions for scaling Ukrainian technology companies [134].

International technology companies play an important role in the development of Ukraine's digital sector by establishing partnership programs, investing in digital infrastructure, and supporting the adoption of artificial intelligence.

Microsoft supports Ukraine through the development of cloud technologies, cybersecurity, and the use of artificial intelligence. The company provides Ukrainian government institutions and businesses with access to cloud platforms used for data storage, analytics, and digital services [140].

Impact:

– development of cloud infrastructure;

– support for cybersecurity;

– implementation of AI solutions in the public sector and business.

Google implements programs supporting Ukrainian entrepreneurs, educational initiatives, and digital skills development. The company promotes the use of artificial intelligence through educational platforms and cloud technologies [141–142].

Impact:

– development of digital competencies;

– support for small businesses;

– wider adoption of AI tools.

Amazon Web Services (AWS) supports digital transformation through cloud solutions that enable companies to use artificial intelligence, machine learning, and big data analytics.

Impact:

– development of technological infrastructure;

– support for startups;

– access to AI services.

International support for Ukraine in the areas of AI and digitalization is developing along three main directions:

The European Union provides the regulatory and financial framework for Ukraine's digital integration with Europe.

The World Bank, EBRD, and IFC provide financing for economic modernization and support for businesses.

International technology companies provide technologies, cloud infrastructure, and expertise for the implementation of AI solutions [145–147].

The combined impact of these programs could become one of the key factors in Ukraine's transition toward an innovative digital economy and a technology-driven development model in the post-war period.

Amazon Web Services (AWS) is one of the world's largest cloud platforms, providing businesses with access to computing resources, data storage, analytics, and artificial intelligence technologies without requiring them to build their own costly IT infrastructure. AWS plays an important role in the digital transformation of businesses by enabling companies to rapidly implement solutions based on machine learning, big data analytics, and business process automation.

AWS supports the development of artificial intelligence through a range of Amazon AI and Machine Learning services, which enable enterprises to develop predictive models, analyze large volumes of information, automate managerial decision-making, and improve customer interactions. For example, companies can use machine learning technologies to forecast demand, optimize logistics, control product quality, and manage production processes.

One of the key areas of AWS's impact is the development of technological infrastructure. AWS cloud solutions provide enterprises with access to high-performance computing resources, data storage systems, and cybersecurity tools. This is particularly important for countries undergoing digital modernization, as it enables them to avoid significant costs associated with building their own data centers and accelerates the adoption of innovative technologies.

The second important area is the support of startups and innovative entrepreneurship. AWS implements programs for technology companies that provide access to cloud resources, educational materials, consulting services, and development tools. As a result, young companies can develop AI-based products more quickly, scale their solutions, and enter international markets.

The third area is providing businesses with access to AI services. AWS offers ready-to-use solutions in the fields of generative AI, text analysis, computer vision, natural language processing, and predictive analytics. This enables even companies without large in-house IT teams to use advanced technologies to improve their efficiency.

The main impact of AWS on the digital economy:

1. Development of technological infrastructure:
– providing access to cloud computing;
– developing digital platforms for businesses;
– providing scalable IT infrastructure;
– enhancing cybersecurity.
2. Support for startups:
– access to cloud resources for young technology companies;
– development of innovation ecosystems;
– support for the development of AI solutions;
– opportunities for rapid entry of products into global markets.
3. Access to AI services:
– use of machine learning;
– automation of business processes;
– big data analytics;
– development of predictive models;
– implementation of generative artificial intelligence.

For Ukraine, the use of AWS is of strategic importance in the context of digital modernization and post-war recovery. Cloud technologies can become the foundation for the development of a digital state, business support, and the creation of new technology companies. AWS enables Ukrainian enterprises to access global technological infrastructure, develop AI-based products, and integrate into the global digital economy.

The use of AWS is particularly important in the following areas:

– Logistics – demand forecasting, route optimization, and supply chain management;

– Industry – production automation, quality control, and digital twins;

– Agriculture – analysis of data from sensors and yield forecasting;

– Financial sector – fraud detection, risk assessment, and customer service automation;

– Public administration – digital services and protection of information systems.

AWS is one of the key technology partners in digital transformation, as it provides access to modern cloud infrastructure and artificial intelligence tools. Its impact extends beyond the implementation of new technologies to the creation of favorable conditions for the development of innovative businesses, support for startups, and enhancement of economic competitiveness.

For Ukraine, the use of AWS could become an important factor in post-war modernization, as it enables the rapid implementation of digital solutions, the development of technology-based entrepreneurship, and the integration of Ukrainian businesses into the global digital ecosystem.

Amazon Web Services (AWS) is one of the key global technology partners contributing to the acceleration of digital transformation in enterprises and the development of a data-driven economy. The use of AWS cloud technologies enables organizations to access modern computing infrastructure, artificial intelligence, machine learning, and analytical tools without the need for significant investments in their own technological systems. This creates favorable conditions for the rapid adoption of innovations and enhances business competitiveness.

An important outcome of AWS's activities is the development of new technological infrastructure that enables the scaling of digital solutions and supports the development of innovative management models. Cloud services allow enterprises to use large volumes of data more efficiently, automate operational processes, optimize costs, and make more informed managerial decisions. This is particularly important for industry, logistics, the financial sector, and services.

A significant impact of AWS is evident in the development of artificial intelligence and machine learning. Access to ready-to-use AI services enables companies to implement predictive analytics,

automated customer service, information recognition systems, intelligent data processing, and generative artificial intelligence. This contributes to the transition of enterprises from traditional management approaches toward digital models in which decisions are based on data analysis and artificial intelligence algorithms.

An important area of AWS's activities is the support of technology entrepreneurship and startup ecosystems. Providing access to cloud resources, educational programs, and technological tools enables young companies to develop innovative products more quickly and enter international markets. Such support contributes to the creation of new jobs, the development of high-tech sectors of the economy, and the formation of a competitive digital environment.

For Ukraine, AWS technologies are particularly important in the context of post-war modernization and economic recovery. The use of cloud infrastructure and AI solutions can accelerate the digitalization of enterprises, improve production efficiency, support the development of electronic services, and facilitate the integration of Ukrainian businesses into the global technology ecosystem. AWS could become one of the instruments supporting Ukraine's transition toward an innovation-driven economic model.

Thus, the impact of AWS extends beyond the provision of technological services and contributes to the formation of a new digital paradigm of business development. Cloud solutions, artificial intelligence, and machine learning are becoming important factors in increasing enterprise productivity, resilience, and competitiveness. In the long term, the continued adoption of AWS technologies could contribute to the development of Ukraine's digital economy, attract international investment, and support the formation of a technology-oriented model of economic growth.

The positive scenario for the development of artificial intelligence in Ukraine largely depends on attracting foreign capital (Table 3.9), as international investment provides access to advanced technologies, financing for digital infrastructure, telecommunications development, cloud services, and the automation of business processes.

Table 3.9 – Examples of Foreign Investments in the Digital Transformation and Technological Development of Ukraine

Investor / Country	Project	Investment Volume	Year	Significance for AI Development and the Digital Economy
IFC (World Bank) + EBRD + EU + France	Merger and development of the Datagroup–Volia–lifecell telecommunications group	USD 435 million	2024	The largest direct foreign investment since the beginning of the full-scale war. The investment is aimed at modernizing digital infrastructure, increasing network resilience, expanding high-speed Internet access, and strengthening cybersecurity
European Bank for Reconstruction and Development (EBRD)	Support for the Ukrainian economy and private sector	EUR 2.4 billion in 2024	2024	A record level of financing that creates a foundation for the digital modernization of enterprises, the energy sector, transport, and industry
IFC + Horizon Capital	Investments in Ukrainian technology companies	USD 60 million + USD 79 million mobilized	2022–2024	Support for the technology sector, IT companies, and innovative business models capable of adopting AI solutions
IFC + European Commission	Better Futures Program for Ukraine's private sector	EUR 90 million in guarantees; more than EUR 500 million in expected mobilized investment	2024	Reduction of investment risks and stimulation of investment in manufacturing, infrastructure, and digital projects
International technology companies and venture capital funds	Investments in startups, software, and AI solutions	Potentially tens to hundreds of millions of US dollars	2025–2030	Formation of the Ukrainian AI ecosystem, development of proprietary digital products, and expansion into international markets

One of the most illustrative examples of support for Ukraine's digital development is an investment project in the telecommunications sector involving the International Finance Corporation (IFC), the European Bank for Reconstruction and Development (EBRD), the European Commission, and the Government of France. The total financing amounts to USD 435 million, making it the largest direct foreign investment in Ukraine since the beginning of the full-scale war. The funds are aimed at modernizing telecommunications infrastructure, increasing the resilience of digital networks, and providing high-quality connectivity to approximately 10 million users, as well as faster Internet access to around 4 million households. Such infrastructure provides a foundation for the further development of AI, as artificial intelligence requires robust digital networks, access to large volumes of data, and reliable connectivity to cloud technologies.

