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TRADING DIGITAL TWIN AS AN INNOVATIVE TECHNOLOGY FOR ENSURING DIGITAL TRADE IN SUSTAINABLE DEVELOPMENT CONDITIONS

ТРЕЙДИНГОВИЙ ЦИФРОВИЙ ДВОЙНИК ЯК ІННОВАЦІЙНА ТЕХНОЛОГІЯ ЗАБЕЗПЕЧЕННЯ ЦИФРОВОЇ ТОРГІВЛІ В УМОВАХ СТАЛОГО РОЗВИТКУ

Iryna Shevchenko
Doctor of Economic Sciences, Associate Professor of the Department of Management and Business Administration National Aerospace University "Kharkiv Aviation Institute",
e-mail: Irina_shev4enko@ukr.net
ORCID ID: https://orcid.org/0000-0001-8188-3551

Ірина Шевченко
Доктор економічних наук, доцент, доцент кафедри менеджменту та бізнес-адміністрування Національного аерокосмічного університету ім. М.Є. Жуковського «ХАІ»,
e-mail: Irina_shev4enko@ukr.net
ORCID ID: https://orcid.org/0000-0001-8188-3551

Abstract. *The scientific work attempts to refine the concept of a digital twin. It is noted that the term "digital twin" is a general scientific term, and the possibility and method of applying digital twins are widely discussed across various fields, including economics, the oil and gas industry, education, and medicine, among others. Therefore, it can be applied in any sector. Within this study, the author proposes a definition specific to digital trade in global markets (as there is currently no universally accepted scientific definition). The scientific novelty of the proposed definition lies in the creation of new approaches to stimulate the development of digital trade in global markets. The use of this category in science directly aims to enhance economic research related to the digital economy in general, as well as the activities of enterprises in global markets. Such a digital entity (digital twin) cannot be considered an independent subject since it serves only as a tool through which a real person interacts in the conditions of digital trade on global markets. The place of the trading digital twin in digital trade in global markets is presented in this study through configuration modeling. A cognitive approach to applying digital tools and technologies to ensure the development of digital trade in global markets is built. The scientific novelty of the proposed approach lies in the application of a conceptual framework for logical-linguistic modeling of intelligent solutions as a breakthrough cognitive technology for developing digital trade in global markets. The approach will allow for the development of a risk-protected strategy for digital trade development in global markets by considering the constantly changing environment, decision-makers, and conflicts of interest based on semantic structures and logical-linguistic modeling.*

Key words: *Digitalization, cross-cutting technologies, sustainable development, integration processes.*

Анотація. *Наукова робота спрямована на уточнення поняття «цифровий двійник». Відзначається, що термін «цифровий двійник» є загальнонауковим і можливості його застосування активно обговорюються у різних галузях, таких як економіка, нафтогазова промисловість, освіта, медицина тощо. Таким чином, він може бути застосований у будь-якому секторі. У межах цього дослідження автор пропонує визначення, специфічне для цифрової торгівлі на глобальних ринках (оскільки на даний момент немає загальноприйнятого наукового визначення). Наукова новизна запропонованого визначення полягає у створенні нових підходів для стимулювання розвитку цифрової торгівлі на глобальних ринках.*

Використання цієї категорії в науці безпосередньо спрямоване на поглиблення економічних досліджень, пов'язаних із цифровою економікою в цілому, а також із діяльністю підприємств на глобальних ринках. Така цифрова сутність (цифровий двійник) не може вважатися самостійним суб'єктом, оскільки вона виступає лише інструментом, через який реальна особа взаємодіє у цифровій торгівлі на глобальних ринках. У дослідженні представлено місце трейдингового цифрового двійника в цифровій торгівлі на глобальних ринках за допомогою конфігураційного моделювання. Побудовано когнітивний підхід до використання цифрових інструментів і технологій для забезпечення розвитку цифрової торгівлі на глобальних ринках. Наукова новизна запропонованого підходу полягає у застосуванні концептуальної бази для логіко-лінгвістичного моделювання інтелектуальних рішень як проривної когнітивної технології для розвитку цифрової торгівлі на глобальних ринках. Цей підхід дозволить розробити стратегію розвитку цифрової торгівлі на глобальних ринках, захищену від ризиків, з урахуванням постійно змінного середовища, осіб, які приймають рішення, та конфліктів інтересів, на основі семантичних структур і логіко-лінгвістичного моделювання.

