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RESULTS OF THE ASSESSMENT OF POSSIBILITIES AND PROSPECTS OF USING BLOCKCHAIN TECHNOLOGY IN THE PRODUCTION ACTIVITIES OF ENTERPRISES

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Malyarets L. M., Starkova O. V., Otenko I. P., Dolhova N. H.

Results of the Assessment of Possibilities and Prospects of Using Blockchain Technology in the Production Activities of Enterprises

The basics of Blockchain technology and its application in various fields of activity are considered. The object of the research is Blockchain technology and the possibilities of its application in industries. This involves a detailed study of its fundamental components – decentralized network, mathematical cryptography, distributed consensus, transaction ledger and smart contracts, as well as their application, in particular, for automating and securing transactions and processes using smart contracts. The main problem to be solved is the integration of secure, transparent and efficient mechanisms for recording and processing transactions, as well as automating processes at different stages of production. The use of Blockchain, or rather smart contracts, has significantly improved production processes by automating routine operations and ensuring the security of transactions. Smart contracts developed using the Ethereum platform and the Solidity language are able to optimize production processes, but they are not devoid of risks, such as code bugs and cybersecurity issues. It is emphasized that the integration of Blockchain into production processes requires a basic understanding of the technology, a clear implementation strategy, and initial investment in infrastructure and integration. Despite the initial difficulties, the benefits of using Blockchain in terms of transparency, efficiency, and reliability can be significant, as evidenced by several specific examples. The authors explore the potential of smart contracts at different stages of the production cycle, highlighting the benefits in automating processes and ensuring security. The results show that smart contracts can significantly improve production processes by automating routine operations and ensuring transparency and security of transactions.

Keywords: *Blockchain technology, smart contract, Ethereum, Solidity, production cycle, automating processes.*

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Malyarets Lyudmyla M. *– Doctor of Sciences (Economics), Professor, Head of the Department of Mathematics and Mathematical Economic Methods, Simon Kuznets Kharkiv National University of Economics (9a Nauky Ave., Kharkiv, 61166, Ukraine)*

E-mail: *malyarets@ukr.net*

ORCID: *https://orcid.org/0000-0002-1684-9805*

Researcher ID: *https://www.webofscience.com/wos/author/record/T-9858-2018*

Scopus Author ID: *https://www.scopus.com/authid/detail.uri?authorId=57189248374*

Starkova Olha V. *– Doctor of Sciences (Engineering), Professor, Head of the Department of Cybersecurity and Information Technology, Simon Kuznets Kharkiv National University of Economics (9a Nauky Ave., Kharkiv, 61166, Ukraine)*

E-mail: *olha.starkova@hneu.net*

ORCID: *https://orcid.org/0000-0002-9034-8830*

Otenko Iryna P. *– Doctor of Sciences (Economics), Professor, Head of the Department of International Economic Relations, Simon Kuznets Kharkiv National University of Economics (9a Nauky Ave., Kharkiv, 61166, Ukraine)*

E-mail: *otenkoip@gmail.com.ua*

ORCID: *https://orcid.org/0000-0001-7849-2381*

Dolhova Natalia H. *– Candidate of Sciences (Engineering), Associate Professor of the Department of Cybersecurity and Information Technology, Simon Kuznets Kharkiv National University of Economics (9a Nauky Ave., Kharkiv, 61166, Ukraine)*

E-mail: *natalya.dolgova@hneu.net*

ORCID: *https://orcid.org/0000-0002-8950-8200*

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Малярець Л. М., Старкова О. В., Отенко І. П., Долгова Н. Г. Результати оцінки можливостей та перспективи використання технології blockchain у виробничій діяльності підприємств

Розглянуто основи технології Blockchain та її застосування в різних сферах діяльності. Об'єктом дослідження є технологія Blockchain та можливості її застосування в галузях промисловості. Це передбачає детальне дослідження її фундаментальних компонентів – децентралізованої мережі, математичної криптографії, розподіленого консенсусу, реєстру транзакцій і смарт-контрактів, а також їх застосування, зокрема, для автоматизації та захисту транзакцій і процесів за допомогою смарт-контрактів. Основною проблемою, що вирішується, є інтеграція безпечних, прозорих і ефективних механізмів для запису й оброблення транзакцій, а також автоматизації процесів на різних етапах виробництва. Застосування Blockchain, а точніше смарт-контрактів, значно покращило виробничі процеси шляхом автоматизації рутинних операцій та забезпечення безпеки

транзакцій. Смарт-контракти, розроблені за допомогою платформи Ethereum і мови Solidity, здатні оптимізувати виробничі процеси, проте вони не позбавлені ризиків, таких як помилки в коді та питання кібербезпеки. Підкреслюється, що інтеграція Blockchain у виробничі процеси вимагає базового розуміння технології, чіткої стратегії впровадження і початкових інвестицій в інфраструктуру та інтеграцію. Незважаючи на початкові труднощі, переваги використання Blockchain з точки зору прозорості, ефективності та надійності можуть бути значними, що підтверджується кількома конкретними прикладами. Автори досліджують потенціал смарт-контрактів на різних етапах виробничого циклу, підкреслюючи їхні переваги в автоматизації процесів і забезпеченні безпеки. Результати показують, що смарт-контракти можуть значно покращити виробничі процеси за рахунок автоматизації рутинних операцій і забезпечення прозорості та безпеки транзакцій.

Ключові слова: *технологія Blockchain, смарт-контракт, Ethereum, Solidity, виробничий цикл, автоматизація процесів.*

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Малярець Людмила Михайлівна *– доктор економічних наук, професор, завідувач кафедри вищої математики та економіко-математичних методів, Харківський національний економічний університет імені Семена Кузнеця (просп. Науки, 9а, Харків, 61166, Україна)*

E-mail: *malyarets@ukr.net*

ORCID: *https://orcid.org/0000-0002-1684-9805*

Researcher ID: *https://www.webofscience.com/wos/author/record/T-9858-2018*

Scopus Author ID: *https://www.scopus.com/authid/detail.uri?authorId=57189248374*

Старкова Ольга Володимирівна *– доктор технічних наук, професор, завідувач кафедри кібербезпеки та інформаційних технологій, Харківський національний економічний університет імені Семена Кузнеця (просп. Науки, 9а, Харків, 61166, Україна)*

E-mail: *olha.starkova@hneu.net*

ORCID: *https://orcid.org/0000-0002-9034-8830*

Отенко Ірина Павлівна *– доктор економічних наук, професор, завідувач кафедри міжнародних економічних відносин, Харківський національний економічний університет імені Семена Кузнеця (просп. Науки, 9а, Харків, 61166, Україна)*

E-mail: *otenkoip@gmail.com.ua*

ORCID: *https://orcid.org/0000-0001-7849-2381*

Долгова Наталя Геннадіївна *– кандидат технічних наук, доцент кафедри кібербезпеки та інформаційних технологій, Харківський національний економічний університет імені Семена Кузнеця (просп. Науки, 9а, Харків, 61166, Україна)*

E-mail: *natalya.dolgova@hneu.net*

ORCID: *https://orcid.org/0000-0002-8950-8200*

Introduction. The experience of recent decades proves that the production complex undergoes some fundamental changes. These changes are due to the rapid development of Internet infrastructure and information technology, revolutionizing the traditional business models and shifting the focus to the development of the conception of digitalization. In the era of globalization and informatization, technological advances not only support business processes, but also become a key instrument for their digital transformation.

Manufacturing enterprises are increasingly focusing on Internet technologies to optimize their activities. There is also a need to create an infrastructure that can adapt to the changing demands of the times, as well as be of value for all participants in the business process. This means not just transferring traditional management methods to the digital environment, but also integrating complex systems, such as hardware and software, to ensure the security, efficiency, and reliability of large amounts of data of various types. In this context, not only technologies such as artificial intelligence, augmented reality or the Internet of Things come to the fore, but there's also Blockchain technology, which was originally associated mainly with cryptocurrencies and now serves to transform core business processes. Its decentralized, transparent, and immutable structure can offer solutions to many of the complex challenges facing manufacturing enterprises.

