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MAIN MECHANISMS OF BLOCKCHAIN TECHNOLOGY IMPLEMENTATION IN DIGITAL TECHNOLOGIES APPLICATION

Purpose. To analyze the basic principles of blockchain technology implementation, highlighting the algorithms for reaching consensus in the blockchain network to ensure its reliability; to identify key problems in the implementation of such technology and suggest ways to overcome them; to perform a systematic analysis of the blockchain technology contradictions and suggest ways to eliminate them.

Methodology. The research used the basics of economic analysis of economic entities to compare their management's centralized and decentralized models. This approach showed that another wave of transformation of business and social models has unfolded in recent years, caused by the next-generation digital technologies involving the economy's transition to the digital area. Revealing the blockchain technology mechanisms is based on modern databases and peer-to-peer computer networks, covering in detail the main means of contradictions, application, and implementation of blockchain technology.

Findings. The main results of these studies are obtained in the digital economy. The paper shows that digital technologies open up a wide range of opportunities for different sectors of the economy. The research highlights the features and principles of distributed registry technology (Blockchain) applications. It is shown that as a decentralized data registry, blockchain technology is the most discussed and relevant topic in the digital economy.

Originality. The paper further developed the main component of the digital economy, which is progressing most intensively, – the distributed ledger technology (Blockchain). The paper analyzed its strengths, such as cost reduction, increased security, and transparency of transactions that attracted the attention of various sectors of the economy. The authors' approach for eliminating the revealed mechanisms of contradictions, application, and implementation of blockchain technology is presented. The definition of the digital economy, digital technologies in the economy, and "end-to-end" digital technologies have been improved to clarify the understanding of the economic management decentralization problems. That showed that the digital economy has several subtleties associated with insufficient research and comprehension of technical implementation and flexibility.

Practical value. The research results will be useful for expanding ideas about the blockchain technology implementation in different sectors of the economy, accompanied by lower costs, increased security and transparency of economic entities, and improving their economic efficiency and development in digital technologies' application. The blockchain technologies implantation at the enterprises of the mining and metallurgical industry allows making the production and sales of products more efficient and transparent, and at the same time significantly reduces the human factor.

Keywords: *digital technologies, contracts, investments, Blockchain, security, transparency, transactions, data register, software*

Introduction. Until recently, the world had been organized on the management centralization principle, resource allocation centralization, money circulation centralization, and centralization of supervisory and regulatory bodies. History knows many examples of inefficiency and ephemerality of the centralized model of government. The point here is simply the banal centralization inefficiency in the conditions of long-term stable development. Note that centralization can effectively solve urgent, critical, and short-term problems. However, in the long run, it is inefficient, as it is poorly amenable to modernization processes, which are usually requested from below.

Stable and high economic growth in the United States is largely due to a decentralized system of government. Each state of the United States in terms of legislative and executive power differs little from the states of Europe; each of them has its laws and, in fact, independent but mutually integrated economies. At the same time, China, which is often mistaken for the top of centralization, is very similar in economic terms to the United States, especially after Deng Xiaoping's reforms, which began with the decentralization of economic management.

General modern information and communication technologies involve the economy's transition to digital. That process directly affects the management methods both at the macro level and at the level of commercial structures, including the transition to a decentralized management system is underway.

Many other examples in economics and history show the centralization inefficiency and, conversely, the decentralization effectiveness.

For a long time, the spread of digital technologies has determined the development of the economy and society and has repeatedly led to radical changes in people's lives. Digital economy development is one of the priorities for most countries, including economic leaders.

In recent years, another wave of business and social model transformation has unfolded, caused by the advent of new generation digital technologies. Due to the scale and depth of impact, they have been called "through" – artificial intelligence, robotics, Internet, wireless technology, and others. Their implementation, according to economists, can increase productivity in companies by up to 40 %. Shortly, the most effective use of new digital technologies will determine the international competitiveness of individual companies and entire countries that form the infrastructure and legal environment for digitalization.

