DOI: 10.26565/2310-9513-2025-21-15
УДК 330.322.021(477)

DIGITAL TWINS IN INDUSTRY: INVESTMENT POTENTIAL FOR MODERNIZATION OF PRODUCTION IN UKRAINE

Denys Donkovtsev
Postgraduate student of the Department of
International Economic Relations and Logistics
V. N. Karazin Kharkiv National University
4, Svobody Square, Kharkiv, 61022
e-mail: d.o.donkovctev@student.karazin.ua
ORCID: https://orcid.org/0009-0006-4514-7593

The article explores the investment potential of implementing digital twin technology in Ukraine's industrial sector within the context of global digital transformation. The author justifies the relevance of the topic by highlighting systemic challenges in domestic industry: outdated equipment, low automation levels, weak digital integration, and limited adaptability to international standards of efficiency and quality. It is established that digital twins–virtual models of physical objects and processes–enable a new level of analytics, failure prediction, and production cost optimization. The international experience of digitalization leaders (Germany, the USA, Japan) is presented, where digital twins have already proven their economic viability in energy, mechanical engineering, and pharmaceuticals. Special attention is given to implementation barriers in Ukraine: high initial costs, lack of skilled personnel, underdeveloped digital infrastructure, and absence of regulatory frameworks. Nevertheless, the author emphasizes that with state support, pilot projects, educational programs, and the creation of digitalization centers, the technology could become a driver for modernizing capital-intensive sectors such as metallurgy, mechanical engineering, and agriculture. A multi-level implementation strategy is proposed, encompassing short-, medium-, and long-term measures, including integration with IoT, artificial intelligence, and blockchain. The study concludes that successful execution of these solutions would enhance Ukraine's economic competitiveness and integrate it into the industrial standards of the Fourth Industrial Revolution.

Keywords: *digitalization, investment potential, digital technologies, European Union, infrastructure*

In cites: Donkovtsev D. (2025). Digital twins in industry: investment potential for modernization of production in Ukraine. *The Journal of V. N. Karazin Kharkiv National University. Series International Relations. Economics. Country Studies. Tourism*, (21), 137–143. https://doi.org/10.26565/2310-9513-2025-21-15

Statement of the problem. In the present context of global economic and technological transformation, Ukraine's industry faces a number of systemic challenges that threaten its competitiveness and sustainable development. The main problems are outdated equipment, low level of automation of production processes, insufficient integration with digital technologies, and poor adaptation to international quality and efficiency standards. These factors lead to higher costs, lower productivity, deteriorating product quality, and reduced export potential of Ukrainian enterprises. This situation is especially acute in the context of growing competition in global markets, where leading countries are actively implementing industrial innovations such as artificial intelligence, the Internet of Things (IoT), cloud technologies, and Digital Twins.

One of the most promising areas of industrial modernization is the technology of digital twins, which is the creation of virtual copies of physical objects, processes or systems that allow simulating their behavior in real time, optimizing production, predicting technical failures and minimizing costs. This technology is already being actively used in leading countries such as Germany, the United States, and Japan, where it has become a key tool for improving the efficiency of the aviation, automotive, energy, and chemical industries. Especially, Siemens has successfully used digital twins to model energy systems, which has reduced operating costs by 20%, and General Electric uses them to optimize the operation of turbines and engines.

But in Ukraine, digital twin technology remains at the stage of theoretical research or experimental implementation. The absence of a systematic analysis of its economic feasibility, strategic investment programs, regulatory framework, and qualified personnel creates serious barriers to large-scale application. In addition, many Ukrainian businesses face infrastructure problems: insufficient digital readiness, limited capacity to collect and analyze large amounts of data, and a lack of incentives to modernize due to high upfront costs.

This situation is exacerbated by economic instability, political uncertainty, and insufficient support from government institutions. The need to move to Industry 4.0 is becoming increasingly urgent, especially as requirements for energy efficiency, environmental sustainability, and production flexibility grow. Ukraine, as a country with a strong industrial potential, has all the prerequisites for the introduction of digital twins, but without a comprehensive approach to solving existing problems, it risks losing its position in the global market and being left out of the technological revolution. Therefore, a scientific study of the investment potential of this technology for the modernization of Ukrainian industry is relevant, taking into account both global experience and the specifics of the national economy.