An important factor in the positive scenario is the activity of the EBRD, which invested a record EUR 2.4 billion in Ukraine in 2024. A significant share of these funds was directed toward supporting the private sector, critical infrastructure, and enterprise modernization. Such investments create favorable conditions for the implementation of artificial intelligence systems in manufacturing, logistics, energy, and enterprise management.

Another important area is support for Ukraine's technology sector. The IFC invested USD 5 million in Miratech and USD 5 million in the Preply platform, as well as USD 60 million in the Horizon Capital fund, which helped mobilize additional financing for technology companies. These examples demonstrate that international partners continue to view Ukraine's IT sector as a promising area for development even under wartime conditions.

Therefore, the positive scenario for AI development in Ukraine (Table 3.10) is based not only on domestic capabilities but also on substantial international support. Investments in telecommunications, digital infrastructure, technology companies, and innovative projects can accelerate Ukraine's transition toward a data- and

Table 3.10 – Forecast of the Impact of Foreign Investment on AI Development in Ukraine

Year	Investment in AI and Digitalization (Forecast)	Result
2025	USD 1 billion	Launch of digital reconstruction programs
2026	USD 1.5 billion	Development of data centers and cloud technologies
2027	USD 2.5 billion	Creation of Ukrainian AI platforms and startups
2028	USD 3.5 billion	Large-scale industrial automation
2029	USD 4 billion	Entry of Ukrainian AI solutions into international markets
2030	USD 5 billion	Formation of a competitive AI ecosystem

AI-driven economy. Provided that the active phase of the war ends and international support is maintained, Ukraine has the potential to develop a competitive AI ecosystem by 2030 and become one of the technology hubs of Eastern Europe.

The statistical indicators of the positive scenario demonstrate that foreign investment can become a key catalyst for the development of artificial intelligence in Ukraine. The scale of future reconstruction creates an opportunity to move from traditional infrastructure recovery toward the formation of a "smart economy", in which AI is used to manage manufacturing, energy, logistics, the agricultural sector, and public services. The required recovery needs of more than USD 500 billion create a significant market for innovative technologies. With active international capital mobilization, Ukraine could increase investment in AI several times over, contributing to the emergence of new technology companies, the development of proprietary algorithms, and the integration of Ukrainian businesses into global digital value chains. In this case, artificial intelligence will become not only a tool for automation but also one of the key factors of post-war economic modernization and the enhancement of Ukraine's international competitiveness.

3.2. ECONOMIC MODERNIZATION AS A NECESSARY CONDITION FOR ENSURING SUSTAINABLE DEVELOPMENT OF SOCIETY

Under current conditions of global transformations, economic modernization is regarded as a comprehensive process of structural, technological, institutional, and social changes aimed at improving the efficiency of the economic system, its competitiveness, and its ability to ensure the long-term development of society. Modernization involves not only the renewal of production capacities or the introduction of new technologies but also a transformation of the principles underlying the functioning of the economy in response to contemporary challenges.

The concept of "economic modernization" emerged within twentieth-century theories of social development and was initially associated with the transition of traditional agrarian economies toward an industrial model. In the contemporary understanding, modernization refers to the transition toward an innovation-driven, digital, and knowledge-based economy, in which the key resources of development include not only material assets but also information, technology, human capital, and intellectual potential.

Economic modernization encompasses several interconnected areas. First, there is technological modernization, which involves the implementation of digital technologies, artificial intelligence, automation, robotics, and modern production systems. Second, there is structural modernization, which involves transitioning from a raw-material and low-technology economic model toward the development of high-tech industries with high added value. Third, there is institutional modernization, which includes improving governance systems, developing entrepreneurship, creating a favorable investment environment, and integrating into international economic systems.

Economic modernization is particularly important for Ukraine, which, under the conditions of the full-scale war and post-war

recovery, needs to undertake not only the physical reconstruction of destroyed facilities but also a qualitative transition toward a new development model. Such a model should be based on digitalization, innovation, human capital development, the attraction of international investment, and integration into the European economic space.

The historical development of economic systems demonstrates a gradual transition from simple economic models toward complex innovation-driven systems based on knowledge and technology. Each stage of economic evolution has been characterized by changes in the main factors of production, methods of labor organization, and sources of economic growth.

The first stage was the traditional agrarian economy, in which land, natural resources, and physical labor served as the main resources for development. Economic growth depended primarily on expanding production and increasing the amount of resources involved. This model had limited development potential due to low labor productivity and dependence on natural factors.

The next stage was the industrial economy, the formation of which was associated with the Industrial Revolution of the eighteenth and nineteenth centuries. Its development was based on mechanized production, the mechanization of labor, industrial enterprises, and mass production. The industrial model generated significant economic growth but gradually led to problems related to excessive resource consumption, environmental pollution, and social inequality.

In the second half of the twentieth century, the post-industrial economy emerged, in which the service sector, information, education, and professional knowledge began to play a central role. The emergence of information technologies contributed to the transition toward a knowledge-based economy, where innovation and the ability to develop new technological solutions became key factors of competitiveness.

The contemporary stage of development is characterized by the formation of a digital and innovation-driven economy. Its foundation is the use of artificial intelligence, big data, cloud technologies, robotics,

the Internet of Things, and automated management systems. Within this model, economic development depends on the ability of governments and enterprises to create, implement, and effectively use new knowledge.

Economic modernization is directly linked to the concept of sustainable development, which involves ensuring economic growth without depleting natural resources or compromising the quality of life of future generations. While traditional development models were primarily focused on maximizing production and profit, the contemporary approach seeks to achieve a balance between economic, social, and environmental objectives.

Economic modernization creates a foundation for sustainable development by improving resource efficiency, developing environmentally friendly technologies, and creating new production models. For example, digital technologies and artificial intelligence make it possible to optimize energy consumption, forecast production processes, reduce resource use, and improve management efficiency.

At the same time, sustainable development determines the directions of economic modernization, as contemporary economic growth must take into account the social needs of the population and environmental constraints. Therefore, important areas of modernization include the development of the green economy, ESG strategies, circular production, and socially responsible business.

Innovation is one of the key factors of economic modernization, as it ensures the creation of new products, technologies, and management models. Under contemporary conditions, the competitive advantages of countries and enterprises are determined not only by the availability of natural resources or production capacities but also by their ability to generate and implement innovative solutions.

Human capital plays a particularly important role and includes the level of education, professional competencies, creative potential, and the ability to adapt to technological change. In the digital economy, qualified professionals have become a key development resource, as they ensure the creation and effective use of new technologies.

Technological development, particularly artificial intelligence, automation, and digital platforms, is transforming the structure of the economy, increasing labor productivity, and creating new opportunities for businesses. Enterprises that actively implement digital solutions gain competitive advantages through faster decision-making, process optimization, and more efficient use of resources.

The concept of sustainable development, developed by the United Nations, envisages a form of societal development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. In 2015, the United Nations adopted 17 Sustainable Development Goals (SDGs), which define global priorities for economic, social, and environmental development.

The economic dimension of sustainable development involves ensuring stable economic growth, fostering innovation, creating decent jobs, and increasing labor productivity. In this context, economic modernization serves as a mechanism for transitioning toward a more efficient and competitive economic system.

The social dimension focuses on ensuring equal opportunities, developing education and healthcare, strengthening social protection, and improving the quality of life of the population. An important task is to develop human capital capable of working effectively in a digital economy.

The environmental dimension involves the rational use of natural resources, reducing the negative environmental impact of production, developing renewable energy, and implementing the principles of a green economy.

Thus, economic modernization is a fundamental prerequisite for sustainable development, as it ensures the combination of technological progress, economic growth, social stability, and environmental responsibility. Under contemporary conditions, innovation-driven and digital modernization determines a country's ability to adapt to global changes and build a competitive economy of the future.

In contemporary studies by Ukrainian scholars, the concept of sustainable development is viewed as a strategic foundation for economic modernization, involving not only economic growth but also structural transformation of production, the development of innovation, more efficient use of resources, and the formation of a socially oriented economic system.