However, the introduction of Blockchain into production processes is never a simple task, but this requires a deep understanding of both the technology itself and its possible consequences for the organization. Issues such as standardization, integration with existing systems, staff training, and many others can afford real challenges for enterprises.

Therefore, research on the development of methods and tools for integrating Blockchain technology into the management and production processes of industrial enterprises, along with the studies of practical cases of successful implementation, are relevant. Particular attention should be paid to creating conditions for further adaptation and implementation of technology in the production cycle. This is due to ensuring competitive advantages in the market and attracting investments for further technological development. Thus, all aspects of working with Blockchain technology in industry require deep scientific consideration and empirical research, which confirms the relevance and practical significance of the chosen research topic.

Analysis of literary sources, formulation of the problem. Both Ukrainian and foreign scholars have conducted scientific research on this topic and developed practical methods for the introduction of innovative technologies and, in particular, Blockchain.

The paper [1] systematizes the existing approaches to defining the essence of the concept of «Blockchain» in order to substantiate the directions of improving the system of public administration and the introduction of Blockchain technology in the sphere of public finance. The authors propose the following interpretation of the definition of Blockchain – it is a distributed database with registered and ordered economic transactions, which, under certain conditions, can be included in blocks and completed with specific agreements [1]. A critical

analysis of the advantages and disadvantages of using Blockchain technology is carried out. It is determined that Blockchain has significant potential for use in various spheres of social life and, despite certain shortcomings, allows to improve the system of public administration. Albeit the paper does not provide proposals and examples of how economic processes, in particular at the state-owned enterprises and organizations, can be improved through the introduction of Blockchain technology. The number of developments that use Blockchain technology in various sectors of the economy, finance, and security is constantly increasing. The authors of the article [2] conducted a detailed analysis of the advantages and opportunities of Blockchain technology in various industries. However, the article in question does not pay attention to industry specifics and important issues of planning, testing and constant monitoring of new projects related to Blockchain. These processes are especially important for the implementation of innovative IT projects.

Blockchain technology offers many possibilities. This primarily applies to cybersecurity, as well as transport and logistics, financial services, banking, education, healthcare, insurance, retail, media and telecommunications, accounting and auditing. A research on the implementation of Blockchain in accounting and auditing is presented in the publication [3]. The authors substantiate why Blockchain technology, which even terminologically correlates with accounting categories, can and should be considered as a real opportunity for changes in the methodology of accounting and auditing. It is shown that Blockchain technology, which even terminologically correlates with the categories of accounting, can and should be considered as a real opportunity for changes in the methodology of accounting and auditing. The introduction of Blockchain technology in accounting will reduce the cost of maintaining and coordinating accounting registers, as well as ensure the security of storing and transmitting information about ownership rights and movement of assets [4]. The issues that remained unresolved, are those demanding to take into account all possible risks and challenges. In particular, the risks associated with the process of passing transactions in accounting systems, as well as the ways in which confidence is achieved when performing the procedures agreed with the client that are regarding financial statements.

The article [5] substantiates that Blockchain, as an environment for economic processes and operations, will lead to changes in methodological accounting tools along with virtualization of accounting processes. The paper also asserts that the use of Blockchain has its advantages not only for companies implementing this technology, but also for the government, since Blockchain technology facilitates the process of digitizing documentation and access to public services. According to the results of research devoted to the analysis of the activity in implementation of Blockchain technology, Ukraine ranks only 14th among the advanced countries, where the leading companies and the governments have expressed the readiness to widely use this technology in management. However, there is an interest of Ukrainian companies in the use of modern information technologies, including Blockchain technology, not only in accounting and financial activities. All this allows to conclude about an expediency to conduct a study devoted to the analysis of the existing possibilities of using Blockchain technology in the management of production processes.

The study of the implementation of Blockchain technology in the management process of the results-based budgeting system (RBB) to improve the management system of a construction enterprise is referenced as [6]. In particular, a scheme of Blockchain interconnection between a construction company and its counterparties (resource suppliers) is proposed. The use of the proposed scheme allows you to control and ensure the security of the system from data loss or fraud and will increase the efficiency of internal and external document management. Instead, there is a need to study the methods and regulations for the implementation of a unified document turnover system for construction companies and their numerous counterparties.

One of the promising areas of urban management is the conception of «smart city». This conception and the conception of Blockchain technology have several common characteristics. A consideration of the issues of modernization of key aspects of urban development, such as municipal infrastructure, urban roads and transport, urban construction through the integration of innovative technologies, in particular Blockchain, into the management of the development processes of the urban environment, is carried out in the another study [7]. Both of the above mentioned areas describe the properties of the functioning of a certain environment that is most suitable for living and doing business and are in the phase of active development and implementation. All this gives grounds to assert that it is expedient to conduct a study on the development of a comprehensive conception of «smart city» using Blockchain technology. It is Blockchain that will improve the interaction between public administration bodies and all participants in urban development through the introduction of effective technological solutions that will create mechanisms for finding consensus between all stakeholders.

In almost all countries of the world, the land registration system is a process of registration of property rights, which certifies the rights of owners. The issues of developing a system of registration of rights to land plots are considered in the next of the referenced studies [8]. This study describes in detail the scheme and mechanism of interaction between property owners and users as parties to a smart contract. In a digitized land registration system making use of Blockchain, data is distributed, and the distributed nodes are connected through a network; the record of transactions is transparent to the public and immutable in its nature. It has been proved that the use of a new registration system will solve the problems of integrity and reliability of records, since Blockchain technology has decentralized, transparent and immutable characteristics. However, there is no analysis of the requirements for information and communication systems that should be used during the introduction of a comprehensive system of registration of property rights.

The results of studying the scientific literature on the possibilities of using Blockchain in the construction industry, published in the period from 2017 to 2021, are presented in the separate study [9]. A total of 33 categories of Blockchain application in construction industry have been identified. The categories are grouped into seven subject areas, including: Pro-

curement and Supply Chain, Design and Manufacturing, Operations and Life Cycle, Smart Cities, Smart Systems, Energy, and Decentralized Organizations. This is an in-depth study of the possibilities of implementing Blockchain technology in the processes of activities of companies in the construction industry, but it should be emphasized the need for continuous monitoring and constant updating of data on the development of innovative methods and approaches.

Yet another study [10] presents the methodology of trade finance using Blockchain and the verification of smart contracts. The authors propose the use of Blockchain in order to improve the efficiency of management of international trade processes. The use of smart contracts to control trade finance allows for clear, automated actions that guide stakeholder interactions. As a result, it is determined that the use of Blockchain can provide solutions that eliminate fraud, increase the degree of trust, reduce transaction processing time and reduce costs. It is proposed to optimize the mechanisms of traditional trading with the help of Blockchain Accepire-BT platforms. Still, the issues of developing a comprehensive set of standards and rules that are necessary for the effective and secure implementation of the technology in the activities of companies engaged in international trade remain open.

Modern production and business largely depend on the efficiency of data management, the security of information storage and the ability to quickly access it.

Blockchain technologies provide a high level of security, as each transaction is to be verified and stored unchanged. This makes it impossible to change or delete data in an unauthorized manner. Also, one of the main principles of Blockchain is full transparency of all operations. This allows to track the movement of goods, changes in their status or parameters at any stage of production. The risk of corruption is eliminated due to decentralization and the abolition of centralized control.

By implementing automation in processes such as transaction confirmation or quality control, businesses can significantly reduce time and costs. At all stages of production activities, Blockchain can be a universal platform for exchanging data between partners, customers, and suppliers, simplifying and speeding up the process of coordination and interaction.

The application of Blockchain allows enterprises to actively implement the latest achievements in technological advancement, opening up new possibilities for innovation in production.

Taking into account the above factors, the active development of software and platforms based on Blockchain, the relevance of researching the possibilities of implementing existing Blockchain technologies and software products at all stages of the production life cycle becomes obvious. This is especially true for industries where a high degree of data protection, transparency and reliability of interaction between participants are required.