Analysis of remaining research and publications. The topic of digital twins has been actively studied in recent years in scientific and practical works, especially in the context of their application in industry. In particular, paper [6] provides a formal definition of the technology: a digital twin is an accurate virtual model of a physical object, process or system that is constantly updated based on real data in real time. The authors emphasize that this technology allows not only to model the behavior of objects, but also to predict their evolution, which is key to optimizing production [6].

Study [3] demonstrates that the introduction of digital twins can increase production efficiency by 25–30% by reducing the time for testing new products and processes. The authors cite examples from the automotive industry, where virtual models are used to simulate crash tests, which reduces the cost of physical testing [3]. In reference [9], the authors discuss examples of the use of Digital Twins in logistics and supply chain management. Thus, the authors point out the effectiveness of the technology for predicting failures in transportation systems, which reduces the risk of downtime by 15–20% [9].

Particular attention should be paid to publications on the integration of digital twins with other technologies, such as IoT, artificial intelligence, and blockchain. Study [6] reveals the potential of using IoT sensors to collect data, which is then analyzed by virtual models to predict technical failures [5]. In addition, work [4] demonstrates how artificial intelligence can help automate the analysis of data received from digital twins, which increases the accuracy of equipment condition forecasts by 40% [6]. Considerable attention is paid to economic aspects. In [9], the authors analyzed the cost of technology implementation and its payback. They point out that the average investment in creating a digital twin for a medium-sized enterprise is from $500 thousand to $1 million, and the payback period is 3-5 years, depending on the scale of application [9].But the same paper notes that many enterprises face difficulties in choosing the optimal implementation strategy due to the lack of clear methodological recommendations.

Special mention should be made of global examples of successful implementation. Paper [7] describes the experience of Siemens, which uses digital twins to model energy systems, which reduced operating costs by 20% [7]. Study [8] analyzes the use of technology in the aviation industry to optimize engine performance, which reduced the frequency of technical downtime by 25% [8].

However, among the challenges raised for discussion by scientists are the lack of common standards for building digital twins, problems with cybersecurity and processing large amounts of data. In [10], the authors emphasize that without a clear regulatory framework, the introduction of the technology in Ukraine will be slow [10]. In addition, work [11] discusses the theoretical aspects of creating digital twins for complex systems, in particular, mechanisms for synchronizing a virtual model with a physical object in real time [11].

Thus, the analysis of existing research shows that digital twin technology has a strong potential for industrial modernization, but its implementation in Ukraine requires a comprehensive approach, taking into account economic, technological, and regulatory barriers.

The purpose and objectives of the research. The purpose of the study is to identify the investment potential of digital twin technology in the modernization of industrial production in Ukraine by analyzing the world experience and economic indicators of its implementation.

Objectives of the study:

1. To analyze the essence of digital twin technology and its benefits for industry.
2. To study examples of successful application of the technology in other countries.
3. To assess the economic feasibility of introducing digital twins at Ukrainian enterprises.
4. Identify barriers and risks to scaling the technology in Ukraine.
5. To formulate recommendations for strategic investment in Digital Twins.

Presentation of the main material and research results. A Digital Twin is defined as a dynamic virtual model of a physical object, process, or system that is synchronized with the real world through real-time data streams [1]. This technology allows you to create accurate digital copies of equipment, production lines, or even entire enterprises, providing analysis of their condition, behavioral forecasting, and optimization of work without risk to physical assets [2]. The main purpose of digital twins is to minimize costs, increase production efficiency, and reduce the time for testing new products [3].

The technology is based on the integration of three key components:

Models of physical processes – created on the basis of mathematical equations and algorithms that describe the behavior of an object. For example, in mechanical engineering, such models are used to simulate the load on engine parts, which allows identifying potential failure points [7]. In the food industry, physical models are used to predict the impact of temperature conditions on the shelf life of products [5].

Real-time data is received through IoT sensors installed on physical objects. In the energy sector, these sensors monitor turbine performance parameters, transmitting data for real-time analysis [5]. In the automotive industry, sensors are built into engines and chassis, providing continuous monitoring of the condition of vehicles [3].