Ключові слова: *цифровізація, наскрізні технології, сталий розвиток, інтеграційні процеси.*

Introduction. Modern trade transformation processes have led to the emergence of digital trade. As a result, traditional trade processes have undergone reform, initially driven by the impact of Covid-19 and later by military actions currently unfolding in various parts of the world. It is worth noting that the influence of such global issues has positively impacted the development of digital trade. Digital trade has supported international economic relations through integration processes in the economy. This has led to the formation of new economic cooperation agreements, the expansion of free trade areas through digitalization (from logistics processes to payment terms), and changes in the competitive landscape due to businesses entering global markets.

Sustainable development goals are supported by digitalization processes worldwide. Digitalization serves as a tool for promoting sustainable development by reducing environmental risks, fostering international integration, decreasing inequality, developing digital literacy, and enhancing financial inclusion. The development of digital trade is driven by cross-cutting technologies, digital literacy, and international integrations.

The purpose of the article. The aim of the research is to form a new paradigm of the trading digital twin by applying digital tools and technologies to ensure the development of digital trade in global markets under sustainable development conditions.

Literature review. This study has focused heavily on analyzing the literature related to the theoretical foundation of the term "digital twin." Specifically, it references M. Grieves *(Grieves, M., 2016)*, D. Essex *(Essex, D., 2022)*, K. Shaw, J. Fruhlinger *(Shaw, K., 2022)*, R. Stark, T. Damerau *(Stark, R., 2022)*, S. Sapon *(Sapon, S., 2022)*, O. Pupena *(Pupena, O., 2022)*, and Z. Wang *(Wang, Z., 2018)*. M. Grieves' work is fundamental to this research since the concept of "digital twin" was first introduced by this scholar. The study also connects the conditions for sustainable development with the cross-cutting technology of a trading digital twin, which was explored in A. Pawlowski's *(Pawłowski, A., 2021)* work.

However, despite the abundance of literature on the topic of digital twins, no works have been specifically devoted to the trading digital twin in digital trade. The foundation for this work was the monograph by I.O. Shevchenko *(Shevchenko, I., 2023)*, which focuses on the harmonization of digital trade in global markets through the lens of international experience.

Main results of the research. To achieve the research aim, the author employed both general scientific and specific research methods. The literature analysis allowed the author to propose, for the first time, their own definition of the term "trading digital twin" by highlighting its most essential characteristics. Using the comparative method, the study established a logical connection between sustainable development and the development of digital trade in global markets through the use of cross-cutting technologies. The cognitive approach was built using the methods of generalization, systematization, analysis, and synthesis.

Today, in the context of digitalization and adherence to sustainable development conditions, the global community faces many problems requiring immediate solutions: rising poverty, overcoming unemployment, and humanitarian crises, among others. However, recent trends have shown that some of these issues can be addressed through innovative and cross-cutting technologies and digital tools.

According to the author, to ensure the development of digital trade, more attention should be given to important issues such as the creation of cross-cutting technologies, ensuring digital sovereignty, and creating value chains through vertical integration between countries. The application of vertical integration technology and the introduction of transfer pricing mechanisms allows for more flexible value creation, providing significant advantages in procedures for entering global markets.

The methodological tools for ensuring the development of digital trade in global markets are also supported by cross-cutting technology management tools for the digital transformation of entities. For the proper development of digital trade in global markets and the digital transformation of entities, cross-cutting technologies based on the digital twin should be implemented. These technologies are instrumental algorithms and intelligent tools aimed at solving strategic problems through cognitive analysis of linguistic (intellectual) activity, logical-linguistic modeling of solutions, and visualization of cognitive scenarios in the dynamics of modern knowledge bases and their contextual development. This includes frame-based representation of necessary and sufficient knowledge for anticipating and resolving problematic situations in the functioning of a managed object.