Purpose and objectives of the study. The purpose of the study is to analyze modern Blockchain technologies and assess the prospects for their implementation in the business processes of a manufacturing enterprise to improve the efficiency of management and production processes. This can bring a number of strategic benefits, contributing to the development and competitiveness of the enterprise in the context of digital market transformation.

To achieve the above formulated purpose, the following objectives were set:

- determine the basic principles of the functioning of Blockchain technology, its key characteristics and features;
- analyze data on the use of Blockchain technology in various industries;
- determine the classes of modern Blockchain technologies according to the criterion of their application at different stages of the production cycle;
- consider the potential benefits of using Blockchain technology in the context of a manufacturing enterprise.

Materials and methods. The object of the research is the Blockchain technology and the possibilities of its application in the industry sectors.

The introduction and integration of Blockchain technologies into different stages of the production cycle can significantly increase the efficiency and transparency of the entire production process.

The assumptions made in the study are that Blockchain technologies can be integrated into various areas of the production process, and the use of Blockchain technologies is expedient and provides additional advantages compared to traditional technological solutions.

The analysis of the efficiency of Blockchain implementation is based on available data and feedback from enterprises already using these technologies.

The study focuses on the analysis and systematization of applications of Blockchain technologies at different stages of the production cycle: from idea and development, advancing to production and procurement of components, and further through marketing and sales, to the stages of delivery, logistics, operation and maintenance.

As a result of the analytical studying, classes of Blockchain platforms and technologies have been identified, the use of which will increase the efficiency of activities at different stages of the life cycle of the production process. For further research, 5 key stages of product production are allocated: idea and development, production and procurement of components, marketing and sales, delivery and logistics, operation and maintenance.

The methodological basis of the research comprise:

- data of software and platform developing companies;
- recommendations for the introduction of Blockchain technology;
- open data on the use of Blockchain technologies by international and Ukrainian companies;
- open information and reference data;
- results of professional research;
- information about the accumulated experience and benefits;
- recommendations of leading experts and practitioners on the topic under consideration.

The methods of scientific analysis, holistic approach, comparison, induction and deduction, systematization, modeling were used.

Results of research on the possibilities and prospects of using Blockchain technology in the production activities of enterprises

Identification of the basic principles of functioning of Blockchain technology, its key characteristics and features

Storage and exchange of information of various formats and quantities is carried out using centralized information systems. Most of the existing mechanisms for protecting confidential information in centralized information systems are characterized by high transaction costs and low transparency. The prospects for overcoming these shortcomings of information protection in centralized systems may be related to the use of Blockchain technology.

Blockchain is an information technology for recording and processing transactions, which is secure because it excludes the possibility of losing or changing data; transparent, as it is characterized by simple verification and tracking. Validation of transactions in a decentralized Blockchain system does not require verification, i. e. there is confidence in implementing agreements without intermediaries [11].

For a more complete definition of Blockchain, it needs to be considered as a decentralized computing system with five constituent components, namely: decentralized network, mathematical cryptography, distributed consensus, transaction ledger, and smart contracts (Fig. 1).

For computing, Blockchain uses a decentralized network of computers called Blockchain peer nodes. The peer nodes provide computing resources for storing and processing transactions. These computers operate autonomously and communicate with each other in a peer-to-peer (P2P) network [12].

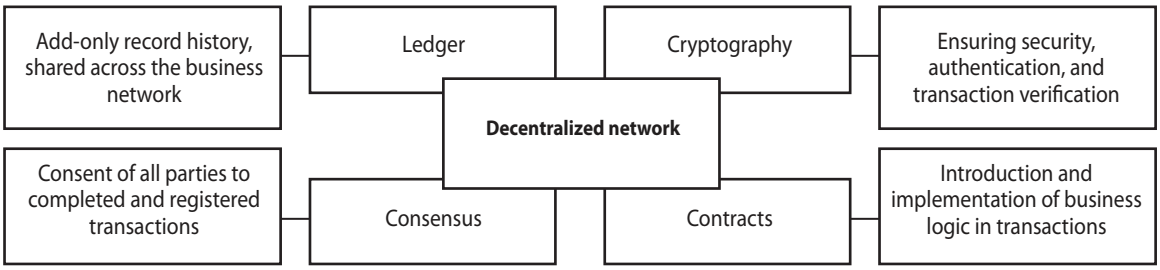

Fig. 1. Five components of Blockchain technology

Source: compiled by the authors

The cryptographic techniques used in Blockchain provide mathematical evidence that Blockchain functions properly. A cryptographic hash is used to link blocks of data on a chain to prevent data from being altered once written to the Blockchain. Every transaction is encrypted using public-key cryptography, to ensure that the sender can be verified with a digital signature, and the intended recipient of the transaction can be the only recipient. The confidentiality of transactions is achieved through a zero-knowledge proof method. The choice of cryptography used determines the performance and guarantees of Blockchain [13].

As a storage technology, Blockchain is a digital ledger in which transactions are stored in chronological order in blocks that can only be incremented. This default ledger data structure is common to almost all Blockchain networks. The structure of the ledger, the structure of the block, and the number of transactions in the block are important factors in the development of the Blockchain ledger component [14].

In the event that a decision needs to be made, for example, whether a transaction is valid and the central authority cannot make a decision, then the decision will be based on the consensus reached among the peer nodes involved in the work. Therefore, a Blockchain network must have a consensus protocol to ensure that each transaction or block added to the Blockchain is a single version of the truth agreed upon by all peers. For example, the Proof-of-Work consensus [15] provides more decision-making power to the nodes with the higher hardware and computing power adopted in early Blockchain networks. The Proof-of-Stake consensus [16], which provides more decision-making power to the nodes with a larger financial stake, is popular among today's Blockchain networks; its first functional use for cryptocurrency was in Peercoin in 2012 [17]. The choice of consensus protocol is the most important factor when projecting a Blockchain network.

Smart contracts are software applications that are executed automatically without human intervention. They are intellectual contracts that do not require a third party (such as a lawyer, notary, or government official) to verify or enforce contracts. This literally means that it is possible to conclude fast, reliable, and trustworthy agreements with a third party, which will also reduce the cost of legal support [18].

The manufacturing industry has a specificity, which is expressed in the presence of dynamic, long chains of document turnover, supply of material resources and financial flows. Thus, the issues that allow us to determine the existing opportunities for the use of innovative technologies, in particular Blockchain in the organization of information exchange and its protection at all stages of the production life cycle, become relevant.

Analysis of data on the application of Blockchain technology in various industries

The review [19] contains data on the largest industry players that have implemented Blockchain technology (Tabl. 1).

The presented list does not reflect the whole picture and the scale of use of Blockchain by manufacturing companies. According to VeChain alone, their clients include more than 30 companies from Fortune 500, including BMW, H&M, BYD, BAYER, and others [20].

The integration of Blockchain technology into the product development process allows you to increase efficiency and reduce the time to market products. In addition, this integration provides additional security and transparency at all stages of development and opens up opportunities for global collaboration and innovation that were previously limited by trust and data security concerns.