V. Heyets [156] examines sustainable development through the interaction of society, the state, and the economy. The scholar emphasizes that modern economic modernization is impossible without improving the quality of institutions, developing human capital, disseminating knowledge, and establishing an innovation-driven development model. According to V. Heyets, the key resource of the modern economy is not limited to material factors of production but also includes society's ability to create and effectively use new knowledge.

B. Danylyshyn, M. Khvesyk, and V. Holian [157] emphasize the environmental component of sustainable development. The researchers note that economic growth should be combined with the rational use of natural resources, the development of environmentally friendly technologies, and the formation of new models of natural resource management. This approach defines economic modernization as a process of transition toward a resource-efficient and environmentally responsible development model.

A. Cherep and A. Leshchenko [155] examine the modernization of Ukraine's economy in the context of post-war recovery and European integration. The scholars emphasize that sustainable development should become the foundation of Ukraine's reconstruction, which should involve the technological renewal of industry, the development of innovation infrastructure, the attraction of international investment, and the implementation of modern management standards.

V. Herasymchuk [158] investigates the modernization of Ukraine's real sector of the economy based on the principles of sustainable

development. The scholar emphasizes that post-war recovery should not aim at returning to the previous production model but rather at creating a modern economy characterized by high added value, innovative industry, and strong export potential.

V. Ivanchenkov [159] notes that sustainable development for Ukraine is not merely a long-term concept but a necessary condition for overcoming structural imbalances in the economy. The scholar highlights the need for economic diversification, the development of high-tech industries, the implementation of innovations, and the transition from a raw-material-based model toward a knowledge-based economy.

Thus, Ukrainian researchers view sustainable development as a comprehensive model of economic modernization that incorporates three interconnected dimensions (Fig. 3.3):

– economic – innovation-driven development, technological renewal, and increased competitiveness;

– social – development of human capital, education, employment, and quality of life;

– environmental – resource efficiency, the green economy, and environmental security.

Thus, in contemporary Ukrainian academic thought, sustainable development is not regarded as a separate area of economic policy but rather as a strategic guideline for economic modernization, ensuring the transition from a traditional development model toward an innovative, digital, and competitive economic system.

The concept of "economic modernization" is multifaceted and is interpreted by scholars depending on the research approach adopted: technological, structural, institutional, social, or innovation-oriented. In the academic literature, modernization is viewed not merely as the renewal of production capacities but as a comprehensive process of transforming the economic system, enabling it to adapt to global changes and creating conditions for sustainable development.

One of the classical approaches interprets modernization as a process of transition from a traditional economy toward

Figure 3.3 – Main Components of Sustainable Development as the Basis for Economic Modernization

a modern industrial and post-industrial development model. Representatives of modernization theory, including D. Bell, W. Rostow, and T. Parsons, viewed it as a natural stage of social development involving changes in the structure of production, the advancement of science and technology, the development of education, and institutional transformation.

The Ukrainian researcher B. Dergaliuk views economic modernization as a process of structural change, technological renewal, and the intellectualization of economic relations. According to the author, modern modernization should focus not only on upgrading production but also on establishing a new quality of development of the economic system that ensures sustainable economic growth and enhances the competitiveness of the state [148].

Researcher O. Liakhovets focuses on the institutional dimension of economic modernization. She notes that economic transformation

is impossible without changes in the institutional environment, since the quality of economic and legal institutions determines a country's ability to implement innovations, attract investment, and ensure the effective functioning of the market. Thus, modernization is viewed as an interrelationship between technological, organizational, and institutional changes [149].

Within the structural approach, economic modernization is regarded as a process of transforming the sectoral structure and transitioning toward high-tech production. M. Shashyna defines structural modernization as a set of changes in the economic structure that ensure the transition toward a more efficient production system, the development of innovative sectors, and a reduction in dependence on low-technology industries [150].

Another approach is associated with the concept of innovation-driven modernization, in which science, technology, and human capital are the main factors of development. In the modern economy, competitive advantages are determined not so much by the availability of natural resources as by the ability to create and use new knowledge. Therefore, modernization today includes digitalization, the development of artificial intelligence, production automation, robotics, and the implementation of Industry 4.0 technologies.

From the perspective of sustainable development, economic modernization should be viewed as a process that ensures a balance between economic growth, social progress, and environmental responsibility. Contemporary researchers emphasize that technological renewal should be accompanied by the rational use of resources, the development of the green economy, and improvements in the quality of life of the population.

Thus, an analysis of scientific approaches makes it possible to conclude that economic modernization is a comprehensive process of qualitative transformation of the economic system, encompassing technological, structural, institutional, and social changes. It involves a transition from a traditional development model toward

an innovation-driven economy based on knowledge, digital technologies, efficient resource use, and human capital development.

In the studies of A. Cherep [155], economic modernization is viewed as a comprehensive process of structural transformation of the economic system involving technological transformation, innovation development, investment attraction, increased enterprise competitiveness, and adaptation of the economy to contemporary global challenges. The author emphasizes that the modernization of Ukraine should not be based on simply restoring existing production capacities but rather on establishing a new economic development model based on European standards, digitalization, and innovation.

In the article "Modernization of Ukraine's Economy in the Post-War Period," A. Cherep and A. Leshchenko identify the following as the key areas of modernization:

Table 3.11 – Summary of Authors' Approaches to the Concept of "Economic Modernization"

Author	Main Approach	Essence of Economic Modernization
W. Rostow	Stage-based development	Transition of the economy through successive stages of development toward a high level of consumption and technological progress
D. Bell	Post-industrial approach	Transition toward a knowledge-based economy in which information and human capital are the main resources
B. Dergaliuk [148]	Structural and technological approach	Technological renewal, structural changes, and the intellectualization of the economy
O. Liakhovets [149]	Institutional approach	Modernization through the improvement of economic institutions and governance systems
M. Shashyna [150]	Structural approach	Restructuring of the economy and development of high-tech sectors
E. Kosmitskyi, D. Penkovskyi [154]	Socio-technological approach	Modernization as the transformation of society through technologies and new development models

– technological renewal of industry;
– development of export potential;
– attraction of international financing;
– integration of Ukraine into the European economic space;
– reform of the economic system in accordance with modern standards.

The academic approach of A. Cherep [155] makes it possible to define economic modernization as a strategic process of transition from a traditional development model toward an innovation-driven economy in which knowledge, technology, human capital, and international cooperation become the main drivers of growth.

Under current conditions of global transformation, the traditional economic development model, which for a long time was based primarily on the extensive use of natural resources, increasing the scale of production and consumption, is gradually losing its effectiveness. This approach ensured economic growth in the short term but resulted in a number of systemic problems, including the depletion of natural resources, environmental degradation, increasing social inequality, and greater economic vulnerability of states. Therefore, the modern economy requires a transition from a quantitative growth model toward a qualitative, innovation-oriented development model.

Economic modernization is a key prerequisite for ensuring sustainable development of society, as it involves the comprehensive renewal of technological, production, institutional, and social spheres. Its essence lies not only in the introduction of new technologies but also in the formation of an effective resource management system, the development of human capital, increased labor productivity, and the creation of conditions for long-term economic growth. Unlike the traditional development model, a modernized economy focuses on knowledge, innovation, and the ability to adapt to rapid changes in the external environment.

An important aspect of modernization is the transition toward an innovation-driven economy, in which scientific knowledge, digital technologies, and the intellectual potential of society become the main

sources of competitive advantage. The innovation-based development model makes it possible to ensure more efficient use of resources, reduce the negative environmental impact of production, and create new opportunities for economic growth. In this process, particular importance is attached to digitalization, automation, the development of artificial intelligence, and other Industry 4.0 technologies, which are transforming approaches to the organization of production and management processes.

Economic modernization also ensures the alignment of the three main components of sustainable development: economic efficiency, social stability, and environmental responsibility. The economic component is implemented through increased productivity, the development of competitive industries, and the creation of new markets. The social component involves the formation of a high-quality education system, the training of a new generation of professionals, and the provision of employment opportunities for the population. The environmental component is reflected in the transition toward resource-efficient production, the use of renewable energy sources, and the implementation of green economy principles.

Thus, economic modernization is not only a tool for increasing the level of economic development but also a strategic condition for building a resilient society capable of effectively responding to contemporary challenges. For Ukraine, this process is particularly important in the context of post-war recovery, as it requires a transition from restoring traditional production models toward creating an innovative, digital, and competitive economy integrated into the European economic space. In this context, the use of artificial intelligence technologies can become one of the key factors accelerating modernization processes and ensuring the country's sustainable development.