In science, a virtual model of a real physical object is called a digital twin. The concept of the digital twin was introduced in 2002 by M. Grieves, a doctor in computer engineering from the University of Michigan, though the term itself was coined by Grieves only in 2011.

Table 1

Modern Definitions of the Term "Digital Twin"

Source	Definition	Essential Characteristic
1	2	3
M. Grieves *(Grieves, M., 2016)*	"…a set of virtual informational constructs that fully describe a potential or real physical manufactured product"	Set (aggregate) of virtual constructs
D. Essex *(Essex, D., 2022)*	"…a virtual representation of a real-world entity or process (a physical person in the real space; a digital twin in the software representation; and the data linking the first two elements)"	Virtual (digital) representation
K. Shaw, J. Fruhlinger *(Shaw, K., 2022)*	"…a digital representation of a physical object or system. The technology behind digital twins has expanded to encompass buildings, factories, and even cities, with some claiming that even people and processes can have digital twins, extending the concept even further."	
R. Stark, T. Damerau *(Stark, R., 2022)*	"…a digital representation of an active unique product (a real device, object, machine, service, or intangible asset) or a unique product-service system (a system consisting of a product and related service) that contains selected characteristics, properties, conditions, and behaviors through models, information, and data at one or even several phases of the lifecycle."	
S. Sapon *(Sapon, S., 2022)*	"…a virtual representation of a physical object (system) that consists of the physical object (system) itself, its digital model, and the two-way informational connections between the physical object and the digital model of the object and/or	

	its components, used for modeling, analysis, and optimization of the state and behavior of the physical object (system) in real-time throughout the entire lifecycle of the product (system)."	
O. Pupena *(Pupena, O., 2022)*	"…a formal digital representation of an asset, process, or system that captures the attributes and behavior of this object, suitable for communication, storage, interpretation, or processing in a specific context."	
Z. Wang *(Wang, Z., 2018)*	"…refers to the processes and methods for describing and modeling the characteristics of behavior, formation processes, and performance of physical objects through digital technologies, and can also be referred to as digital twin technology."	Process and method
M. Derkach *(Derkach, M., 2023)*	"…a comprehensive digital model of an environment, product, or system that uses real data to create simulations and forecasts without affecting the real counterpart. It is also referred to as the technology of creating virtual clones. It allows testing multiple hypotheses or products at once."	Digital model
M. Shacklett *(Shacklett, M., 2023)*	"…a digital model of a physical object or process. Its goal is to help organizations identify bottlenecks and/or problems in the process or physical object before they occur. Thus, proactive (and preventive) measures can be taken."	
Ye. Sulema *(Sulema, Ye., 2020)*	"…a model of a physical object or process (physical twin) that fully reflects its characteristics in dynamics over a specific period."	

Thus, based on the above morphological analysis, we can conclude that most researchers present a "digital twin" as a digital model or digital representation. Researchers such as K. Shaw, J. Fruhlinger *(Shaw, K., 2022)*, R. Stark, T. Damerau *(Stark, R., 2022)*, O. Pupena *(Pupena, O., 2022)*,M. Derkach *(Derkach, M., 2023)*, M. Shacklett *(Shacklett, M., 2023)*, Ye. Sulema *(Sulema, Ye., 2020)*, D. Essex *(Essex, D., 2022)* and S. Sapon *(Sapon, S., 2022)* belong to this category. Z. Wang *(Wang, Z., 2018)*, however, offers a slightly different interpretation by revealing the concept through the attribute of process/method, which is entirely understandable considering the initial purpose of this concept and its application areas.

Despite the varying terminology, all the definitions converge on one point: they refer to what enables a real individual to interact with the virtual space and how they perceive themselves within it. Therefore, we find it appropriate to further define the concept of a digital twin as a modeled virtual representation of the physical characteristics of objects and/or processes in dynamics over a certain period.

It is worth noting that the term "digital twin" is a general scientific term, and the possibility and method of applying digital twins are widely discussed across various human activities — in economics, the oil and gas industry, education, medicine, and other fields — making it applicable to any industry.