Table 1

Global companies that have implemented Blockchain technologies

Company	Sector	Blockchain solutions
Ford	Automotive industry	Using Blockchain technology to improve mobility technologies
Toyota	Automotive industry	Using Blockchain technology to improve autonomous driving technology
HSBC	Banking	Using Blockchain technology to fully digitize accounting and improve the security of the storage system
Anheuser Busch InBev	Beverage production	Using Blockchain technology for the beverage supply chain and increasing transparency
Alibaba	e-Commerce	Using Blockchain Technology to track luxury goods on the own e-commerce platforms
Tencent	e-Commerce / Retail trade	Using Blockchain technology to verify the authenticity of invoices and ensure tax compliance
Metlife	Health care	Using Blockchain technology to store patients' medical records for insurance purposes
UnitedHealthcare	Health care	Using Blockchain technology to improve physician directories to ensure accurate completion of insurance claims
AIA Group	Insurance	Launch of a first-of-its-kind bank guarantee for policy data sharing
Prudential	Insurance	Providing a Blockchain-based trading platform for small and medium-sized enterprises
BHP Billiton	Mining	Using Blockchain technology for supply chain management
Shell	Automotive lubricant	Using Blockchain technology to trade crude oil with a target of preventing corruption manifestations
Pfizer	Pharmacy	Record tracking and digital inventory management of pharmaceutical products
JLL	Real estate	Blockchain research for commercial real estate valuation in Spain
Nestle	Retail trade	Using Blockchain technology in supply management to track baby food products
Walmart	Retail trade	Using Blockchain technology to track the movement of products from farmers to stores
Baidu	Search engine	Using Blockchain technology to improve intellectual property rights management
UPS	Shipping	Logistics monitoring and management solutions based on Blockchain technology
Maersk	Shipping	Blockchain system for tracking the movement of cargoes between ports
FedEx	Shipping	Work on a Blockchain solution for resolving customer disputes
Google	Technologies	Exploring the use of Blockchain technology to improve the security of cloud services and data protection
Facebook	Technologies	Exploring the use of Blockchain technology to improve data security and user privacy
Samsung	Technologies	Using Blockchain technology to improve electronics supply chain management
Apple	Technologies	Patented Blockchain technology for time-stamping
British Airways	Tourism industry	Introduction of Blockchain technology to manage flight data and verify the identity of the traveler

Source: compiled by the authors

Thus, the integration of Blockchain into the production cycle can act as a strategic innovative solution that contributes to the stability, growth and competitive advantage of enterprises.

This not only streamlines existing processes, but also provides a platform for future innovation and adaptation to dynamically changing market conditions, and creates significant competitive advantages in the long run.

Classification of modern Blockchain technologies according to the criterion of their application at different stages of the production cycle

The following are classes of tasks, the efficiency of solving of which can be increased by using software products that apply Blockchain technology.

At the stage of creating a new product and developing a model or prototype of a new product, the introduction of Blockchain technology allows you to solve the following tasks:

- support for cooperation in the field of research and development (R&D); formation of a single database of research works and new developments; industries often collaborate with other companies, universities, or research institutes in order to advance R&D;
- Blockchain can help securely track and verify the work of each participant, ensuring that intellectual property (IP) rights are correctly specified and protected;
- modeling and product prototype data can be stored on the Blockchain, ensuring data integrity, a chronological record of iterations and changes;
- with product development, sourcing raw materials becomes crucial. Blockchain can provide a transparent and tamper-proof record of where and how raw materials are extracted, ensuring sustainability and quality;
- Blockchain can provide time-stamped registration of product designs, guaranteeing proof of originality, which can be useful for patent applications or in case of intellectual property disputes;
- as the product goes through the development stages, feedback from stakeholders becomes pivotal. Blockchain can provide a transparent and immutable feedback loop. This guarantees the authenticity of the feedback and allows the chain to be traced back to its source; for products in industries such as pharmaceuticals, aviation, or automotive, regulatory compliance is pivotal. Blockchain can provide auditors and regulators with a transparent and immutable record of product development and testing processes;
- the results of quality tests at different initial stages of product development can be recorded in the Blockchain, providing an invariable record of quality checks and their results;
- smart contracts on the Blockchain platform can automate and simplify agreements with development partners, developers, or knowledge service providers, guaranteeing transparency and automatic implementation;
- for companies looking to leverage the power of crowdsourcing to develop products, Blockchain can provide a platform for transparent input, ensuring that innovators are rewarded for their ideas and contributions;
- Blockchain can provide a clear record of design configurations, ensuring that any iteration is documented and stakeholders can track the evolution of the product;
- some industries are moving to decentralized platforms where multiple parties collaborate on product development. Blockchain provides the foundation for such decentralized collaboration with built-in trust mechanisms.

At the production stage, which is accompanied, among other things, by the purchase of components, the introduction of Blockchain technology allows you to solve the following tasks:

- to check the authenticity of the necessary components and components. Storage of nomenclature information about components used in production in the Blockchain registry allows you to check new deliveries for authenticity and identify counterfeit copies;
- quickly and accurately identify the products that need to be recalled. If a defect in a certain batch of components is detected, the manufacturer can use Blockchain to quickly track a specific supplier of defective products;
- ensure and prove the compliance of products with industry standards;
- thanks to the integration of the Internet of Things with Blockchain, procurement processes can be automated. An organization's ERP system can be integrated with Blockchain. When the inventory level of a particular product drops below a set threshold, the system can automatically create a purchase order on the Blockchain;
- with a fixed record of transactions, procurement disputes can be resolved faster and more transparently. If there is a dispute between the supplier and the buyer about the volume of supply, you can refer to the Blockchain record to verify the details of the transaction;
- smart contracts for payments to suppliers allow you to automate payment processes after certain conditions are met, such as delivery or quality checks;
- to promote the creation of secure and transparent payment systems, which is especially useful for international transactions. When purchasing components from another country, it is possible to use cryptocurrency or Blockchain-based payment systems to make secure and fast transactions;
- protection of intellectual property, copyright projects, patents is implemented through the introduction of an appropriate entry in a specialized Blockchain system. A manufacturer can use Blockchain to ensure that its unique designs are protected from duplication;
- the immutable and transparent nature of Blockchain can simplify and optimize the audit process. During internal or external audits, companies can easily access records in the Blockchain to verify procurement processes and transactions without having to go through a large number of documents on paper or digital carriers.
- Blockchain can record the maintenance history of production equipment and machinery, and when integrated with the Internet of Things (IoT), it can automate maintenance schedules;
- partner companies can form Blockchain-based networks to work together on joint procurement, shar-

ing risks and benefits. It is becoming relevant to unite several small businesses on the Blockchain network to order materials in bulk, providing better prices and conditions than if they ordered materials separately.

The decentralized and transparent nature of Blockchain technology offers various applications at the stage of marketing and sales, and the introduction of this technology provides manufacturers with additional competitive advantages:

- when promoting a product on the market and conducting advertising campaigns, manufacturers can use Blockchain to track the movement of advertising, ensuring that it is seen by real people, not bots. Blockchain can help create transparent systems in which advertisers can see how the advertising budget is spent, whether advertising contributes to sales growth;
- manufacturers of exclusive goods can use Blockchain to confirm the authenticity of the brand of their products. Once a product is sold, its unique code or identifier can be registered to the Blockchain, allowing customers to verify its authenticity and provenance;
- in competitive markets, the use of Blockchain-based loyalty programs, where customers are provided with tokens, is becoming relevant. These tokens can be traded, used for discounts, or exchanged for special offers, providing a secure and transparent loyalty system;
- secure peer-to-peer transactions allow you to replace traditional payment gateways. Manufacturers can make P2P transactions using cryptocurrencies. This ensures secure, fast, and low-cost transactions, which is especially beneficial for international purchases;
- the introduction of Blockchain technology in interaction with customers allows you to increase the level of customer security and ensure the confidentiality of personal data;
- the manufacturer has the possibility to verify the supply chain for its marketing statements when using unique components or supplements in production. With the help of the Blockchain registry, customers can check the product path, ensuring that the manufacturer's sustainability claims or ethical sourcing choices are genuine;
- Blockchain can facilitate the creation of decentralized marketplaces in which buyers and sellers can transact directly, without intermediaries, providing greater transparency in the price and origin of goods;
- Blockchain can be used to automate affiliate marketing and increase its transparency. Smart contracts can provide immediate, secure, and transparent payment to a partner for every sale made through an affiliate link;
- Blockchain can be used to create a platform where customer feedback is protected from unauthorized access. Once a feedback is added to the Blockchain, it cannot be changed, which provides genuine customer feedback;
- based on tokens for new products, manufacturers can launch crowdfunding campaigns. Interested customers can buy tokens that can be exchanged for a product once it is launched.