Digital transformation gains special importance for the mining and metallurgical complex (MMC) of Ukraine. It significantly increases productivity, reduces cost, improves product quality, and reduces losses. The blockchain technologies implementation at MMC enterprises will make the production and sales of products more transparent while significantly reducing the human factor.

Notably, there is no clear definition of the digital economy in international practice. In most international sources, when describing the digital economy, the emphasis is on technology, and related changes in the way economic agents interact. At the same time, specific types of technologies or certain forms of changes in economic processes can be mentioned. Definitions of the digital economy are often replaced by a list of areas of its impact on the economy and social sphere. In this regard, we share the digital economy and digital technologies concepts. We introduced our own authors' understanding of those provisions for clarity and certainty of concepts.

Definition 1. The digital economy is creating, disseminating, applying digital technologies and related products and services.

Definition 2. Digital technologies in economics are technologies for collecting, storing, processing, retrieving, transmitting, and presenting data in electronic form.

Definition 3. "Through" digital technologies in the economy are technologies used to collect, store, process, search, transmit and submit data in electronic form, which are based on the operation of software and hardware and systems in demand in all sectors of the economy that create new markets and changing business processes.

The most intensively developed technology is distributed ledger (Blockchain) – algorithms and protocols for decentralized storage and processing of transactions, structured as a sequence of related blocks without the possibility of their further change.

Given the above, those studies highlight the analysis of the main mechanisms of contradictions, realization, and implementation of blockchain technology.

Literature review. In terms of decentralization, the current topic is the possibility of applying the Blockchain at different levels of government. Blockchain technology is built according to certain rules of a continuous sequential chain of blocks containing information. The Blockchain is based on decentralized storage of the data chain. In this case, the data on the transactions are stored in a certain order and form a constant sequence of related blocks. After that, the information contained in the block is replicated and copied to each node on the network. This algorithm ensures the stability of this technology to data changes.

Usually, the Blockchain is managed by a peer-to-peer network. After recording, the data in any block cannot be changed without a complete change of all subsequent blocks demanding the consent of the majority of network participants. In the book "Blockchain: the scheme of the new economy" [1], M. Swan identifies three types of Blockchain:

1. Blockchain 1.0 is a cryptocurrency. Examples are Bitcoin, Ethereum, Litecoin, and so on.

2. Blockchain 2.0 is smart contracts. A wide class of financial applications deals with stocks, bonds, futures, collateral, and many other financial assets.

3. Blockchain 3.0 – all other applications based on this technology go beyond the financial sphere.

A fundamental feature of blockchain technology involves processing the transactions without intermediaries [2]. Transactions are distributed by nodes connected through hash numbers. Miners compute these hash numbers for a block, and based on consensus, such a block is accepted into the blockchain network. Those blocks contain a ledger of transactions or smart contracts. This evolution of the Blockchain has changed the view of the Internet as a source of some economic value [3]. Experts in the digital economy claim that by 2027 10 % of world GDP will remain in the blockchain system [4]. Despite the serious attention to that technology, Blockchain still requires appropriate research and refinement to solve, for instance, problems related to the time of transaction processing [5], and others.

Blockchain as a decentralized data registry also has a great future. Based on the Blockchain, one can simplify the work of registration chambers, notaries, medical institutions. Moreover, registration chambers will become unnecessary if blockchain technology evolves. There will also be no need for registrars of various securities, which will reduce the transaction costs of their ownership.

Purpose. Based on the review of literature sources and the analysis results of the current state of digital economy development, to analyze the blockchain technology main mechanisms, identify fundamental problems of its implementation, perform a systematic analysis of blockchain technology contradictions, and suggest ways to eliminate them.