Economic modernization is a comprehensive process that encompasses not only the renewal of production technologies but also the transformation of institutions, management systems, the social

sphere, and approaches to the use of natural resources. Under modern conditions, the effectiveness of economic development is determined by the ability of governments and enterprises to adapt to technological changes, ensure innovation, use resources rationally, and create conditions for long-term resilience. Therefore, modernization is viewed as a multidimensional process that combines economic, technological, social, and environmental transformations.

One of the key areas is technological modernization, which involves the introduction of modern digital technologies, automated management systems, robotics, artificial intelligence, and other Industry 4.0 tools. Its primary objective is to increase labor productivity, optimize production processes, reduce costs, and enhance the competitiveness of enterprises. The use of digital technologies makes it possible to move from a traditional production model toward smart manufacturing, based on the analysis of large volumes of data, forecasting, and informed managerial decision-making.

Another important area is innovation-driven modernization, which involves the development of scientific research, support for R&D activities, the creation of innovation infrastructure, and the development of startup ecosystems. In the modern economy, the ability to generate and implement new knowledge determines the competitive advantages of countries and enterprises. Innovation-driven modernization contributes to the emergence of new types of economic activity, the development of high-tech sectors, and the transition from a resource-based development model toward a knowledge-based economy.

Particular importance is attached to environmental modernization, which aims to ensure a balance between economic growth and environmental protection. It includes the development of renewable energy, the introduction of energy-efficient technologies, the reduction of emissions, the application of circular economy principles, and the rational management of natural resources. Environmental modernization not only helps reduce the negative impact of production

on the environment but also creates new economic opportunities through the development of green technologies and environmentally responsible businesses.

No less important is institutional modernization, which involves improving the system of public administration, the legislative framework, mechanisms for regulating economic processes, and ensuring transparency in organizational activities. Effective institutions create a favorable environment for investment, innovation, and entrepreneurial activity. This area is particularly relevant for Ukraine, as successful economic modernization requires improving the quality of public administration, aligning with European Union standards, and creating conditions for attracting international capital.

An important element of the modernization process is social modernization, which is associated with the development of human capital, improvement of the education system, training of a new generation of professionals, and the development of digital competencies among the population. In the modern economy, knowledge, professional skills, and the ability to work with new technologies are becoming decisive factors of development. Investments in human capital contribute not only to economic growth but also to improving the quality of life, ensuring social stability, and enhancing society's ability to adapt to global changes.

Thus, the main areas of economic modernization form an interconnected system of changes in which technological development is complemented by innovation-driven, institutional, environmental, and social transformations. A comprehensive approach to modernization makes it possible to ensure not only economic growth but also the long-term resilience of society. For Ukraine, under conditions of post-war recovery, these areas should become the foundation for the formation of a new economic model focused on digitalization, innovation, European integration, and the effective use of the potential of artificial intelligence.

In modern economic science, economic modernization is viewed as a multicomponent process of qualitative changes aimed at renewing the production system, increasing competitiveness, developing human

Table 3.12 – Main Areas of Economic Modernization and Their Impact on Sustainable Development

Modernization Area	Content of the Area	Impact on Sustainable Development
Technological modernization	Introduction of digital technologies, artificial intelligence, automation, robotics, and Industry 4.0 technologies	Increased productivity, resource efficiency, and enterprise competitiveness
Innovation-driven modernization	Development of science, research and development (R&D), support for startups, and creation of innovation infrastructure	Formation of a knowledge-based economy, creation of new markets and high-tech industries
Environmental modernization	Use of green energy, resource-efficient technologies, and circular economy principles	Reduction of negative environmental impacts and enhancement of environmental security
Institutional modernization	Improvement of governance, legislation, regulatory mechanisms, and business support systems	Creation of a favorable environment for investment, innovation, and entrepreneurship development
Social modernization	Development of education, digital competencies, professional training, and human capital	Improvement of quality of life, employment, and social resilience

capital, and ensuring sustainable development of society. Most scholars define modernization not merely as technological upgrading but as a comprehensive transformation of the economic, social, institutional, and environmental components of development.

V. Heyets [161] considers the modernization of Ukraine's economy as a comprehensive process of structural and technological changes aimed at ensuring the transition toward a knowledge-based economy. The scholar emphasizes that the key conditions for modernization are the development of innovation, human capital, and effective institutions.

L. Fedulova [164] focuses on the technological and innovation components of modernization. In her view, the competitiveness of the economy depends on a country's ability to create and utilize new technologies, develop its scientific potential, and establish innovation infrastructure.

A. Halchynskyi [162] associates modernization with Ukraine's transition toward a post-industrial economy, in which knowledge, information, and the intellectual potential of society become the main resources of development.

O. Amosha [165] and V. Vyshnevskyi [166] examine the modernization of the industrial sector, emphasizing the need for technological renewal of enterprises, the development of digital production, and the formation of a new-generation industry.

S. Illiashenko [164] considers modernization from the perspective of innovative development of enterprises, emphasizing the importance of innovation management, marketing technologies, and the development of intellectual capital.

E. Libanova [169] draws attention to the social dimension of modernization, noting that economic transformations should be accompanied by the development of human potential, education, employment, and social security.

B. Danylyshyn [167] and M. Khvesyk [168] emphasize the need to green the economy, ensure the rational use of resources, and develop a sustainable development model in which economic growth is combined with environmental responsibility.

Thus, the analysis of scientific approaches [161–169] makes it possible to define economic modernization as a systemic process that includes technological, innovation, structural, institutional, digital, environmental, social, and investment components. Ukrainian scholars agree that modern modernization should focus on the formation of an innovation-driven economy based on knowledge, digital technologies, and the effective use of human potential. Such a model creates the necessary conditions for Ukraine's sustainable development and its integration into the European economic space.

Main Areas of Economic Modernization of Ukraine as a Prerequisite for Sustainable Development

1. Technological and Digital Modernization of the Economy

Technological modernization is a fundamental component of economic transformation, as it ensures the transition from traditional production toward a digital, automated, and intelligent development model. Its main elements include the digitalization of business processes, the use of artificial intelligence, production automation, robotics, and the implementation of Industry 4.0 technologies.

In recent years, Ukraine has demonstrated significant progress in digital transformation. The development of electronic services, digital platforms, online services, and the IT sector creates a foundation for the modernization of public administration and business.

Share of enterprises using information and communication technologies	➡	Over 90%
Number of IT specialists in Ukraine	➡	Over 300,000 people
Exports of computer services (2023)	➡	Over USD 8 billion
Ukrainian companies using AI elements	➡	Increasing trend

Figure 3.4 – Statistical Indicators

Statistical sources: [170–180]

At the same time, the level of adoption of advanced technologies in the manufacturing sector remains lower than in EU countries, highlighting the need to accelerate technological upgrading.

The presented dynamics (Table 3.13) demonstrate a steady increase in the level of digitalization of Ukraine's economy during 2019–2025. Over this period, the conditional digitalization index increased from 45 points in 2019 to 82 points in 2025, representing an increase of 37 points, or more than 82%. This indicates the gradual formation of a digital economic model based on the use of information technologies, electronic services, and innovative management solutions.

Table 3.13 – Dynamics of the Development of Ukraine's Digital Economy (2019–2025) [172]

Year	Level of Digitalization (Conditional Index)
2019	45
2020	52
2021	60
2022	68
2023	74
2025	82

During 2019–2021, the digital transformation accelerated, with the index increasing from 45 to 60 points. The main factors behind this development were the active expansion of electronic document management, the development of online banking, the increased use of cloud services by enterprises, and the establishment of digital public infrastructure.

In 2022, despite the outbreak of the full-scale war, the level of digitalization increased to 68 points. This can be explained by the fact that digital technologies became a critically important tool for maintaining economic resilience, enabling remote work, ensuring the functioning of public services, supporting businesses, and managing operations under crisis conditions. A significant role was played by the scaling-up of digital public services through the Diia platform, as well as the development of cloud technologies and digital communications.

In 2023, the growth rate slowed somewhat, reaching 74 points. This was associated with the need to restore production infrastructure, limited investment resources, and high risks for enterprises. At the same time, this period saw increased adoption of artificial intelligence, process automation, big data analytics, and digital platforms in business.

The projected increase in the index to 82 points in 2025 characterizes Ukraine's transition from the stage of basic digitalization toward the stage of intelligent modernization, which involves more active use of artificial intelligence, robotics, Industry 4.0 technologies,

and digital enterprise management models. Thus, the dynamics of digitalization in Ukraine during 2019–2025 demonstrate a positive trend in the technological modernization of the economy. The main drivers of this process have been the development of digital public services, the growing role of the IT sector, the expansion of automation, and the gradual adoption of artificial intelligence technologies. At the same time, further improvements in digital maturity require increased investment in production automation, digital infrastructure, workforce development, and the integration of Ukrainian enterprises into the European digital space.