Blockchain technology is increasingly preferred because of its transformative potential in the logistics of manufacturing companies and in the transport sector in general. The tasks of optimizing logistics processes at production facilities are relevant, some of which can be solved by introducing this technology:

- Blockchain can be integrated in the internal transportation and logistics phase to track the movement of raw materials, components, and finished products in a manufacturing plant in real-time;
- a large manufacturer can use Blockchain to monitor the movement of parts between different warehouse stations, ensuring that parts arrive in the desired sequence and on time;
- an important aspect is to maintain a real-time inventory register protected from unauthorized access, reducing discrepancies and minimizing cases of out-of-stock or excess inventory. A manufacturer can use Blockchain to automatically reorder components from internal warehouses when inventory levels fall below a certain threshold;
- introduction of smart contracts to automate the internal logistics process when certain conditions are met, when at the stage of passing the quality control of the product, the smart contract can automatically initiate its transportation to the packaging area;
- in a high-security production environment, Blockchain can be used to verify vehicle and personnel credentials before granting access;
- monitoring and storage of environmental data for temperature-sensitive goods as they move can be implemented using Blockchain. The registry can store data from IoT sensors, ensuring that products are always stored and transported under the required conditions;
- Blockchain allows tamper-proof records of transport events to aid in resolving disputes in the event of damage to goods or delays. If the goods are damaged during transit, the exact shipping and handling events can be checked to determine the location of the damage;
- maintaining a register of records of maintenance work on internal vehicles in order to track the maintenance history of each vehicle and predict the timing of subsequent maintenance;
- analysis of movement data stored in the Blockchain allows you to increase the efficiency of the redistribution of warehouse space.

By incorporating Blockchain into transportation and logistics processes, manufacturers can increase transparency, accountability, and efficiency, leading to lower costs and increased operational flexibility.

The main value of Blockchain technology, namely, the decentralized and immutable nature of the data ledger, can offer numerous advantages when implemented at the stage of operation of the finished product and its maintenance:

- maintaining a register of records to the Blockchain of all operation or maintenance activities, which will ensure a transparent and tamper-proof history;

- Blockchain can store product warranty data, providing transparency and increasing the efficiency of claims processing;
- implementation of smart contracts can automate the activation, expiration, and payments of the service agreement;
- verification of the originality of spare parts used during maintenance can be tracked using Blockchain-based registers;
- storage of feedback entries and data on the quality of maintenance services, indicating the provider and type of service, can be recorded to the Blockchain to ensure accountability and support decision-making for future customers;
- the introduction of integrated software for IoT and Blockchain devices can be used in the planning of preventive maintenance work;
- maintaining a decentralized register of spare parts in different locations based on Blockchain allows them to be tracked in real time and logistics optimized;
- credentials and certificates of service specialists can be verified through Blockchain;
- the introduction of loyalty points or tokens in the Blockchain for regular maintenance and service inspections can contribute to timely service and the formation of trusting relationships with customers;
- service technicians can log common problems and their solutions in the overall block chain, assisting colleagues in solving similar problems.

Blockchain integration in the maintenance phase can increase trust and efficiency, ensure transparency between suppliers and customers. This increases the efficiency of maintenance and operation processes, and raises a level of safety and inspection that traditional systems may lack.

The Tab. 2 comprises the data obtained from open sources. This table contains information about companies that develop complex and specialized platforms of various scales and application specializations. The Tabl. 2 also contains data from manufacturing companies and corporations that announced the introduction of Blockchain technology into business processes.

Table 2

A matrix of existing Blockchain technology products and their implementation in business processes

Blockchain platform	Platform link	Development stage	Production stage	Marketing & sales stage	Delivery and logistics stage	Operation and maintenance stage
1	2	3	4	5	6	7
VeChain	https://www.vechain.org/	×	×	–	×	×
Chronicled	https://www.chronicled.com/	–	×	–	×	×
Ethereum	https://ethereum.org/	×	×	–	–	×
Hyperledger	https://www.hyperledger.org/	×	×	–	–	×
IBM Blockchain	https://www.ibm.com/blockchain	×	×	–	–	×
Modum	https://www.modum.io/	–	×	–	×	×
OriginTrail	https://origintrail.io/	×	×	–	×	–
Ambrosus	https://ambrosus.io/	–	×	–	×	–
Provenance	https://www.provenance.org/	×	–	–	–	×
AdChain	https://adchain.com/	–	–	×	–	–
AdEx Network	https://www.adex.network/	–	–	×	–	–
BAT i Brave	https://brave.com/brave–bsc/	–	–	×	–	–
CargoX	https://cargox.io/	–	–	–	×	–
Civic	https://www.civic.com/	–	–	×	–	–
Colu	https://colu.com/	–	–	×	–	–
Everledger	https://everledger.io/	–	–	–	×	–
Gitcoin	https://www.gitcoin.co/	×	–	–	–	–
IBM Food Trust	https://www.ibm.com/blockchain	–	–	–	×	–
IOTA	https://www.iota.org/	–	–	–	–	×
Loyyal	https://loyyal.com/	–	–	×	–	–
Papyrus	https://www.isis–papyrus.com/	–	–	×	–	–
SAP (IBP)	https://www.sap.com/products/technology–platform.html	–	–	–	×	–
ShipChain	https://www.supplychain247.com/	–	–	–	×	–

End tbl. 2

1	2	3	4	5	6	7
SingularDTV	https://www.singulardtv.com/	–	–	×	–	–
Slock.it	https://blog.slock.it/	–	–	–	–	×
Steem	https://steem.com/	–	–	×	–	–
SyncFab	https://syncfab.com/manufacturing–blockchain/	–	×	–	–	–
UpLink	https://uplink.weforum.org/	–	–	–	–	×
Warranteer	https://apprecs.com/android/com.warranteer.app/warranteer–e–warranty–tracker	–	–	×	–	–
ChainSafe	https://chainsafe.io/	×	–	–	–	–
OpenBazaar	https://github.com/OpenBazaar	–	–	×	–	–
TE–FOOD	https://te–food.com/solution/blockchain/	–	–	–	×	–

Source: compiled by the authors

The proportion of technological products with Blockchain, which are offered by five leading developers – VeChain, Chronicled, Ethereum, Hyperledger, IBM Blockchain, takes more than 50% of the total market offering.

With the development of Blockchain technology as such and the growing interest of manufacturing companies in introducing innovations in business processes, the share of tools with functionality that allows the use of this technology at the production stage has increased significantly (Fig. 2).

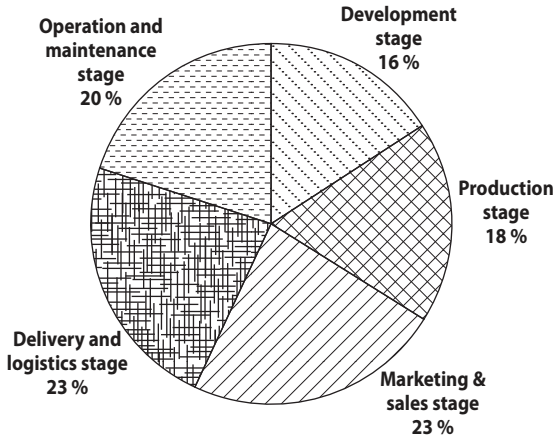

Fig. 2. A diagram of the distribution of software with Blockchain depending on the stage of the production life cycle

Source: compiled by the authors

In this way, Blockchain can be integrated at different stages of the production cycle to increase efficiency, reduce risk, and provide greater transparency across industries. However, it is worth noting that specific applications and implementation activities may vary not only by specific industries (Tab. 1), but also by the stage of the production cycle. Thus, Blockchain technologies are most actively implemented in management and automation systems at the following stages: marketing and sales, delivery and logistics (Fig. 2).

Consideration of the potential benefits of using Blockchain technology

Let's consider the possibility of using Blockchain technology at the stage of agreeing on a new product model (development stage). Let's highlight the task, which includes checking the compliance of a new product with certain standards, specifications and consumer requirements.

In general, the agreement model is a multi-criteria model of decision-making.

Let be the set C_i, where $i=\overline{1,...n}$ is the set of criteria for a given product model. The criteria may include product features, environmental sustainability, manufacturing costs, and more.

Each criterion corresponds to a score S_i in the range [0...1], which shows how well the parameter of the new product corresponds to the corresponding criterion. Estimates can be obtained by expert methods through laboratory tests, as a result of questioning groups of potential consumers, etc.

Let's introduce the set W_i – the value of the weight of each criterion depending on its importance.