Presentation of the main research material. ***Analysis of the main mechanisms of blockchain technology implementation.*** The main task for which blockchain technology is applicable is to coordinate the actions of system participants, united by one goal, but deprived of trust in each other. The "task of the Byzantine generals" has long been a classic one among cryptologists, stating: "The Byzantine army is besieging the city. The generals need to develop a common strategy leading to victory, even if there are traitors who deliberately distort information about the number of their troops and the time of the offensive. Blockchain solves this problem through consensus-building mechanisms".

That technology has a huge potential for those systems with no mutual trust, as it provides reliable storage of personal data, making inaccessible changes in them for fraud [6,7]. Moreover, the Blockchain allows making various transactions without intermediaries, significantly saving money and time. All this is relevant for banking systems [8, 9].

The most valuable link in blockchain technology is the algorithms for reaching consensus as those provide it with reliability. There are three main mechanisms for reaching appropriate agreements. So, to highlight the peculiarities of blockchain technology consensus mechanisms, we consider them in a more extensive form:

1. Proof-of-work is the system protection protocol. Anyone wishing to write a block to a database must perform a complex computational task based on a one-way function. The computation process takes a long time, while the host quickly checks the result. Checking computations on the receiving side is fast – due to a single computation of the SHA-1 function with a pre-prepared label. Before transmitting the message, some mark was added to the header, whose validity can be confirmed using the exhaustive search only.

At the moment, the algorithm of proof-of-work has earned the greatest authority among other mechanisms for creating reliable systems. The fact is that it can resist the "Sibyl attacks", whose essence is that the attacker creates a lot of fake participants and thus draws consensus in their favor. Carrying out such an attack complicates the proof-of-work algorithm because the fraudster will have to spend a huge amount of computing power to work it. Also, most blockchains charge a commission for participating in the consensus, so the "Sibyl attack" will be a very expensive operation. The proof-of-work algorithm is often criticized for its excessive energy consumption. However, it is the only way to resist interference in such a system at this stage of technology development.

2. Proof-of-stake is a protection protocol, an alternative to proof-of-work, where it is necessary to confirm as evidence the storage of a certain amount in the account. With a higher probability of the next block formation, the system will choose a miner with a large amount of money in the account. This choice probability does not depend on the power of its processors. In order to undermine the system's reliability, one of the participants must collect more than 50 % of all system funds in their hands, which is an extremely costly operation.

Proof-of-stake has more advantages over proof-of-work. The main thing is lower time costs (no need for lengthy com-

putations), but this does not eliminate possible problems. There is also no evidence of effectiveness in protecting against the risks posed by cryptocurrencies.

Arguments against are as follows: the method motivates to accumulate funds in separate accounts, which calls decentralization into question; when forming a small number of participants who have concentrated most of the funds in their hands, that group may impose its conditions on the system functioning. Two significant advantages of this protocol include the following: an attack on the system is very expensive. If a participant still conducts it, the attacker will suffer significantly because it will violate the system's stability.

3. Delegated-proof-of-stake is an improved version of the proof-of-stake protection protocol, whose specificity is that the system's blocks are generated by a predetermined number of users (101 delegates) who are rewarded for their duties and punished for malicious behavior (such as participation in double spending). The list of users to sign blocks changes periodically according to certain rules; for instance, in Slasher, delegates are selected based on their fate and blockchain history. Delegates can receive votes from all users; the voting strength depends on the share of the voter currency. Delegated-proof-of-stake has the same advantages and disadvantages as proof-of-stake.

Problems of implementation of the blockchain technology. Blockchain technology gets attractive, evolutionary and promising, but that could be inappropriate for each system. There could be some prerequisites indicating its implementation possibility. Let us note them:

a) public databases application;

b) distrust among the participants;

c) striving for non-existence of intermediaries;

d) interdependence of operations, need to create chains.

However, it should be stated that even for the systems using blockchain technology, its implementation has several obstacles caused by technology's very structure and principles [9]. Consider some of them.