The innovation component of modernization involves the development of science, research and development (R&D), support for startups, technology transfer, and the creation of innovation infrastructure.

The Ukrainian economy has significant scientific potential; however, the level of practical implementation of innovations remains insufficient. The main challenges include low levels of research funding, limited cooperation between universities and businesses, and an insufficient number of high-tech manufacturing enterprises.

Official statistics monitor the following indicators of enterprise innovation activity: the number of innovation-active enterprises, expenditures on innovation, and the implementation of new products and technologies.

Expenditures on research and development (R&D) are one of the key indicators of a country's technological capacity, as they determine the economy's ability to create and implement new technologies, develop innovative entrepreneurship, and increase labor productivity.

Global experience demonstrates that countries with high levels of R&D investment develop competitive advantages in high-tech sectors such as artificial intelligence, robotics, biotechnology, digital manufacturing, and defense technologies.

Israel is the leader in this indicator, with R&D expenditures exceeding 5% of GDP. This model has contributed to the development of a strong innovation ecosystem based on cooperation among

Table 3.14 – Key Indicators

Indicator	Description
Innovation-active enterprises	Lower share compared with EU countries
R&D expenditures	Below the EU average
Main source of innovation	Internal enterprise resources
Main barrier	Lack of funding

Country	R&D Expenditures (% of GDP)
Israel	5.4
South Korea	4.9
Germany	3.1
EU average	2.2
Ukraine	≈0.4

Figure 3.5 – Comparison of Research and Development Expenditures (% of GDP)

universities, the government, and businesses. Technological startups, venture capital financing, and the transfer of research results into production play a significant role.

South Korea (4.9% of GDP) (Fig. 3.5) provides an example of the transition from an industrial economy to a knowledge-based economy. High levels of R&D expenditure have become the foundation for the development of world-class companies in electronics, semiconductors, artificial intelligence, and robotics.

Germany (3.1% of GDP) uses investment in research as a basis for industrial modernization within the framework of the Industry 4.0 concept. Systematic support for science and innovation enables German enterprises to actively implement automated production systems, digital twins, and the Industrial Internet of Things.

The average indicator for the European Union is approximately 2.2% of GDP, which is consistent with the strategic objective of developing a competitive digital economy. In 2023, total EU expenditure on R&D amounted to approximately EUR 381 billion, while average R&D intensity remained at around 2.2% of GDP.

Ukraine: Problems and Challenges

Ukraine has a significantly lower level of funding for research and development – approximately 0.4% of GDP, which is nearly:

– 5.5 times lower than the EU average;

– 7–8 times lower than in Germany;

– more than 12 times lower than in the leading countries (Israel and South Korea).

According to the State Statistics Service of Ukraine, the share of expenditures on research and development has remained low in recent years: it amounted to 0.43% of GDP in 2019, 0.38% in 2021, and approximately 0.33% in 2023.

The National Institute for Strategic Studies notes that the R&D intensity of Ukraine's GDP has remained below 1% for an extended period, whereas in EU countries this indicator exceeds 2%.

1. Formation of Technological Independence

Investment in research enables a country to develop its own technologies rather than merely importing ready-made solutions. For Ukraine, this is particularly relevant in the following areas:

– artificial intelligence;

– defense technologies;

– energy;

– mechanical engineering;

– digital manufacturing.

2. Increasing Enterprise Productivity

According to the concept of the knowledge economy developed by Ukrainian economists A. Chukhno, V. Heyets, and A. Hrytsenko, the accumulation of knowledge and innovative development are becoming the key factors of long-term economic growth.

V. Heyets emphasizes that the transition to an innovation-driven development model requires the formation of a national system of science, education, and technological entrepreneurship.

3. Human Capital Development

R&D creates demand for:

– engineers;

– programmers;

– researchers;

– artificial intelligence specialists;

– digital manufacturing specialists.

Human capital thus becomes a key resource for the competitiveness of the economy.

4. Creation of Innovative Businesses

Countries with high levels of R&D expenditure tend to have a greater number of:

– technology startups;

– patents;

– high-tech exports;

– Industry 4.0 enterprises.

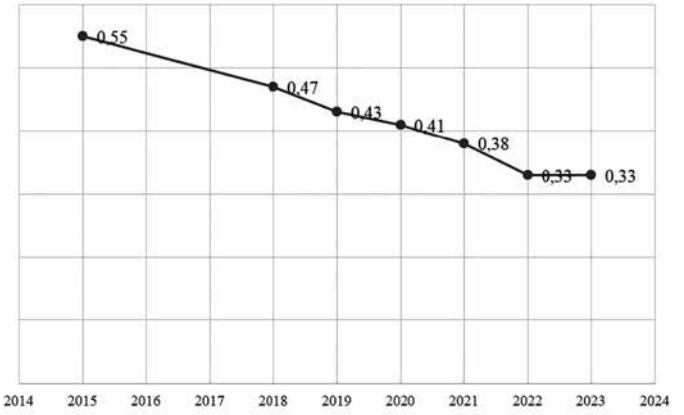

Figure 3.6 – Share of R&D Expenditure in Ukraine's GDP, 2015–2023

Data from international organizations demonstrate a clear relationship between the level of research funding and technological outcomes. The OECD defines R&D expenditure (GERD) as the total expenditure of businesses, governments, and universities on the creation of new knowledge and technologies.

There is a direct relationship between investment in research and the number of patents.

China, the United States, Japan, and South Korea are simultaneously among the largest investors in R&D and the largest

Table 3.15 – Leaders in International Patent Applications

Country	PCT Patents (approximately per year)
China	>70,000
United States	>50,000
Japan	>45,000
South Korea	>20,000
Germany	>15,000–20,000

producers of patents. WIPO confirms that countries with high research expenditures develop the largest innovation clusters and patent centers.

3. R&D and High-Tech Exports

High levels of research expenditure create opportunities to transition from the production of standard goods to the export of technologically sophisticated products.

Country		Main Areas of High-Tech Exports
China	➡	Electronics, smartphones, batteries, AI technologies
United States	➡	Software, aerospace systems, pharmaceuticals
South Korea	➡	Semiconductors, displays, electronics
Germany	➡	Industrial equipment, automotive technologies
Japan	➡	Robotics, electronics, precision engineering

Figure 3.7 – Main Areas of High-Tech Exports in Leading Countries

According to the WIPO methodology, high-tech exports are one of the key indicators of the performance of a country's innovation system, along with patents and venture capital investment.

4. R&D and Industry 4.0 Enterprises

Countries with high levels of R&D have the largest number of enterprises using:

– industrial robotics;
– artificial intelligence;
– digital twins;
– IoT;
– automated production management systems.

Table 3.16 – Examples of Industry 4.0 Implementation in Leading Countries

Country	Industry 4.0 Example
Germany	The Industrie 4.0 concept, Smart Factories at Siemens and Bosch enterprises
Japan	Production robotization at Toyota and Fanuc
South Korea	More than 30,000 Smart Factories established through government programs
United States	AI platforms, autonomous production, digital factories
China	Large-scale implementation of industrial robots

In the Global Innovation Index, WIPO uses indicators such as R&D, venture capital financing, patents, and high-tech exports as key indicators of the strength of a country's innovation ecosystem.

A comparison of research and development expenditure demonstrates (Fig. 3.5) that Ukraine significantly lags behind technologically developed countries in terms of financing innovation activities. Insufficient R&D expenditure is one of the key constraints on the technological modernization of the economy, as it reduces the capacity to create domestic technological solutions, slows down the digital transformation of industry, and limits the competitiveness of Ukrainian enterprises. Therefore, Ukraine's post-war recovery should be based

not only on rebuilding production capacities but also on developing an innovation-driven economy through increased investment in science, education, artificial intelligence, and Industry 4.0 technologies.

3. Structural Modernization of the Economy

Structural modernization is aimed at changing the model of economic development by shifting from dependence on raw material exports to the production of goods with high added value.

For Ukraine, a significant role of raw material sectors in the export structure remains a persistent problem. Therefore, one of the strategic priorities is the development of mechanical engineering, the defense industry, digital services, biotechnology, and other high-tech sectors.