Then the total assessment of the parameters of a new product by certain standards can be calculated as follows:

$$A=\sum_{1}^{n} W_i \times S_j. \quad (1)$$

Possible integrations of this simple model into Blockchain:

- after expert or experimental measurements, the values of C_i are recorded in the Blockchain ledger, which guarantees the immutability and transparency of data;
- Blockchain will store information about who provided the assessment, when it was provided, as well as any relevant comments or feedback, which is particularly useful for tracking and auditing purposes;
- creation of a smart contract, the task of which will be to automatically check the compliance of the acquired value of parameter A with a certain threshold value.

When creating a smart contract, a condition is introduced: if the value of A exceeds a predetermined threshold, the new product model can be considered acceptable and trans-

ferred to the prototype developers; otherwise, the model is rejected or reverted for improvement.

The smart contract of the presented model is developed with Solidity, one of the popular programming languages for Ethereum smart contracts.

Fig. 3 shows the program code of the smart contract for

```
/ /SPDX-License-Identifier: MIT
pragma solidity  ^0.8.9;

contract ProductModelMatching {

 struct Product {
    uint256 productID;
    uint256[ ] criteriaScores;
    uint256[ ] weights;
    uint256 aggregateScore;
    uint256 evaluator;
    uint256 timestamp;
}

m apping(uint256=> Product) public products;
uint256 public acceptanceThreshold = 500; // Arbitrary value; set your threshold here

event ProductEvaluated(uint256 productID, uint256 aggregateScore, bool accepted);

function evaluateProduct(
    uint2evaluate56 productID;
    uint256[ ] memory_criteriaScores,
    uint256[ ] memory_weights
)public {
Require(_criteriaScores.Length ==_weights.length, “Scores and weights array length must
match”);
    uint256 aggregateScore = 0:
    for(uint256 i = 0; I <_criteriaScores[i]*_weights[i];
   }
    products[_productID] = Product({
       productID: _ productID,
       criteriaScores: _ criteriaScores,
       weights: _ weights,
       aggregateScore: _ aggregateScore,
       evaluate: msg.sender,
       timestamp: block. Timestamp
    });

    bool isAccepted =_ aggregateScore >=acceptanceThreshold;
    em it  ProductEvaluated(_ productID, _ aggregateScore, isAccepted);
}
function setAcceptanceThreshold(uint256_newThreshold) public {
   // This function could include access control, so only authorized personnel can update
the threschol.
    acceptanceThreshold = _newThreshold;
    }
}
```

Fig. 3 A snippet of the code for a smart contract to verify the compliance of a new product with certain requirements

verifying the compliance of a new product with certain standards, specifications, and consumer requirements.

In Blockchain, data is structured into blocks. To compare the product model, each product evaluation can be thought of as a block with fields (Fig. 3):

ProductID: a unique identifier for the product;

CriteriaScores: a list of S_i scores for each C_i criterion;

Weights: a list of W_i weights;

AggregateScore: the calculated cumulative score of A;

Time-stamp: date of evaluation;

Evaluator: information about the expert who conducted the assessment.

Let's consider the functionality of smart contract blocks.

Struct Product – a structure that contains data for each

product, including scores by criteria, weight, cumulative score, evaluator's address, and evaluation time-stamp.

Mapping products – a product map that compares each product ID with the corresponding product structure, making it easy to retrieve and store product data.

AcceptanceThreshold – an arbitrary threshold for determining the acceptability of a product. Established on the basis of business requirements.

Function evaluateProduct – the function allows the evaluator to submit scores and weights for the product. Next, the total score is calculated and all the information is saved in the product map.

Function setAcceptanceThreshold – the function allows you to update the acceptance threshold. In a real-world scenario, it may be necessary to add access control mechanisms to ensure that only authorized personnel can update this value.

Event ProductEvaluated – events in Solidity allow certain actions to be recorded to the Blockchain. This event occurs whenever a product is evaluated, denoting its total score and whether it has been accepted.

In this way, the smart contract can automatically make decisions based on the cumulative score, once the data is entered into the Blockchain, it cannot be changed, thus ensuring the credibility of the evaluation process, while all stakeholders can see how and who has awarded the points.

Based on the proposed version of the smart contract, which sets and changes the threshold for accepting the values of the characteristics of a new product of a given level, it is also possible to solve the problems of tracing, quality management, automation of approval, integration with IoT devices and others.

Next, we will take a closer look at the mathematical model and smart contract for the tasks of tracing the origin of products and materials, determining their compliance with the established criteria.

To solve the problems of tracing the origin of materials and checking their compliance with the specified criteria in the context of Blockchain, we will use a mathematical model:

M – the set of all materials or components;

P – the set of suppliers;

C – the set of quality criteria or standards;

$f: M \times P \rightarrow \{0, 1\}$ – a function that determines whether the supplier supplies a given material (1 if yes, 0 otherwise);

$g: M \times C \rightarrow \{0, 1\}$ – a function that determines whether a material meets a certain criterion (1 if yes, 0 otherwise).

To determine which supplier a particular material $m \in M$ comes from, you can use the f function to get a list of suppliers providing that material.

To verify that the material $m \in M$ meets all criteria of C, it is possible to apply the function g to each criterion. If the material meets all the criteria, then:

$$\forall c \in C, \quad g(m,c) = 1. \qquad (2)$$

This model is a high-level description of how tracing and compliance verification can be implemented in the Blockchain.

The implementation of this model for specific tasks will depend on the specifics and features of the Blockchain platform used. It is important to consider that Blockchain ensures the immutability of data, which adds an extra layer of trust to the tracing and compliance verification process.

To implement the proposed model in the code of a smart contract on the Ethereum platform (using the Solidity language), it is possible to create the structure presented in the Fig. 4.

The contract in question contains the following functions:

addMaterial – the function adds a new material to the contract; function parameters (_name: the name of the material, _supplier: the Ethereum address of the provider of this material). The function creates a new Materiali structure with a given name, provider, and sets the isVerifiedto flag to false;

addCriteriaToMaterial – the function adds criteria for a specific material; function parameters (_materialName: the name of the material to which the criterion should be added, _description: description of the criterion). The function creates a new Criterioni structure with a given description and sets the isMet flag to false. This criterion is then added to the list of criteria for the relevant material;

verifyMaterialAgainstCriteria – the function checks whether the material meets all the criteria and, if so, sets its status as checked; function parameters (_materialName: the name of the material to be tested). The function follows all the criteria associated with this material. If all criteria are met (isMet is true), then the status of isVerified is set to true.

setCriterionMet – the function sets the correspondence of the material to a certain criterion; Parameters (_materialName: The name of the material whose criterion is to be set to true, _criterionIndex: The index of the criteria in the list of criteria for this material). The function sets the isMet value of the selected criterion to true.

In addition to these basic functions, there are other structures and variables that are used to store and manage data. All the features are quite simple and aim to manage the material and criteria data in the contract

It should be noted that the integration of mathematical test models into the Blockchain system allows for transparency, immutability and minimal automation of the process of selecting a model for a new product. In addition, this integration offers solutions to the problems of tracing the origin of products and materials with the determination of their compliance with the established criteria.

However, it is important to approach the integration with a clear understanding of the technical nuances of Blockchain technology and with the involvement of experts from both Blockchain and a specific manufacturing industry in the process of creating contracts.

Discussion of the results of the assessment of possibilities and prospects for the use of smart contracts

Despite the fact that Blockchain technology is primarily associated with the financial sector, its application at different stages of production demonstrates the high potential for the introduction of this technology in various industries. The results of data monitoring of the use of decentralized systems (Tab. 1) allow us to conclude that there is a significant increase in the list of industries where instruments with use of Blockchain technology have been successfully implemented.