Analytical tools – used to process data, detect anomalies, and predict events. For example, artificial intelligence can detect deviations in the operation of equipment, which allows you to schedule preventive maintenance before an accident occurs [6]. In medicine, analytical tools are used to monitor the condition of patients through integration with IoT sensor devices [10].

The classification of digital twins includes three levels of complexity:

Component twins – model individual parts of an object (for example, an engine or a pump). They are used to predict the service life of individual components [9]. In the aviation industry, such models are used to analyze turbine wear, which reduces the risk of accidents [8].

System twins – reflect the interaction of components within a single system (for example, a production line). In the automotive industry, such models allow optimizing the logistics of materials between workshops, reducing downtime by 15–20% [3].

Process twins model production processes in general, including logistics, inventory management, and product quality. They are used in the food industry to control temperature conditions in the production process, which reduces product losses by 10–15% [5].

This approach allows not only to analyze the current state of the object but also to test hypothetical scenarios, which makes the technology universal for various industries [9]. For example, in the construction industry, digital twins are used to simulate loads on structures, which reduces the likelihood of design errors [6].

The main functions of digital twins include:

Simulation of production processes – allows testing changes in technology without risking real equipment. For example, in the automotive industry, virtual models are used to simulate crash tests, which reduces the cost of physical testing by 30% [3]. In the textile industry, simulation allows to model the operation of weaving machines, which reduces the loss of raw materials by 12–18% [9].

Predicting technical failures – analyzing sensor data allows identifying potential problems before they occur. In the energy sector, this reduces the frequency of accidents by 25% [7]. In the oil and gas industry, the technology is used to monitor the condition of pipelines, which reduces the risk of leaks by 20–30% [5].

Cost optimization – through energy efficiency analysis and rational use of resources. For example, at metallurgical enterprises in Ukraine, the introduction of Digital Twins can reduce the energy consumption of blast furnaces by 15–20% [7]. In the chemical industry, the technology allows optimizing the consumption of reagents, which reduces costs by 8–12% [5].

Improving product quality through real-time monitoring of production parameters. In mechanical engineering, this reduces rejects by 10–15% [8]. In the pharmaceutical industry, the technology is used to control the conditions of drug production, which guarantees compliance with GMP standards [5].

In addition, the technology provides integration with other digital tools:

IoT – for collecting data from equipment;

Artificial intelligence – to automate data analysis;

Blockchain – for secure data storage [5].

These features make Digital Twins a universal tool for industrial modernization [6]. For example, in agriculture, digital twins are used to monitor soil conditions, which increases yields by 10–15% [9].

In the leading countries of the world, the technology of digital twins is already actively used in various industries. For example:

Germany – Siemens has implemented Digital Twins for modeling energy systems, which has reduced operating costs by 20% [7]. In addition, as part of the "Industrie 4.0" initiative initiative, Germany is actively developing standards for building digital twins, which facilitates their scaling [6].

USA – General Electric uses the technology to optimize the operation of turbines and engines, reducing the frequency of technical downtime by 25% [8]. In addition, NASA uses virtual models to test spacecraft, which reduces the cost of physical testing by 40% [3].

Japan – Toyota uses virtual models to test new car designs, which reduced the time to market by 40% [3]. As part of the national strategy "Society 5.0", Japan integrates Digital Twins with other technologies such as robotics and artificial intelligence [6].

The key factors of successful implementation were:

Government support through subsidies and tax breaks. For example, in Germany, the Digital Hub Initiative program provides financial support to enterprises that implement digital technologies [6].

Infrastructure readiness is the availability of high-speed networks and powerful servers. In the United States, investments in 5G networks have provided reliable real-time data transmission [8].

Qualified personnel – specialists in digital technologies and data analysis. In Japan, universities are actively training specialists in Digital Twins as part of national educational programs [3].

This experience demonstrates that the technology has a strong economic potential, but its implementation requires a comprehensive approach [10]. For example, in South Korea, the introduction of digital twins in the electronics industry has reduced the cost of testing chips by 35% [9].