1. *Security and privacy issues.* Despite several security solutions using sophisticated encryption algorithms, cybersecurity issues remain most discussed. Any software is artificial and therefore imperfect. The more complicated it becomes, the faster the number of vulnerabilities grows. In addition, the integrity of software and networks is fundamentally important for the transformation of Blockchain into infrastructure technology [10]. If Blockchain integrates with all major financial systems globally, powerful attacks on it can lead to catastrophic consequences.

2. *The problem of implementation and integration*. When an organization implements some technology to modernize its business processes, it faces the challenge of transferring its old data to a new format. In this situation, the blockchain implementation is no easier than other similar tasks, so the planning issue of the transition from current systems to the Blockchain remains open. Reducing the costs promised by the blockchain implementation inspires, but any implementation will require high initial costs, which cannot be ignored.

3. *The problem of understanding technology*. One of the biggest operational risks is that a relatively small number of people understand the system's mechanisms [11]. If one plans to implement a blockchain in a certain system, which users are broad sections of the population, it may lead to unpleasant consequences. The fact is that the Blockchain does not protect against the most popular type of fraud – phishing, whose essence is to steal sensitive user data. Compromise of the key can lead to permanent loss of funds protected by cryptography. Unfortunately, today not every ordinary user can boast of knowledge of the basic rules of personal data protection. There is a possible solution to the problem of identifying theft: to link public keys with an individual or legal entity, but this mechanism involves additional costs.

4. *Problems with the speed of operations*. In order to protect against 51 % attack (when one member of the network takes more than half of the computing power of the system), block size (e.g., Bitcoin) remains no more than 1 megabyte, which allows decentralization, but significantly limits the speed of transactions – 3.3 per second, then as the same Visa spends 22 thousand per second. Increasing the bandwidth of at least ten transactions per second would require increasing the block size to 1.6 gigabytes, which would cause problems for low-power miners, and secondly, would complicate the spread of blocks across nodes. Today, the chain of Bitcoin blocks "weighs" about 38 GB of memory [10]. Suppose blockchain systems appear later, which will store transaction information and other more voluminous data. They will most likely fail because of forcing miners to store other people's data for free; the developer deprives them of incentives to support the network, as miners' costs exceed profits.

System analysis contradictions of the blockchain technology. Being a revolutionary technology, the Blockchain possesses a good deal of tasks which require solution for full-scale implementation. The decentralized data storage is among the most essential problems; its peculiarity is presented for clarity in Fig. 1 by visual interpretation with major contradictions for that technology. Thus, if each network node stores the full data ledger allowing one to restore entire network until the last node gets demolished. Nevertheless, it is considered that the network grows persistently, which leads to unrestrained data amounts. Furthermore, one needs large amount of data synchronization for a new participant to enter the network [12].

Alternatively, default database that records accurate data encryptedly, imputing only the hash in the Blockchain could solve the problem. Then obsolete blocks get archived. However, it is worth noting that that could be the only partly solution to the problem.

However, the following circumstance must be borne in mind. When using blockchain technology for data storage, it is important to remember that modern technology does not allow storing large amounts of information in the Blockchain. For this reason, in essence, blockchain technology in this area is practically used as an intermediary and registry that monitors compliance with the transaction terms to provide storage from one user to another (Fig. 1). Neither blockchain technology, smart contracts, nor cryptography protects the information in decentralized storage [13]. Moreover, it can be argued that information has the same protection under the same circumstances as in traditional repositories.

Respecting the above, one can apply such methods as "big data" [13] for solving the problems that concentrate on dealing with storage and processing of huge amount of data. That approach was integrated and improved in different structures like *Shared Disk*, *Shared Nothing*, *Shared Memory*, *Map Reduce*, etc. A major problem for big data tools integration into a blockchain is system type. The matter is that a blockchain represents a decentralized distributed system, which means that the computations are distributed among various nodes. The more so, there are no nodes controlling other nodes operation in the network. Nevertheless, another approach is applicable here.