Leading automotive concerns are using Blockchain technologies to improve mobility and autonomous driving. Health-

```
pragma solidity   0.8.0;

contract TraceabilityAndComliance {

 struct Material {
    stiring name;
    address supplier; // Ethereum provier adderess
    bool isVerified; // Flag indicating whether the material assed the test }

struct Criterion {
     stiring escription;
     bool isMet; // Flag indicating whether the material meet the crierion
 }

// Comparison of material with its criteria
mapping(string => Materail) public materials;
mapping(string => Crierion[[]) public materialCriteria;

function addMaterial(string memory_name, address_suplier) public {
    material[_name] = Materai({
       name: _name;
       suppliers: suppliers;
       isVerified: false
 })
}

        function addCriteriaToMaterial(string memory_materialName, string_memory
_deacription) public {
    Criterion memory newCriterion = Criterion ({
    isMet: false
  });
   materialCriterial[_materialName].push(newCriterion);
}

function verifyMaterialAgainCriterial(string memory_materialName) public {
    Material storage material = material [_materialName];
    Criterion[] storage criteria =materialCriterial[_materialName]:

    bool allCriteriaMet = true;
     for(uint I = 0; I < criteria. Length; i++) {
        // can add criterion checking logic
       if(!criteria[i].isMet) {
          allCriteriaMet = false;
          break;
        }
}

If(allCriteriaMet) {
          material.isVerified = true;
            }
```

Fig. 4. A snippet of the smart contract code for the tasks of tracing the origin of products and materials, with the determination of their compliance with the established criteria

care corporations are adopting Blockchain technologies to store patients' medical records for insurance purposes and to improve physician directories to secure that insurance claims are filled out accurately.

Financial institutions are fully digitizing credentials, which makes it possible to increase the security of the storage system. Merchants and e-commerce companies are actively using Blockchain to supply chains and increase transparency in customer relationships, as well as to track the movement of goods on their e-commerce platforms. Travel companies are implementing Blockchain to manage flight data as well as verify the identity of travelers.

Studies of existing software complexes and platforms that use the latest information technologies (Tab. 2) prove that

Blockchain technologies are on the verge of large-scale integration into the production sector. Leading technology companies are actively developing and offering Blockchain-based solutions adapted to the needs of manufacturers.

Manufacturing companies have a wide variety of platforms to choose from, each with its own unique features and benefits. The choice of the appropriate platform depends on the specific needs and goals of the enterprise. The Tab. 2 presents a classification of common software complexes depending on the available technological capabilities for implementation and use at different stages of the production cycle.

Thanks to Blockchain technology, production processes can be automated and become more transparent and secure. This can lead to lower costs, improved product traceability, and stronger relationships with partners and customers.

The use of smart contracts, fragments of which are shown in the Fig. 2 and Fig. 3, can automate numerous production processes, including payments, agreements, and other transactions, resulting in higher efficiency and cost reduction. Smart contracts can be programmed to automatically perform certain actions when certain conditions are met, allowing for a high degree of flexibility and automation.

We can confidently say that with the development of Blockchain technologies, new tools and solutions are expected to emerge that most accurately respond to the challenges of modern productions.

The results of improving production processes through the introduction of smart contracts can be explained by their ability to automate routine operations and ensure transparency and security of transactions.

Smart contracts contribute to reliability and transparency at every stage of production, which can be crucial for various areas of production and enterprise activities. The benefits come from smart contract features such as automation, security, and transparency. A special value is that smart contracts provide a high level of trust between the participants in the transaction, the absence of the need for intermediaries, as well as the ability to monitor all stages of the transaction and/or production process.

Among the shortcomings of the study should be mentioned the lack of certain data and metrics on the effectiveness of the implementation of smart contracts, also no sufficient analysis of alternative technologies or strategies was carried out.

The findings can be applied to many industries, including finance, supply chains, health care, and any other field that requires secure and transparent transactions and processes. Practical use is particularly important in environments that require a high level of transparency and security without the need for a central authority.

Conclusions

1. The study solves the problem of defining the principles and mechanisms of Blockchain, which include decentralization, cryptographic protection and distributed consensus. Special attention is paid to smart contracts as an instrument that performs automatic actions when certain conditions are met in Ethereum. Smart contracts are distinguished by autonomy, objectivity of fulfillment of conditions and independence in performing operations, which are key to automating and ensuring the security of transactions in the system.
2. The application of Blockchain in various sectors was examined, including its impact on operational efficiency, transparency, and reliability of processes from idea to production and technical support of the product. Examples in various industries confirm its versatility and adaptability. Examples of applications of Blockchain technology from leading companies in the world include: the use of Blockchain to improve mobility technologies, the application of Blockchain to improve autonomous driving technologies. In addition, it is important to integrate Blockchain for digital record processing and improve the security of the storage system, using Blockchain to track the movement of products from farmers to stores. There are also other cases where companies from different sectors of the economy successfully integrate Blockchain technologies to optimize production and management processes.
3. Blockchain technology has been classified and analyzed in the context of its use at different stages of the production cycle. The key differences and specifics of the use of smart contracts and other Blockchain technologies were studied at different stages of the product life cycle, from idea to operation.

The benefits of using Blockchain were considered in a production context, including increased transparency, data security, and optimization of business processes through automation. Specific cases have shown how the implementation of Blockchain can increase efficiency and reduce costs by providing new possibilities for enterprises.

4. The introduction of Blockchain technologies and, in particular, the use of smart contracts written in the Solidity language, opens up new opportunities for automation and optimization of business processes of a manufacturing enterprise. The program code created using Solidity allows you to implement conditional actions and transactions in the Blockchain. This can enable automated fulfillment of contract terms to verify the compliance of a new product with certain requirements and for the tasks of tracing the origin of products and materials, determining their compliance with established criteria.

The presented examples and analytics can be used as a basis for further research and development in the field of Blockchain technologies, as well as an illustration of the real application of the technology in various industries.

LITERATURE

1. Solodovnik O. O., Dokunina K. I. Blockchain Technology: The Essence and Prospects for Use in the Public Finance System of Ukraine. *Business Inform.* 2021. No. 3. P. 126–131.

DOI: 10.32983/2222-4459-2021-3-126-131

2. Літошенко А. В. Технологія Blockchain: переваги та неочевидні можливості використання у різних галузях. *Економіка та держава.* 2017. № 8. С. 77–79. URL: http://www.economy.in.ua/pdf/8_2017/20.pdf

3. Попівняк Ю. М. Технологія блокчейн у бухгалтерському обліку й аудиті: сучасний стан, можливості та перспективи застосування. *Економіка, управління та адміністрування.* 2019.

№ 3 (89). С. 137–144.
DOI: 10.26642/ema-2019-3(89)-137-144

4. Kwilinski A. Implementation of blockchain technology in accounting sphere. *Academy of Accounting and Financial Studies Journal.* 2019. No. 23 (25). URL: https://www.abacademies.org/articles/implementation-of-blockchain-technology-in-accounting-sphere-8219.html

5. Манчур І. Рівень використання блокчейн–технології підприємствами України в сфері бухгалтерського обліку та аудиту. *Економічний аналіз.* 2021. № 31 (3). С. 183–189.
DOI: 10.35774/econa2021.03.183

6. Криворучко Г. В. Технологія Блокчейн та перспективи її застосування в процесі бюджетування, орієнтованого на результат. *Вісник економічної науки України.* 2018. № 2 (35). Р. 108–113. URL: http://dspace.nbuv.gov.ua/handle/123456789/150564

7. Андрієнко А., Маматова Т. Технологія блокчейн як драйвер розвитку концепції розумного міста. *Міжнародний науковий журнал «Грааль науки».* 2021. № 2–3. С. 101–106.
DOI: 10.36074/grail-of-science.02.04.2021.018

8. Suganthe R. C., Shanthi N., Latha R. S., Gowtham K., Deepakkumar S., Elango R. Blockchain enabled Digitization of Land Registration. International Conference on Computer Communication and Informatics (ICCCI). 2021. P. 1–5. URL: https://www.semanticscholar.org/paper/Blockchain-enabled-Digitization-of-Land-Suganthe-Shanthi/e4eee515df21df0a3fb5c72f817f4790ea20d304

9. Scott D. J., Broyd T., Ma L. Exploratory literature review of blockchain in the construction industry. *Automation in Construction.* 2021. Vol. 132. P. 103914.
DOI: 10.1016/j.autcon.2021.103914