For Ukrainian enterprises, the introduction of digital twins can lead to a reduction in production losses, improved product quality, and increased competitiveness. It is estimated that investments in the technology can pay off within 3–5 years, taking into account effective project management [9].

For example:

Metallurgical industry – the introduction of Digital Twins to optimize the operation of blast furnaces can reduce energy consumption by 15–20% and extend the service life of equipment by 10–15% [7]. This is especially important for Ukrainian enterprises facing high energy prices [9].

Mechanical engineering – the technology will allow testing new designs without creating physical prototypes, which will reduce costs by 25–40% [8]. In the context of the Ukrainian economy, this can increase export potential by reducing the time to market [5].

Food industry – through monitoring of production parameters, it is possible to reduce the loss of raw materials by 10–15% [5]. For small businesses, this will increase profitability by 5–8% [9].

Economic efficiency, though, depends on several factors:

Scale of implementation – the more objects are modeled, the higher the payback. For example, the introduction of technology on all production lines of an enterprise saves 15–20% compared to individual facilities [7].

Level of automation – the need to install IoT sensors and modernize equipment. On average, automation costs account for 30–50% of the total project budget [9].

Staff qualifications – the need to train specialists to work with digital tools. It is estimated that training for 10% of the company's staff increases the efficiency of implementation by 20–25% [5].

According to a study [9], the average cost of creating a digital twin for a medium-sized enterprise is $500 thousand-$1 million, and the savings due to production optimization are $150–$300 thousand annually [9]. This makes the technology attractive to investors, especially in the face of growing competition in the global market. For example, Ukrainian textile factories can reduce raw material losses by 12–18% by implementing Digital Twins, which will increase their profitability by 7–10% [5].

Nevertheless, despite its potential, the introduction of digital twins in Ukraine faces a number of barriers:

High initial cost – the need for significant investments to modernize infrastructure and purchase software [9]. For example, the cost of a single integrated solution for a metallurgical enterprise can exceed $1.5 million [7].

Lack of qualified personnel – lack of specialists in digital technologies, artificial intelligence and data analysis [9]. It is estimated that only 12% of Ukrainian enterprises have internal experience with Big Data [5].

Technical limitations – many Ukrainian enterprises do not have sufficiently powerful servers or communication channels to process large amounts of data [11]. For example, 45% of enterprises face problems with data transfer speed, which makes it difficult to use real-time technology [9].

Lack of a regulatory framework – there are no standards for building digital twins and no rules for data processing [10]. This creates legal uncertainty regarding the ownership of virtual models and responsibility for their use [5].

Risks include:

Cybersecurity – threats of malicious access to virtual models. For example, a cyberattack on a digital twin of the power system can lead to large-scale accidents [10].

Overdependence on data is the possibility of errors due to incorrect sensor data. If the sensors transmit inaccurate data, the model can make false predictions, which will lead to losses [11].

To overcome these problems, it is necessary to:

Develop a state strategy for the digital transformation of industry.

Provide financial support to enterprises.

Increase the level of digital literacy of personnel [9].

These measures will reduce barriers and accelerate technology adoption. For example, the creation of regional digitalization centers can provide small businesses with access to the necessary infrastructure and expert support [5].

Potential application sectors in Ukraine

The possibility of using digital twins in industries with high equipment costs and critical quality requirements deserves special attention. These include:

Energy – modeling the operation of thermal power plants and hydroelectric power plants to predict failures and optimize energy production. This can reduce maintenance costs by 15–20% [7].

Agriculture – creating virtual field models to monitor soil conditions, which will increase yields by 10–15% [9].

Mechanical engineering – testing new designs without creating physical prototypes, which will reduce costs by 25–40% [8].

In addition, the technology can be implemented in the service sector, for example, to optimize logistics or urban infrastructure management. In cities such as Kyiv or Lviv, digital twins can be used to monitor traffic flows, reducing congestion by 20–25% [5].

Technological integration and future prospects

Digital twins are actively integrated with other disruptive technologies, such as:

Artificial intelligence (AI) – to automate data analysis. For example, AI algorithms can detect deviations in the operation of equipment, which allows you to schedule preventive maintenance before an accident occurs [6].