In this study, the author proposes a definition that would be unique to digital trade in global markets (as a universally accepted scientific definition currently does not exist). To address the methodological tools for developing digital trade in global markets, the author introduces the concept of a "trading digital twin" and presents its definition for the first time:

Trading Digital Twin – a digital representation of objects and processes (person, store, company, business processes, etc.) in virtual space, allowing the creation and implementation of personalized and unique goods and services on behalf of a physical and/or legal entity through interaction with other participants in the trade process in global markets.

The scientific novelty of the proposed definition lies in the creation of new approaches to

stimulate the development of digital trade in global markets. The use of this category in science is directly aimed at advancing economic research related to both the digital economy as a whole and the activities of enterprises in global markets. At the same time, it is important to emphasize that such a digital entity (digital twin) cannot be regarded as an independent subject, as it merely acts as a tool through which a real individual interacts in the context of digital trade in global markets. The place of the trading digital twin in digital trade in global markets is depicted in Figure 1.

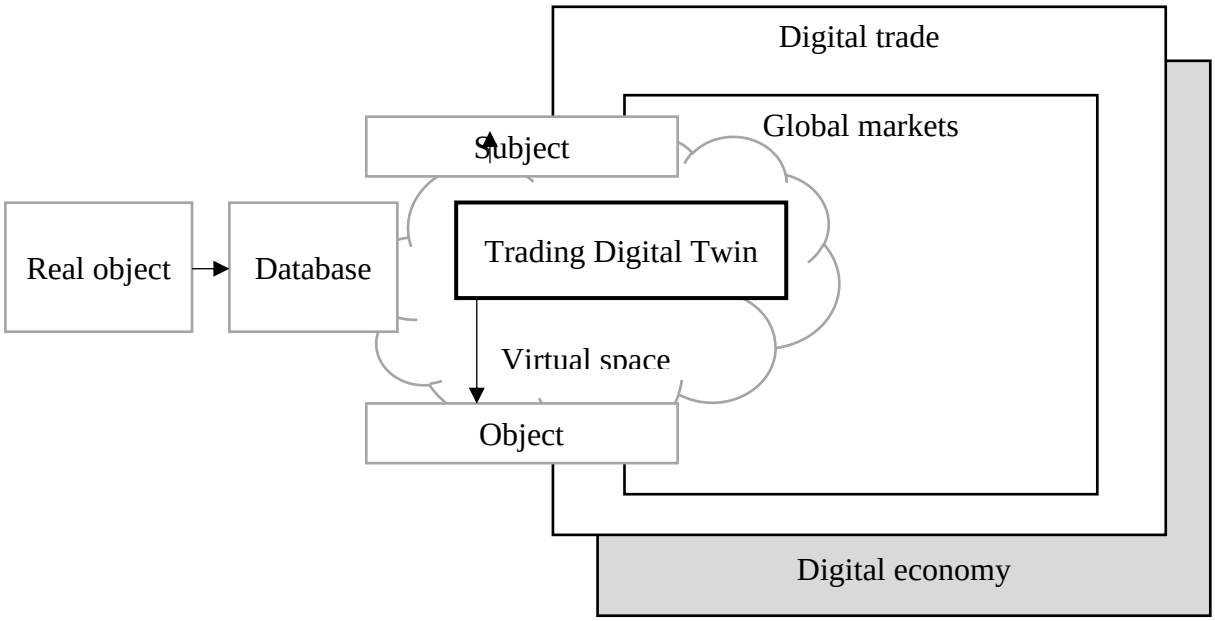


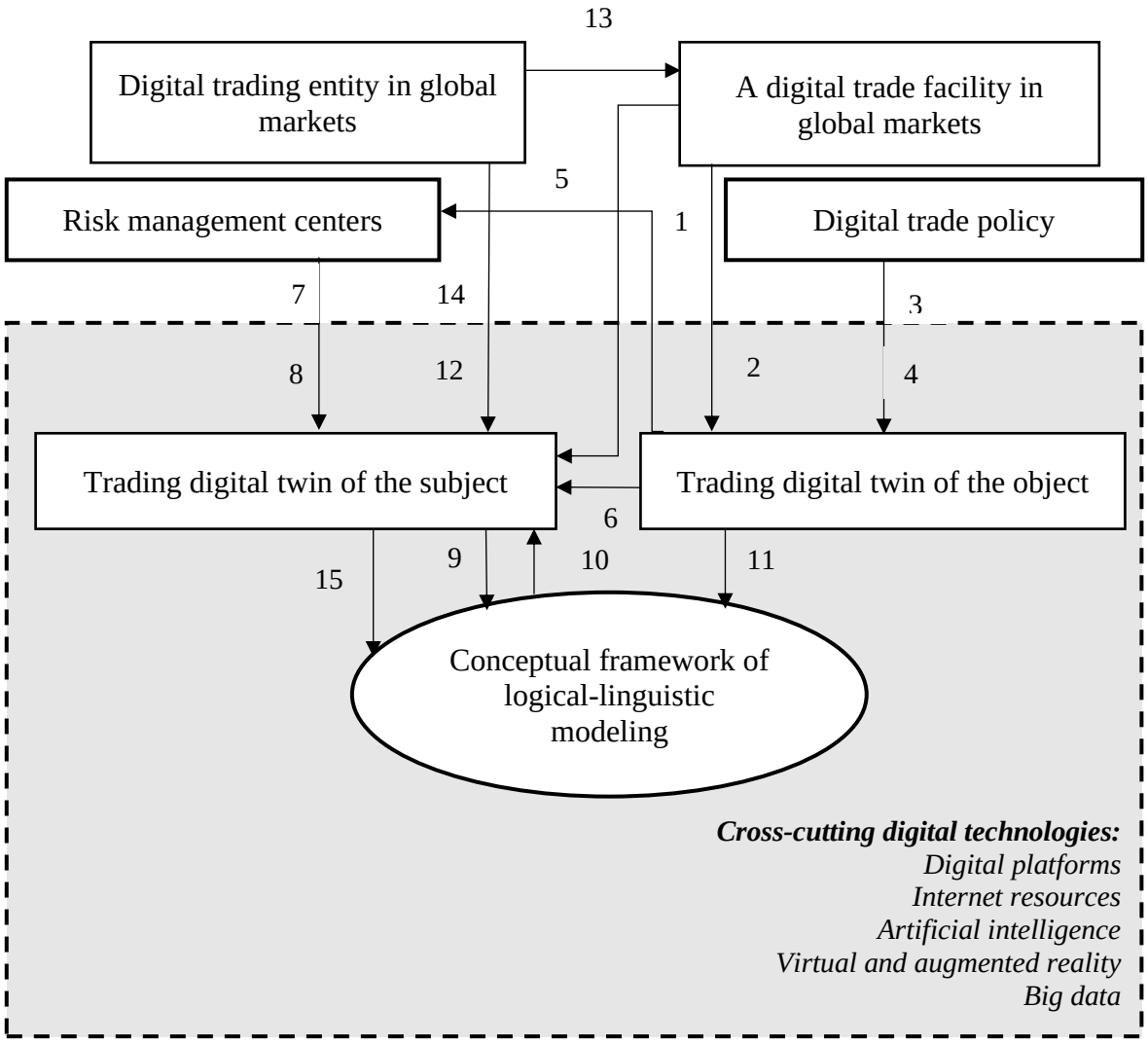
Figure 1. The Place of the Trading Digital Twin in Digital Trade in Global Markets.
Source: developed by the author

The figure represents the trading digital twin of a managed object as detailed modeling of the configurations of physical entities and dynamic modeling of changes in the product or service, process, and resources within the trading process. The digital twin of the managing subject represents individuals interacting in global markets to meet their needs by purchasing goods or services, following specific normative guidelines that have a digital prototype.

It is worth noting that not only the legal owner of the digital identity can use this digital tool, but also another person. This gives rise to numerous consequences that need to be considered both in theory and in practice when conducting further research.

Trading digital twins can ensure the process of digital trade in global markets and be used to improve the efficiency of trade processes. With this tool, it is possible to identify risks and threats of problematic situations within these processes, based on diagnostic and control procedures for their state. The use of trading digital twins in digital trade processes in global markets leads to decision-making that must meet cybersecurity requirements, ensuring confidentiality and anticipating threats inherent in the new technology.