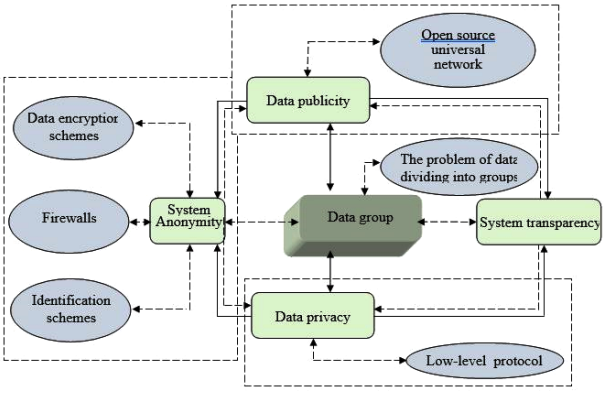

Fig. 1. Contradictory scheme for decentralized data storage in the blockchain system

Blockchain is noted to technically be a simple database with significant scalability and no query languages. However, its shortcomings are compensated by its decentralization, consistency, lucidity, and comprehensive data sharing. Hence, *Bigchain DB* and *IPDB* technology gets developed [14], becoming global decentralized databases.

One more essential task is to guarantee trust. Participants must have anonymous and transparent system. Fig. 2 depicts Contradiction scheme for decentralized data storage in the blockchain system. Nevertheless, it should be noted that the distributed ledger concept creates comprehensive tools for solving the trust problem in business relationships implementation by applying information and telecommunications systems. The distributed ledger idea is embodied in open, closed, and hybrid software platforms, most of them remain general, but some are specialized. Relevant software platforms allow making applications for many areas of business relationships.

It is worth noting the next fundamental aspect. System users would like to observe data transfer via the network without allowing other users to know what operations they actually perform. Therefore, we used asymmetric encryption algorithms when every user has a pair of keys (private and public). Herein, Fig. 3 represents the user data relationship. The private key serves to sign blocks that were transmitted by a user. Meanwhile the public key shows the user address on the network. Before a user can make a transaction, one needs both public and private keys. That represents chain of characters, e. g. they could reach from 26 to 35 for a public key. Both public and private keys have close connection (Fig. 3) – and a user needs to transmit and receive data via the network. Here are examples of the basic features of customizable keys.

Interestingly, the network always knows that public and private keys of the user are interconnected, even without seeing the private key (Fig. 3). Therefore, the configurable public key is communicated both to a sender and a recipient. It could be transmitted further to anyone. Meanwhile, a private key must be stored completely safe. It is inherent in the public key

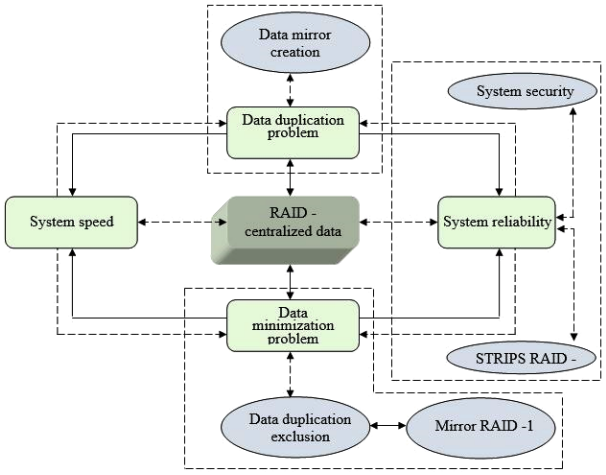

Fig. 2. Contradiction scheme for decentralized data storage in the blockchain system