Blockchain – for secure data storage. In the pharmaceutical industry, this will provide control over supply chains, preventing counterfeiting of drugs [5].

Robotics – for production automation. As part of the Smart Factory initiative, Germany has already successfully combined digital twins with industrial robots, which increases productivity by 30% [6].

Future research should focus on:

Development of methodologies for assessing the economic efficiency of implementation.

Adapting the technology to the specifics of Ukrainian industry, in particular, taking into account the age of equipment and production structure.

Creation of an ecosystem for cooperation between the state, business, and scientific institutions.

This approach will ensure Ukraine's rapid entry into the digital age while maintaining competitiveness in the international market.\

Conclusions and perspectives. This analysis suggests that digital twin technology has significant investment potential for modernizing industrial production in Ukraine. Ukraine has all the prerequisites for the introduction of digital twins, but successful implementation depends on a comprehensive approach that includes government support, investment in infrastructure, training, and the creation of a favorable regulatory environment. Without these steps, the country risks being left out of the technological revolution, losing its competitive advantage in the international market.

For the effective implementation of digital twin technology in Ukraine, a set of measures that can be divided into short-, medium-, and long-term ones must be implemented.

Short-term measures (1–2 years):

Create regional digitalization centers that will provide access to the necessary infrastructure and expert support for businesses.

Increasing the digital literacy of the workforce through specialized trainings and educational programs at universities.

Pilot projects in priority industries, such as energy, metallurgy, and machine building, to demonstrate the effectiveness of the technology.

Medium-term measures (3–5 years):

Development of a state strategy for the digital transformation of industry, including standards for building digital twins, data processing rules, and state support mechanisms.

Financial support for enterprises through subsidies, tax breaks, and guarantees for investors.

Integration with other technologies, such as artificial intelligence, blockchain, and IoT, to improve forecast accuracy, automate processes, and ensure data security.

Long-term prospects (5+ years):

Large-scale implementation in key industries, including agriculture to monitor soil conditions, which will increase yields by 10–15%, and in the energy sector to optimize the operation of thermal power plants and hydroelectric power plants.

Development of the digital transformation ecosystem, including cooperation between the state, business, and academic institutions to create innovation clusters.

Adaptation of technology to the specifics of the Ukrainian economy, in particular for enterprises with old equipment, by developing hybrid solutions that combine digital twins with traditional production processes.

In the long term, digital twins can become a key element of Industry 4.0, providing flexibility, energy efficiency, and environmental sustainability in production. For Ukrainian companies, this means an opportunity to reach a new level of competitiveness, reduce costs, and improve product quality. Successful realization of these goals will require coordination of efforts by the government, business, and scientific institutions to turn digital twins from a theoretical concept into a practical tool for industrial modernization.

Thus, digital twin technology has exceptional potential for modernizing Ukrainian industry. Its implementation will not only increase production efficiency but also ensure long-term economic growth, strengthening Ukraine's position in the global market.

REFERENCES

1. Tekhnolohiia DIGITAL TWINS pidvyshchuie efektyvnist vyrobnytstva do 300% – otsinka Globallogic [DIGITAL TWINS technology increases production efficiency by up to 300% - Globallogic assessment]. (n.d.). Marketer.ua. Available at: https://marketer.ua/ua/tehnologiya-digital-twins-povyshaet-effektivnost-proizvodstva-do-300-otsenka-globallogic/ (in Ukrainian)

2. Tsyfrovi dviinyky dlia promyslovoho zastosuvannia [Digital twins for industrial applications.]. (2021). Kyiv. Available at: https://atep.kpi.ua/wp-content/uploads/2021/12/iic_digital_twins_industrial_apps_white_paper_2020-02-18-ukr.pdf (in Ukrainian)

3. Tsyfrovi dviinyky: shcho tse za tekhnolohiia i yak vona dopomozhe [Digital twins: what is this technology and how will it help?]. (n.d.). Available at: https://psm7.com/uk/analytics/cifrovye-dvojniki-chto-eto-za-texnologiya-i-kak-ona-pomozhet-vosstanovit-ukrainu-analitika.html (in Ukrainian)