Considering the role of digital twins and cross-cutting digital technologies in the context of the development of digital trade in global markets, the author suggests a visual representation (Figure 2).



1 – An information flow that characterizes the object; 2 – An information flow that characterizes the object after formalization; 3 – An information flow generated by digital trade policies; 4 – An information flow generated by digital trade policies after formalization; 5 – Data transmission for object condition monitoring to external situational risk management centers; 6 – Data transmission on the object's condition monitoring to the subject's digital twin; 7 – Information flow on decision-making based on condition monitoring data; 8 – Information flow on decision-making based on condition monitoring data after formalization; 9 – Addressing the knowledge base containing solutions to problematic situations; 10 – Output of alternative options for solving the problematic situation; 11 – Adding new data to the knowledge base about problematic situations; 12 – Reverse logical feedback; 13 – Implementation of the decision; 14 – Feedback on the result of the decision implementation; 15 – Adding data to the knowledge base on the connection between the problematic situation and the solution.

Figure 2. Cognitive Approach to the Application of Digital Tools and Technologies to Ensure the Development of Digital Trade in Global Markets
Source: constructed by the author

The scientific novelty of the proposed approach lies in the application of the conceptual framework of logical-linguistic modeling of intelligent solutions as a breakthrough cognitive

technology for the development of digital trade in global markets. This approach will allow for the construction of a risk-protected strategy for the development of digital trade in global markets, accounting for the ever-changing environment, decision-makers, and conflicts of interest based on semantic structures and logical-linguistic modeling.

When considering the key concepts characterizing the development of digital trade in global markets, it is crucial to define the strategy for developing digital trade in global markets as an integrated information-logical model of actions by the subject aimed at achieving development in the context of globalization. From a systems theory perspective, digital trade is a complex system consisting of functioning elements (resource complexes) and the relationships between them, integrated into an order management system, a risk management system based on situational centers, aimed at transforming the forms and properties of incoming resources, as well as selling goods and services.

Compared to traditional approaches that involve the creation of a physical prototype and real-life testing, the application of trading digital twins helps reduce the number of errors during design and can ensure the reduction of time, financial, and other resource costs. Trading digital twins also allow for the incorporation of characteristics of global competitiveness and high consumer demands into products and increase the level of customization.

To fully reveal the purpose of the research, the author proposes a visual representation of the relationship between digital trade and the trading digital twin in sustainable development conditions (Figure 3).