Sector	→	Role in Modernization
Agricultural sector	→	Transition from raw material exports to processing
Metallurgy	→	Decarbonization and technological modernization
IT	→	Development of digital services
Mechanical engineering	→	Creation of high-value-added products

Figure 3.8 – Structure of Ukraine's Exports by Product Type

Categories:

– raw materials;

– industrial goods;

– services;

– high-tech products.

4. Environmental Modernization

Environmental modernization involves a transition to a green economy, resource-efficient production, the development of renewable energy, and the reduction of emissions.

In the context of Ukraine's post-war recovery, this area is becoming strategically important, as the reconstruction of industry should be carried out in accordance with European environmental standards.

Table 3.17 – Key Indicators and Strategic Priorities fo Ukraine's Energy Transition

Indicator	Value
Share of renewable energy	Gradual increase
Main problem	High energy intensity of the economy
Strategic direction	Decarbonization of production

5. Social Modernization and Human Capital Development

Sustainable development is impossible without the development of human potential. The modern economy requires workers with digital competencies who are able to work with automated systems, artificial intelligence, and new technologies.

Table 3.18 – Key Indicators

Area	Significance
Education	Training of STEM professionals
Digital skills	A key competency for the future
Labor market	Growing demand for IT and engineering professions

Technological modernization is one of the key directions of the structural transformation of Ukraine's economy, as it forms the foundation for the transition toward a digital, innovative, and knowledge-based development model. An important indicator of this process is the widespread adoption of digital technologies in public administration, business, and the manufacturing sector.

In recent years, Ukraine has made significant progress in digitalization. One of the most substantial achievements has been the development of a national digital ecosystem, including the development of the Diia platform, which provides citizens and businesses with access to electronic administrative services. According to the Ministry of Digital Transformation of Ukraine, digital services have become one of the key instruments for improving the efficiency of public administration and reducing administrative costs.

An important indicator of technological development is the dynamics of the IT sector. Ukraine's IT sector remains one of the most competitive segments of the economy: exports of computer services exceeded USD 7 billion per year in the pre-war period, while the share of IT services in Ukraine's total services exports increased significantly. Even under wartime conditions, digital companies continue to support the country's economic resilience.

Another important area of modernization is the implementation of artificial intelligence and business process automation technologies. According to international studies, the use of AI enables enterprises to increase labor productivity, optimize resource management, forecast

Table 3.19 – Key Statistical Indicators of Technological Modernization of Ukraine's Economy

Indicator	Value	Characteristics of the Impact on Modernization
Exports of IT Services from Ukraine (2022–2023)	More than USD 7 billion annually	Formation of the digital sector of the economy and generation of foreign exchange revenues
Number of Users of Diia Digital Services	More than 20 million users	Scaling up electronic government services
Share of Enterprises Using Information and Communication Technologies	More than 80% of enterprises	Expansion of digital management and electronic document management
Development of Digital Infrastructure	Expansion of 4G coverage and development of cloud services	Ensuring technological accessibility
Innovation Activity of Industrial Enterprises	Remains below the EU level	Demonstrates the need to accelerate technological modernization
Use of AI and Automation	Rapid growth in services, IT, finance, and logistics	Transition toward intelligent management models

Source: Compiled by the author based on data from [170–180]

demand, and facilitate the transition toward "smart manufacturing" models. At the same time, the level of adoption of industrial digital technologies in Ukraine remains lower than in EU countries due to limited investment, insufficient technological infrastructure, and the consequences of war-related risks.

Thus, the technological modernization of Ukraine has a dual nature. On the one hand, the country demonstrates rapid development of digital services, e-government, and IT exports. On the other hand, the manufacturing sector requires accelerated adoption of Industry 4.0 technologies, including the Industrial Internet of Things (IIoT), robotics, artificial intelligence, digital twins, and automated management systems. The integration of these technologies will become a decisive factor in Ukraine's post-war recovery and transition toward an innovation-driven model of economic development.

3.3. FORMATION OF STATE POLICY FOR THE MODERNIZATION OF UKRAINE'S ECONOMY BASED ON THE USE OF ARTIFICIAL INTELLIGENCE

The prerequisites for the formation of state policy for the modernization of Ukraine's economy based on the use of artificial intelligence are determined by profound transformations in the global economy driven by digitalization, automation, and the rapid development of intelligent technologies. Today, artificial intelligence is not merely an individual technology but a strategic factor of economic development that is shaping new models of production, management, innovation, and public regulation. Under these conditions, state policy should create favorable institutional, legal, and economic conditions for the large-scale adoption of artificial intelligence technologies across all sectors of the economy.

For Ukraine, the development of such a policy is particularly relevant in the context of the full-scale war and the need for post-war

recovery. Economic modernization requires a rapid transition toward a high-tech development model capable of increasing labor productivity, enhancing the competitiveness of enterprises, and ensuring the efficient use of limited resources. State policy should define strategic priorities for digital transformation, coordinate the activities of government authorities, business, science, and education, and stimulate investment in the development of innovation infrastructure [182–185].

The use of artificial intelligence creates significant opportunities to improve the efficiency of public administration. Intelligent systems make it possible to forecast socio-economic development, analyze large volumes of data, automate administrative processes, increase the transparency of management decision-making, and optimize the use of public budget resources. This creates the prerequisites for a transition toward a data-driven governance model, which is being widely adopted in leading countries around the world.

An important component of state policy is to stimulate the use of artificial intelligence in the manufacturing sector. Intelligent algorithms contribute to the automation of production processes, predictive maintenance of equipment, optimization of logistics chains, quality control, and reduction of production costs. This enables Ukrainian enterprises to integrate more rapidly into global production networks, increase their export potential, and meet the requirements of Industry 4.0 [186].

Another important area of state policy is support for the development of the innovation ecosystem. Creating favorable conditions for the development of startups, research centers, technology parks, innovation clusters, and venture capital financing facilitates the commercialization of scientific developments and accelerates the adoption of artificial intelligence in the economy. The state should develop effective mechanisms to support scientific research, digital infrastructure, and international technological cooperation.

The formation of state policy also involves the development of human capital, which is a fundamental prerequisite for digital

modernization. The use of artificial intelligence requires highly qualified specialists in data analysis, programming, cybersecurity, digital management, and machine learning. Therefore, one of the priorities of state policy should be the modernization of the education system, the introduction of modern educational programs, support for lifelong professional education, and the retraining of personnel in accordance with the needs of the digital economy.

Of particular importance is the development of a modern regulatory and legal framework for the use of artificial intelligence. State policy should ensure a balance between stimulating innovation and minimizing potential risks associated with personal data protection, information security, cyber threats, algorithmic discrimination, transparency in automated decision-making, and the ethical aspects of using intelligent systems. Harmonization of national legislation with European standards will create the necessary conditions for Ukraine's integration into the European Union's digital environment.

An important area of state policy is stimulating the digital transformation of small and medium-sized enterprises (SMEs) [186–190]. This sector generates a significant share of economic activity but often has limited access to advanced technologies. Providing financial incentives, tax benefits, grant programs, advisory support, and access to digital infrastructure will accelerate the adoption of artificial intelligence technologies in business activities and enhance the competitiveness of Ukrainian companies.

In the context of post-war recovery, state policy on the use of artificial intelligence should become one of the key instruments of structural modernization of the economy. Intelligent technologies can be used to forecast infrastructure reconstruction needs, manage logistics flows, assess damage, optimize investment projects, develop "smart" cities, digitalize public services, and improve the efficiency of international financial assistance. This will contribute to accelerating economic recovery and strengthening the resilience of the national economy [190–192].

Thus, the formation of state policy for the modernization of Ukraine's economy based on the use of artificial intelligence is a necessary condition for ensuring long-term economic development, enhancing international competitiveness, and integrating Ukraine into the global digital space. A comprehensive state policy that combines institutional reforms, the development of human capital, innovation infrastructure, digital technologies, and modern legal regulation provides the foundation for a transition toward an innovation-driven economic development model focused on knowledge, technology, and sustainable economic growth.