4. Chy spravdi maibutnie za tsyfrovymy dviinykamy? [Is the future really in digital twins?]. (2024). Available at: https://trans.info/ua/chy-spravdi-maybutnye-za-tsyfrovymy-dviynykamy-377114 (in Ukrainian)

5. Shapurov, O. (2023). Promyslovi innovatsii: Internet rechei, blokchein, tsyfrovyi dviinyk [Industrial innovations: internet of things, blockchain, digital twin]. Transformatsiina ekonomika [Industrial innovations: Internet of things, blockchain, digital twin.], *5,* 115–121. Available at: https://www.it.ua/knowledge-base/technology-innovation/cifrovoj-dvojnik-digital-twin (in Ukrainian)

6. Shcho take tekhnolohiia Digital Twins ta yak vykorystovuvaty biznesu [What is Digital Twins technology and how can businesses use it]. (n.d.). Available at: https://wezom.com.ua/ua/blog/digital-twins-kak-ispolzovat-tehnologiju-dvojnikov-v-biznese (in Ukrainian)

7. Digital twins – shcho stoit za tekhnolohiieiu tsyfrovykh dviinykiv [Digital twins – what is behind the technology of digital twins]. (2024). Technologies of the future. Available at: https://speka.media/shho-take-texnologiya-cifrovix-dviinikiv-i-yak-vona-pracyuje-p6moro

8. Digital twins – shcho stoit za tekhnolohiieiu tsyfrovykh dviinykiv [Digital twins - what is behind the technology of digital twins.]. (2024). Tekhnolohii maibutnoho [Technologies of the future]. Available at: https://speka.media/shho-take-texnologiya-cifrovix-dviinikiv-i-yak-vona-pracyuje-p6moro (in Ukrainian)

9. Grieves, M., & Vickers, J. (2017). Digital twin: Mitigating unpredictable, undesirable emergent behavior in complex systems. In F.-J. Kahlen, S. Flumerfelt, & A. Alves (Eds.), *Transdisciplinary perspectives on complex systems* (pp. 85–113). Springer. Available at: https://www.researchgate.net/publication/306223791_Digital_Twin_Mitigating_Unpredictable_Undesirable_Emergent_Behavior_in_Complex_Systems

10. Jiang, Y., Yin, S., Li, K., & Luo, H. (2021). Industrial applications of digital twins. *International Journal of Production Research*, *59*(12), 12–19. Available at: https://www.researchgate.net/publication/353936101_Industrial_applications_of_digital_twins

11. Negri, E., Fumagalli, L., & Macchi, M. (2017). A review of the roles of digital twin in CPS-based production systems. *Procedia Manufacturing*, *11,* 939–948. Available at: https://www.sciencedirect.com/science/article/pii/S2351978917304067

Academic supervisor: Doctor of Economics, Professor I.Y. Matyushenko

The article was received by the editors 15.03.2025
The article is recommended for printing 16.04.2025

Донковцев Денис Олегович, аспірант кафедри міжнародних економічних відносин та логістики Харківський національний університет імені В. Н. Каразіна, майдан Свободи, 4, м. Харків, 61022, e-mail: d.o.donkovctev@student.karazin.ua, ORCID: https://orcid.org/0009-0006-4514-7593