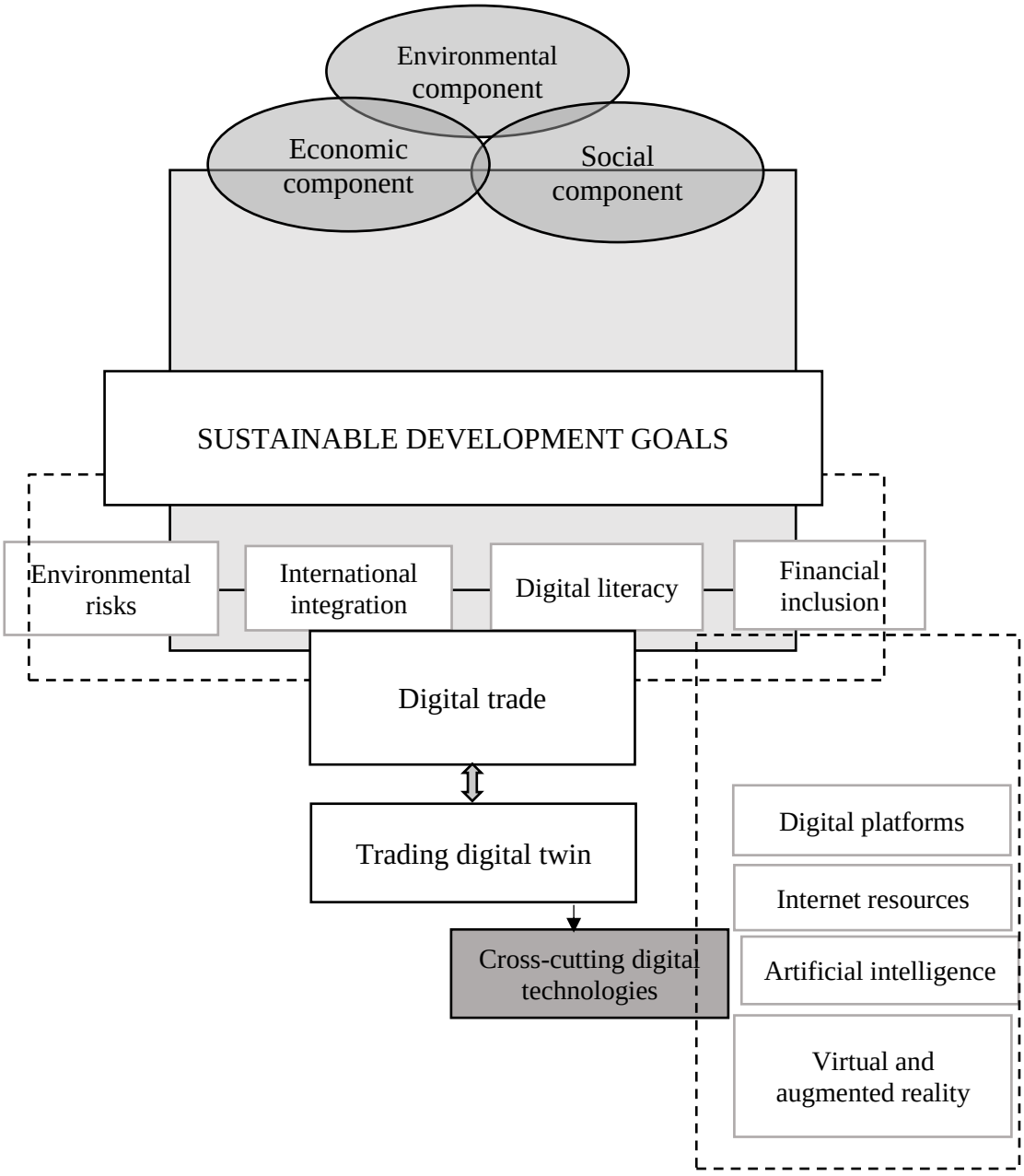


Figure 3. Relationship Between Digital Trade and the Trading Digital Twin in the Context of Sustainable Development. (Author's Vision)

This figure emphasizes the connection between digital trade and sustainable development's three main pillars: the environmental component, the economic component, and the social component. Through international organizations and national governments, strategies for sustainable development and digital economy growth can be balanced. The development of the digital economy encourages the advancement of digital trade by reducing the digital divide between different regions. Investments in ICT development in remote areas and the legislative regulation of digital business activities prevent market monopolization and strengthen the protection of consumer rights and the interests of small and medium-sized enterprises.

Conclusions. This process is of particular importance when establishing the virtualization of specialized systems used in the modeling and testing of developing processes, as well as for real-time status monitoring; the development of standards for digital documentation; standards for digital trade; standards for the use of artificial intelligence; distributed data storage system standards and

blockchain technology; and standards for digital twins. The use of digital technologies ensures environmental protection and the reduction of digital waste. Innovative digital technologies aim to increase potential for environmental improvement and reduce industrial emissions.

The use of big data, cloud computing, digital twin technologies, and artificial intelligence transforms businesses considering sustainable development. This leads to independent environmental monitoring, evaluation, and analysis of ecosystems (environmental changes, pollution, etc.).

Therefore, the industrial business, in the context of digitalization, is transforming toward sustainable production. The development of digitalization must consider the consequences of climate change, not only from the perspective of diseases and human lives but also from the significant economic damage that can act as a destabilizing force affecting the economic growth of countries and hindering sustainable development.

Digital economy is a critical driver of economic development, and the transformation of traditional trade into digital trade has become a global consensus. However, according to the concept of sustainable development, digital trade has both positive and negative effects on the social and environmental components.

Future research directions should include the examination of "digital inequality" and the use of digital technologies for environmental protection, as well as the development of strategies for the sustainable development of the digital economy in general and digital trade in particular.

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