State policy for the modernization of Ukraine's economy should be aimed at developing an innovative, digital, and competitive model of development in which artificial intelligence (AI) serves as a key instrument for increasing productivity, improving the efficiency

Table 3.20 – Main Measures of State Policy for Artificial Intelligence Development

No.	Area of State Policy	Main Content of Measures	Expected Outcome
1	2	3	4
1	Development of a National Artificial Intelligence Development Strategy	Development of a long-term national AI strategy; identification of priority areas of application (economy, defense, healthcare, education, industry); establishment of a coordination system between the government, business, and academia	Unified AI development policy and accelerated technological modernization
2	Development of Digital Infrastructure and Computing Capacity	Expansion of access to high-speed Internet, cloud technologies, data centers, and systems for storing and processing large volumes of data	Creation of a technological foundation for AI adoption across various sectors of the economy
3	Support for Research and Development (R&D)	Increased public funding for science; grant support for research in machine learning, data analysis, and robotics; development of university AI laboratories	Growth in the number of innovations, patents, and technology startups

End of Table 3.20

1	2	3	4
4	Modernization of Industry Based on Industry 4.0	Implementation of robotics, production automation, digital twins, predictive equipment maintenance, and production process management systems	Increased industrial productivity and enterprise competitiveness
5	Digital Transformation of Public Administration	Use of AI for government data analysis, automation of administrative services, forecasting of socio-economic processes, and combating corruption	Improved efficiency of public administration and quality of public services
6	Development of Human Capital and AI Education	Integration of AI, data analysis, and digital technology disciplines into educational programs; training engineers, managers, and next-generation specialists	Development of human resources for the digital economy
7	Support for Innovative Entrepre-neurship and Technology Startups	Establishment of AI startup support funds, tax incentives, accelerators, and university-business cooperation platforms	Development of technology businesses and creation of new jobs
8	Integration of AI into Strategic Economic Sectors	Use of AI in agriculture, energy, logistics, transport, finance, healthcare, and the defense industry	Increased efficiency of key economic sectors
9	Development of a Regulatory and Legal Framework for AI Use	Development of rules for the ethical use of AI; personal data protection; regulation of algorithmic risks in accordance with EU standards	Safe and responsible use of AI technologies
10	International Integration and Cooperation in AI	Participation in European digital development programs; attraction of investment; cooperation with technology companies and EU research centers	Integration of Ukraine into the global innovation ecosystem

of public administration, developing industry, and integrating Ukraine into global technology value chains.

The implementation of state policy in the field of artificial intelligence should ensure Ukraine's transition from a resource-based economic model to an innovation-driven knowledge economy. Key priorities should include the development of R&D, the digitalization of industry, workforce training, support for technological entrepreneurship, and the creation of a favorable regulatory environment. The use of AI can become one of the main drivers of Ukraine's post-war economic modernization and its integration into the European technological space.

The formation of state policy for the development of artificial intelligence in Ukraine is carried out through a comprehensive set of regulatory and legal acts that define strategic directions for digital transformation, the development of an innovation-driven economy, support for technological entrepreneurship, and Ukraine's integration into the European digital space. The legislative framework is gradually creating conditions for the use of AI as a tool for increasing productivity, enhancing enterprise competitiveness, and modernizing public administration.

The Concept for the Development of Artificial Intelligence in Ukraine [197], approved by Resolution No. 1556-r of the Cabinet of Ministers of Ukraine dated December 2, 2020, is the principal strategic document defining state policy directions in the field of AI. The document provides for the creation of conditions for the development of artificial intelligence technologies, support for scientific research, development of a system for training specialists, expansion of digital infrastructure, and implementation of AI in priority areas of the economy. Particular attention is paid to the use of artificial intelligence in industry, public administration, healthcare, education, defense, and the provision of administrative services. The implementation of the Concept is aimed at transitioning Ukraine toward an innovation-driven development model and creating a competitive digital economy.

The Law of Ukraine "On Stimulating the Development of the Digital Economy in Ukraine" No. 1667-IX of July 15,

2021 [198] established the legal foundations for the development of the high-tech sector through the introduction of the special legal regime Diia City. The Law is aimed at supporting IT companies, technology enterprises, innovative startups, and attracting investment in the digital sector. Its provisions contribute to the development of areas related to artificial intelligence, big data analytics, cloud technologies, cybersecurity, and business process automation. A practical outcome of the implementation of the Law has been the creation of a favorable environment for the development of technology businesses and the formation of Ukraine's digital ecosystem.

The Law of Ukraine "On Electronic Trust Services" No. 2155-VIII of October 5, 2017 [199] provides the legal framework for the functioning of a digital environment in which artificial intelligence technologies can be implemented. The Law regulates the use of electronic signatures, electronic identification, and digital documents, which are important elements of digital interaction between the government, businesses, and citizens. The development of an electronic services system provides a foundation for the accumulation and use of high-quality digital data, which is an essential resource for the operation of AI algorithms.

The Law of Ukraine "On Personal Data Protection" No. 2297-VI of June 1, 2010 [200] establishes legal mechanisms governing the use of information that forms the basis for the functioning of artificial intelligence systems. Since modern AI technologies rely on the analysis of large volumes of data, the Law establishes rules for their collection, storage, and processing. Implementation of this Law ensures a balance between the development of digital technologies and the protection of citizens' rights, which is one of the key principles of responsible artificial intelligence use.

The National Economic Strategy of Ukraine until 2030, approved by Resolution No. 179 of the Cabinet of Ministers of Ukraine dated March 3, 2021 [201], identifies digitalization and innovative development as important directions of economic modernization.

The document provides for the development of high-tech industries, increased enterprise productivity, support for innovation activities, and the implementation of modern digital technologies across various sectors of the economy. Within the framework of this strategy, artificial intelligence is considered one of the key instruments for improving the efficiency of economic processes and shaping a new development model for Ukraine.

The Law of Ukraine "On Scientific and Scientific-Technical Activities" No. 848-VIII of November 26, 2015 [202] establishes the legal foundations for the development of science and innovation activities. Its provisions are aimed at supporting fundamental and applied research, developing scientific infrastructure, and promoting cooperation between research institutions, universities, and businesses. For the field of artificial intelligence, this Law is particularly important because it creates a foundation for the development of research centers, implementation of R&D projects, creation of new technological solutions, and their subsequent commercialization.

The Law of Ukraine "On Innovation Activity" No. 40-IV of July 4, 2002 [203] defines mechanisms for state support of innovation processes and the development and implementation of new technologies. Its provisions are aimed at encouraging enterprises to adopt modern technologies, develop innovative projects, and enhance the competitiveness of the economy. In the context of artificial intelligence development, the Law creates prerequisites for supporting technology startups, digital solutions, and innovative production models.

The European Artificial Intelligence Act (EU AI Act, 2024) [204] is an important reference point for Ukraine in the process of European integration. The document establishes rules for the safe and responsible use of AI, provides for the classification of AI systems according to their level of risk, and introduces requirements concerning algorithmic transparency and the protection of users' rights. Aligning Ukrainian legislation with European approaches will enable the creation

of an EU-compatible environment for the development of AI technologies and facilitate Ukrainian companies' access to the European digital market.

Thus, the current legislative framework of Ukraine forms a comprehensive mechanism of state policy for the development of artificial intelligence, covering strategic planning, digitalization of the state, support for innovative businesses, development of science, data regulation, and alignment with European standards. Further improvement of the regulatory framework should focus on creating favorable conditions for the use of AI as a key factor in the technological modernization and post-war recovery of Ukraine's economy.

The analysis of the regulatory and legal framework for the development of artificial intelligence in Ukraine demonstrates that the state has already established the basic prerequisites for transitioning toward a digital and innovation-driven economic development model. The adoption of the Concept for the Development of Artificial Intelligence in Ukraine, as well as laws in the areas of the digital economy, electronic trust services, personal data protection, science, and innovation, has created a foundation for implementing AI technologies in public administration, business, industry, education, and scientific activities.

At the same time, the existing regulatory framework is largely framework-based and does not provide comprehensive regulation of all aspects of artificial intelligence use. Ukrainian legislation currently focuses more on the development of digital infrastructure and support for the IT sector than on comprehensive risk management associated with the application of AI technologies. Given the rapid development of generative artificial intelligence, automated decision-making, and the use of large volumes of data, there is a growing need to further improve the legal and regulatory environment.

Of particular importance is the harmonization of Ukrainian legislation with European approaches, particularly the provisions

of the EU Artificial Intelligence Act, which establishes a risk-based regulatory model for AI. The adoption of European standards will enable Ukraine to ensure compatibility with the EU digital market, increase trust in AI solutions, create favorable conditions for attracting international investment, and ensure the responsible use of technologies.

For the effective modernization of Ukraine's economy based on artificial intelligence, it is necessary to move from individual digital initiatives toward a comprehensive state policy that combines technological development, economic incentives, scientific research, workforce training, and legal regulation. AI should be viewed not merely as a technological tool but as a strategic factor in enhancing the country's competitiveness, supporting post-war economic recovery, and integrating Ukraine into the European innovation ecosystem [205].