10. Bhat A., Nor R. M., Amiruzzaman M., Islam Md. R. Methodology and Analysis of Smart Contracts in Blockchain–Based International Trade Application. *International Conference on Computing and Technological Solutions with Artificial Intelligence.* 2021. URL: https://journals.iium.edu.my/kict/index.php/IJPCC/article/view/313

11. Nakamoto S. Bitcoin: A Peer–to–Peer Electronic Cash System. 2008. URL: https://bitcoin.org/bitcoin.pdf

12. Gad A. G., Mosa D. T., Abualigah L., Abohany A. A. Emerging Trends in Blockchain Technology and Applications: A Review and Outlook. *Journal of King Saud University – Computer and Information Sciences.* 2022. Vol. 34 (9). P. 6719–6742.
DOI: 10.1016/j.jksuci.2022.03.007

13. Haw–Bin How, Swee–Huay Heng. Blockchain–Enabled Searchable Encryption in Clouds: A Review. *Journal of Information Security and Applications.* 2022. No. 67. P. 103183.
DOI: 10.1016/j.jisa.2022.103183

14. Gietzmann M., Grossetti F. Blockchain and other distributed ledger technologies: Where is the accounting? *Journal of Accounting and Public Policy.* 2021. Vol. 40 (5). P. 106881.
DOI: 10.1016/j.jaccpubpol.2021.106881

15. Gramoli V. From blockchain consensus back to Byzantine consensus. *Future Generation Computer Systems*. 2020. No. 107. P. 760–769.
DOI: 10.1016/j.future.2017.09.023

16. Zhang Yu., Zhang L., Liu Yo., Luo X. Proof of service power: A blockchain consensus for cloud manufacturing. *Journal of Manufacturing Systems*. 2021. No. 59. P. 1–11.
DOI: 10.1016/j.jmsy.2021.01.006

17. Papadimitriou Th., Gogas P., Gkatzoglou F. The evolution of the cryptocurrencies market: A complex networks approach. *Journal of Computational and Applied Mathematics.* 2020. No. 376. P. 112831.
DOI: 10.1016/j.cam.2020.112831

18. Hu B., Zhang Z., Liu J., Liu Yi., Yin J., Lu R., Lin X. A comprehensive survey on smart contract construction and execution: paradigms, tools, and systems. *Patterns.* 2021. Vol. 2 (2). P. 100179.
DOI: 10.1016/j.patter.2020.100179

19. Iredale G. Top 20+ Enterprises Implementing Blockchain Technology. 2021. URL: https://101blockchains.com/enterprises-implementing-blockchain/

20. Blockchain for our better world // Vechain. URL: https://www.vechain.org/

REFERENCES

Andriienko, A., and Mamatova, T. "Tekhnolohiia blokchein yak draiver rozvytku kontseptsii rozumnoho mista" [Blockchain Technology as a Driver of the Development of the Concept of a Smart City]. *Mizhnarodnyi naukovyi zhurnal «Hraal nauky»*, no. 2-3 (2021): 101-106.
DOI: 10.36074/grail-of-science.02.04.2021.018

"Blockchain for our better world". Vechain. https://www.vechain.org/

Bhat, A. et al. "Methodology and Analysis of Smart Contracts in Blockchain-Based International Trade Application". International Conference on Computing and Technological Solutions with Artificial Intelligence. 2021. https://journals.iium.edu.my/kict/index.php/IJPCC/article/view/313

Gad, A. G. et al. "Emerging Trends in Blockchain Technology and Applications: A Review and Outlook". *Journal of King Saud University - Computer and Information Sciences*, vol. 34 (9) (2022): 6719-6742.
DOI: 10.1016/j.jksuci.2022.03.007

Gietzmann, M., and Grossetti, F. "Blockchain and other distributed ledger technologies: Where is the accounting?" *Journal of Accounting and Public Policy*, vol. 40 (5) (2021): 106881.
DOI: 10.1016/j.jaccpubpol.2021.106881

Gramoli, V. "From blockchain consensus back to Byzantine consensus". *Future Generation Computer Systems*, no. 107 (2020): 760-769.
DOI: 10.1016/j.future.2017.09.023

Haw-Bin, How, and Swee-Huay, Heng. "Blockchain-Enabled Searchable Encryption in Clouds: A Review". *Journal of Information Security and Applications*, no. 67 (2022): 103183.
DOI: 10.1016/j.jisa.2022.103183

Hu, B. et al. "A comprehensive survey on smart contract construction and execution: paradigms, tools, and systems". *Patterns*, vol. 2 (2) (2021): 100179.
DOI: 10.1016/j.patter.2020.100179

Iredale, G. "Top 20+ Enterprises Implementing Blockchain Technology". 2021. https://101blockchains.com/enterprises-implementing-blockchain/

Kryvoruchko, H. V. "Tekhnolohiia Blokchein ta perspektyvy yii zastosuvannia v protsesi biudzhetuvannia, oriientovanoho na rezultat" [Blockchain Technology and Prospects for its Application in the Budgeting Process, Oriented to the Result]. Visnyk ekonomichnoi nauky Ukrainy. 2018. http://dspace.nbuv.gov.ua/handle/123456789/150564

Kwilinski, A. "Implementation of blockchain technology in accounting sphere". Academy of Accounting and Financial Studies Journal. 2019. https://www.abacademies.org/articles/implementation-of-blockchain-technology-in-accounting-sphere-8219.html

Litoshenko, A. V. "Tekhnolohiia Blockchain: perevahy ta neochevydni mozhlyvosti vykorystannia u riznykh haluziakh" [Blockchain Technology: Benefits and Non-obvious Uses in Various Industries]. Ekonomika ta derzhava. 2017. http://www.economy.in.ua/pdf/8_2017/20.pdf

Manchur, I. "Riven vykorystannia blokchein-tekhnolohii pidpryiemstvamy Ukrainy v sferi bukhhalterskoho obliku ta audytu" [The Level of Use of Blockchain Technology by Enterprises of Ukraine in the Field of Accounting and Auditing]. *Ekonomichnyi analiz*, no. 31(3) (2021): 183-189.

DOI: 10.35774/econa2021.03.183

Nakamoto, S. "Bitcoin: A Peer-to-Peer Electronic Cash System". 2008. https://bitcoin.org/bitcoin.pdf

Papadimitriou, Th., Gogas, P., and Gkatzoglou, F. "The evolution of the cryptocurrencies market: A complex networks approach". *Journal of Computational and Applied Mathematics*, no. 376 (2020): 112831.

DOI: 10.1016/j.cam.2020.112831

Popivniak, Yu. M. "Tekhnolohiia blokchein u bukhhalterskomu obliku i audyti: suchasnyi stan, mozhlyvosti ta perspektyvy zastosuvannia" [Blockchain Technology in Accounting and Auditing: Current State, Possibilities and Prospects of Application]. *Ekonomika, upravlinnia ta administruvannia*, no. 3(89) (2019): 137-144.

DOI: 10.26642/ema-2019-3(89)-137-144

Scott, D. J., Broyd, T., and Ma, L. "Exploratory literature review of blockchain in the construction industry". *Automation in Construction*, vol. 132 (2021): 103914.

DOI: 10.1016/j.autcon.2021.103914

Solodovnik, O. O., and Dokunina, K. I. "Blockchain Technology: The Essence and Prospects for Use in the Public Finance System of Ukraine". *Business Inform*, no. 3 (2021): 126-131.

DOI: 10.32983/2222-4459-2021-3-126-131

Suganthe, R. C. et al. "Blockchain enabled Digitization of Land Registration". International Conference on Computer Communication and Informatics (ICCCI). 2021. https://www.semanticscholar.org/paper/Blockchain-enabled-Digitization-of-Land-Suganthe-Shanthi/e4eee515df21df0a3fb5c72f817f4790ea20d304

Zhang, Yu. et al. "Proof of service power: A blockchain consensus for cloud manufacturing". *Journal of Manufacturing Systems*, no. 59 (2021): 1-11.

DOI: 10.1016/j.jmsy.2021.01.0066

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