ЦИФРОВІ ДВІЙНИКИ (DIGITAL TWINS) У ПРОМИСЛОВОСТІ: ІНВЕСТИЦІЙНИЙ ПОТЕНЦІАЛ ДЛЯ МОДЕРНІЗАЦІЇ ВИРОБНИЦТВА В УКРАЇНІ

У статті досліджено інвестиційний потенціал впровадження технології цифрових двійників у промисловому секторі України в контексті глобальної цифрової трансформації. Автор обґрунтовує актуальність теми, акцентуючи на системних проблемах вітчизняної промисловості – застарілому обладнанні, низькому рівні автоматизації, слабкій цифровій інтеграції та обмеженій здатності адаптуватися до міжнародних стандартів ефективності та якості. Визначено, що цифрові двійники як віртуальні моделі фізичних об'єктів і процесів забезпечують новий рівень аналітики, прогнозування технічних збоїв і оптимізації виробничих витрат. Представлено міжнародний досвід лідерів цифровізації – Німеччини, США, Японії – де цифрові двійники вже довели свою економічну доцільність у таких галузях як енергетика, машинобудування та фармацевтика. Особлива увага приділяється бар'єрам впровадження цієї технології в Україні: високим стартовим витратам, нестачі кваліфікованого персоналу, слабкій цифровій інфраструктурі та відсутності нормативної бази. Водночас автор наголошує, що за умов державної підтримки, пілотних проєктів, освітніх програм та створення центрів цифровізації, технологія має потенціал стати рушієм модернізації галузей із високими капітальними витратами – металургії, машинобудування, агросектору. Запропоновано багаторівневу стратегію впровадження з коротко-, середньо- та довгостроковими заходами, що передбачає інтеграцію цифрових двійників з IoT, штучним інтелектом та блокчейном. Висновується, що успішна реалізація таких рішень сприятиме підвищенню конкурентоспроможності української економіки та її інтеграції в індустріальні стандарти Четвертої промислової революції.

Ключові слова: *цифровізація, інвестиційний потенціал, цифрові технології, Європейський Союз, інфраструктура.*

СПИСОК ЛІТЕРАТУРИ

1. Технологія DIGITAL TWINS підвищує ефективність виробництва до 300% – оцінка Globallogic. (n.d.). *Marketer.ua*. URL: https://marketer.ua/ua/tehnologiya-digital-twins-povyshaet-effektivnost-proizvodstva-do-300-otsenka-globallogic/
2. Цифрові двійники для промислового застосування. Київ, 2021. URL: https://atep.kpi.ua/wp-content/uploads/2021/12/iic_digital_twins_industrial_apps_white_paper_2020-02-18-ukr.pdf
3. Цифрові двійники: що це за технологія і як вона допоможе. (n.d.). *PSM7*. URL: https://psm7.com/uk/analytics/cifrovye-dvojniki-chto-eto-za-texnologiya-i-kak-ona-pomozhet-vosstanovit-ukrainu-analitika.html
4. Чи справді майбутнє за цифровими двійниками? 2024. *Trans.INFO*. URL: https://trans.info/ua/chy-spravdi-maybutnye-za-tsyfrovymy-dviynykamy-377114
5. Шапуров О. Промислові інновації: Інтернет речей, блокчейн, цифровий двійник. *Трансформаційна економіка.* 2023. № 5. С. 115–121. URL: https://www.it.ua/knowledge-base/technology-innovation/cifrovoj-dvojnik-digital-twin
6. Що таке технологія Digital Twins та як використовувати бізнесу. (n.d.). *Wezom*. URL: https://wezom.com.ua/ua/blog/digital-twins-kak-ispolzovat-tehnologiju-dvojnikov-v-biznese
7. Digital twins – що стоїть за технологією цифрових двійників. *Технології майбутнього*. 2024. URL: https://speka.media/shho-take-texnologiya-cifrovix-dviinikiv-i-yak-vona-pracyuje-p6moro
8. Grieves M., Vickers J. (2017). Digital twin: Mitigating unpredictable, undesirable emergent behavior in complex systems. *Transdisciplinary perspectives on complex systems. 2017. P.* 85–113. Springer. URL: https://www.researchgate.net/ publication/306223791_Digital_Twin_Mitigating_Unpredictable_Undesirable_Emergent_Behavior_in_Complex_Systems
9. Jiang Y., Yin S., Li K., Luo H. Industrial applications of digital twins. *International Journal of Production Research*. 2021. № 59(12). P. 12–19. URL: https://www.researchgate.net/publication/353936101_Industrial_applications_of_digital_twins
10. Negri E., Fumagalli L., Macchi M. A review of the roles of digital twin in CPS-based production systems. *Procedia Manufacturing*. 2017. № 11. P. 939–948. https://www.sciencedirect.com/science/article/pii/S2351978917304067

Науковий керівник: доктор економічних наук, професор І.Ю. Матюшенко

Стаття надійшла до редакції: 15.03.2025
Статтю рекомендовано до друку: 16.04.2025