Key Areas for Improving the Legislative Framework for AI Development in Ukraine

1. Adoption of a Special Law of Ukraine "On Artificial Intelligence"

Ukraine needs a separate comprehensive legislative act that would establish the legal principles governing the development, use, and oversight of artificial intelligence systems. Such a law should establish:

– classification of AI systems according to their level of risk;
– requirements for high-risk systems;
– rules concerning algorithmic transparency and explainability;
– liability of AI developers and users;
– mechanisms of state oversight and control.

2. Harmonization of Ukrainian Legislation with the EU Artificial Intelligence Act

As part of the European integration process, it is necessary to align Ukrainian legislation with the European model of AI regulation. This should include:

– introduction of a risk-based approach;
– establishment of mechanisms for assessing the conformity of AI systems;

– designation of state supervisory authorities;

– ensuring the compatibility of Ukrainian companies with the European digital market.

3. Development of a Legal Framework for the Use of Big Data

Since artificial intelligence operates on the basis of analyzing large volumes of information, it is necessary to improve legislation concerning:

– access to government data;

– reuse of open data;

– data sharing between the government, businesses, and research institutions;

– information security and data anonymization.

4. Regulation of Liability for Decisions Made by AI Systems

It is necessary to determine:

– who bears liability for errors made by AI systems;

– rules governing the use of AI in critical sectors (healthcare, finance, transport, defense);

– mechanisms for auditing algorithms;

– procedures for appealing automated decisions.

5. Establishment of a State System to Support AI Innovation

At the legislative level, it is necessary to provide for:

– tax incentives for enterprises implementing AI technologies;

– government funding for AI research;

– support for university AI laboratories;

– development of technology parks and innovation clusters;

– grant programs for AI startups.

6. Development of Legislation on Education and Workforce Training

To meet the needs of the digital economy, it is necessary to:

– incorporate AI, data analytics, and digital transformation disciplines into professional training programs;

– establish state workforce retraining programs;

– develop cooperation between universities and technology companies.

7. Introduction of Mechanisms for the Ethical Use of Artificial Intelligence

It is necessary to establish:

– national principles for responsible AI;

– standards for preventing algorithmic discrimination;

– requirements for model transparency;

– mechanisms for protecting citizens' digital rights.

8. Development of Legislation on the Use of AI in Industry and Economic Recovery

During the post-war period, it is necessary to create legal incentives for the application of AI in:

– industrial automation;

– the energy sector;

– logistics;

– the agricultural sector;

– infrastructure project management.

Thus, Ukraine already has an initial regulatory foundation for the development of artificial intelligence; however, further economic modernization requires a transition toward systematic legislative regulation. A key priority for the state should be the creation of a comprehensive legal framework for the safe, ethical, and innovative use of AI that combines support for technological development with the protection of public interests. The development of a modern legislative framework for artificial intelligence will become one of the key factors in Ukraine's post-war economic recovery, enhancement of its competitiveness, and integration into the European digital economy.

CONCLUSIONS

The conducted research into the theoretical and methodological foundations and practical aspects of using artificial intelligence (AI) as a tool for modernizing Ukraine's economy has made it possible to develop a comprehensive understanding of the role of digital technologies in ensuring the country's innovation-driven development, enhancing economic competitiveness, and creating the prerequisites for sustainable development. In the context of the current global technological transformation, artificial intelligence is becoming one of the key drivers of structural change, as it enables process automation, improves the efficiency of managerial decision-making, optimizes the use of resources, and creates new models of economic activity.

The study of the essential characteristics of artificial intelligence made it possible to define it as a set of technologies that enable information systems to perform tasks that have traditionally required human intellectual capabilities, including data analysis, forecasting, pattern recognition, decision-making, and learning based on acquired information. Unlike traditional digital technologies, AI is characterized by its ability to adapt to changes, process large volumes of information, and generate new management solutions, making it a strategic resource for economic modernization.

It has been established that economic modernization is a comprehensive process of structural, technological, and institutional transformation aimed at increasing the efficiency of the economic system, developing innovation potential, and ensuring long-term resilience. Under current conditions, modernization is inextricably linked to digitalization, the development of high-tech production, the formation of a knowledge-based economy, and the use of artificial intelligence as one of the key drivers of economic growth.

It has been substantiated that the use of artificial intelligence has significant potential for modernizing key sectors of Ukraine's

economy. The implementation of AI solutions in industry contributes to the development of Industry 4.0 through production automation, the use of robotics, digital twins, and predictive maintenance systems. In enterprise management, AI contributes to improving the quality of strategic planning, optimizing business processes, and developing competitive advantages in domestic and international markets.

The analysis of the current state of artificial intelligence use in Ukraine has shown that the country has significant development potential in the field of digital technologies, supported by a high level of IT competencies, the presence of technology companies, the development of digital public services, and the active adoption of innovative solutions by businesses. At the same time, the level of AI adoption remains insufficient compared with developed countries due to limited funding for scientific research, insufficient development of production automation, a lack of specialized infrastructure, and an underdeveloped regulatory and legal framework.

A study of the experience of developed countries around the world demonstrates that successful AI-based economic modernization is possible provided that a comprehensive state policy is implemented, combining the development of science, support for innovative entrepreneurship, investment in digital infrastructure, and the training of highly qualified specialists. The practices of the United States, European Union countries, Japan, South Korea, and China demonstrate that artificial intelligence is becoming one of the key elements of industrial policy, technological leadership, and national economic security.

It has been determined that the rationale for using artificial intelligence in the process of modernizing Ukraine's economy is driven by the need to overcome structural problems of economic development, increase labor productivity, create new high-tech industries, and integrate Ukraine into global innovation value chains. The use of AI is particularly relevant in the context of Ukraine's post-war recovery, as these technologies can enable more effective

reconstruction planning, resource management, and the development of competitive industries.

It has been established that the development of artificial intelligence is accompanied by a number of strategic challenges, including the need to ensure cybersecurity, protect personal data, promote the ethical use of algorithms, overcome the digital divide, and adapt the labor market to technological changes. Therefore, state policy in the field of AI should focus not only on technological adoption but also on creating a safe, responsible, and socially oriented environment for the use of digital technologies.

It has been proven that the modernization of Ukraine's economy is a necessary condition for ensuring sustainable development of society, as it contributes to the transition from a resource-based economic model to an innovation-driven model based on knowledge, technology, and the effective use of human capital. The use of AI can become one of the key mechanisms for achieving sustainable development goals through the optimization of natural resource use, the development of a green economy, improved energy efficiency, and the formation of new production models.

An analysis of the legislative framework for the development of artificial intelligence in Ukraine has shown that the state has already established basic regulatory prerequisites for digital transformation. The Concept for the Development of Artificial Intelligence in Ukraine, legislation on the digital economy, electronic trust services, personal data protection, scientific activities, and innovation activities are of particular importance. At the same time, the existing regulatory framework requires further development, taking into account international standards and European experience in AI regulation.

The need to develop a comprehensive state policy for the modernization of Ukraine's economy based on the use of artificial intelligence has been substantiated. Such a policy should include strategic planning for the development of AI technologies, support for scientific research, development of digital infrastructure, stimulation of innovative

entrepreneurship, and training of a new generation of specialists. An important direction should be the creation of a favorable environment for cooperation among the government, business, academia, and educational institutions. At the legislative level, Ukraine needs to develop and adopt a special regulatory act on artificial intelligence that would define the principles governing the use of AI systems, risk assessment procedures, mechanisms for determining the liability of developers and users, and requirements for algorithmic transparency. Of particular importance is the alignment of Ukrainian legislation with the provisions of the European Artificial Intelligence Act (EU AI Act), which will contribute to Ukraine's integration into the European digital space.

A promising direction of state policy should be the development of a national AI ecosystem encompassing research centers, university laboratories, technology startups, innovation clusters, and state support mechanisms. To achieve this, it is necessary to increase R&D funding, create incentives for enterprises implementing AI solutions, and ensure the development of digital competencies among the population.

Thus, under current conditions, artificial intelligence is not merely a technological tool but a strategic factor in modernizing Ukraine's economy, enhancing its competitiveness, and ensuring national security. Its effective use will accelerate structural transformations, create new opportunities for business development, improve the quality of public administration, and facilitate Ukraine's integration into the global digital economic space.

Therefore, the formation of state policy for the modernization of Ukraine's economy based on the use of artificial intelligence should become one of the key strategic priorities of the country's development. The combination of technological innovation, modern legislation, human capital development, and international cooperation will create the foundation for Ukraine's transition toward an innovation-driven knowledge economy capable of ensuring sustainable development, economic security, and competitive positions in the global environment.

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