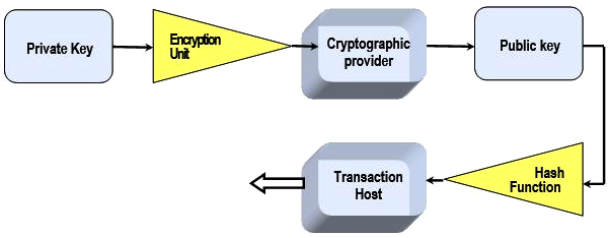

Fig. 3. The custom keys relationship in the blockchain system

of a user that applies a cryptographic cipher and becomes as a digital signature for the transaction authorization. Besides, for accessing the information transmitted to a user, one needs both keys (Fig. 3). Figuratively, the contact between public and private keys could be described in the following way. There is a box, wherein its single branch can be disclosed by a public key. Someone puts money in this box and closes it. After closing this compartment, the funds are transferred to the adjacent compartment, whose lid can only be opened with a private key. If one gets lost, the money remains in the box forever. Moreover, as long as someone has one private key, others will never have access to the appropriate funds. Although, notably, some cryptocurrency wallets provide a private key backup feature.

Thus, one of the main problems of blockchain technology is data reliability, which contributes to the practical encryption algorithms [15]. Those must ensure sufficient cryptographic information stability on the network and allow the implementation of the digital signature [16]. It is necessary to consider unique algorithms for simultaneous access and conflict resolution in the network.

Conclusions. The research presented in this paper shows that digital technologies reveal a huge range of opportunities, from money transfers to music transfer, from coordination of large government projects to innovations in land management, from transparent monitoring of public spending to the regulation of officials' salaries and deputies. Its strengths – lower costs, increased security, and transparency of transactions – drew attention to various sectors of the economy. The application of this approach is multifaceted, and it is difficult to predict where humanity will find a place for digital technology in the foreseeable future. Hence, for clarity and certainty of understanding the problems, the author's definition of the digital economy, digital technologies in economics, and "end-to-end" digital technologies in economics are introduced.

The authors' approach concluded that the digital economy has several subtleties associated with insufficient study and understanding of the technical implementation and its flexibility. There is no doubt that the digital approach can transform the internal structure of various enterprises.

At the same time, the production process at enterprises is featured by a continuous production cycle. Appropriately, the uninterrupted operation principle of all its production components becomes vital. That operation mode of the enterprise is provided effectively only via the introduction of modern information and communication technologies. In addition, the urgent problem for enterprises is to upgrade the server fleet, storage, and transmission systems, storage security, data transmission, and processing systems, increase bandwidth and protect corporate networks. Instability in at least one of these components leaves a significant imprint on the enterprise's capabilities. Therefore, the problem of raising the digital level significantly distinguishes this industry among others.

The paper also covers the composition of the digital economy that develops most intensively: distributed ledger technologies (Blockchain).

As a decentralized data ledger, the paper shows that blockchain technology is the most discussed and relevant topic in the digital economy. Its strengths, such as cost reduction, increased security, and transparency of transactions, which drew attention to various sectors of the economy, are analyzed.

The main mechanisms of contradictions, realization, and implementation of blockchain technology are covered in detail. The authors' approach to eliminating the identified contradictions is presented.

The research conducted in this paper demonstrates that one of the main problems of the studied technologies is the peculiarities of the modeling process – both machine and mathematical ones. For instance, to maintain and solve the security problems of those technologies, it is necessary to use powerful computer equipment and high-performance ones. On the other hand, the problem of hash function modeling

can be solved only based on the modern, complex mathematical apparatus. The authors attribute these problems to the prospect of further research on that topic.

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Основні механізми реалізації технології блокчейн в умовах застосування цифрових технологій

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Мета. Провести аналіз основних принципів реалізації технології блокчейн, висвітливши алгоритми досягнення консенсусу в мережі блокчейн для забезпечення її надійності; виявити принципові проблеми впровадження такої технології й запропонувати шляхи їх подолання; виконати системний аналіз протиріч технології блокчейн і запропонувати шляхи їх усунення.

Методика. У проведених дослідженнях використовувалися основи економічного аналізу діяльності господарчих суб'єктів з метою порівняння централізованої й децентралізованої моделей їх управлення. Такий підхід дозволив показати, що останніми роками розгортається чергова хвиля трансформації моделей діяльності в бізнесі й соціальній сфері, викликана появою цифрових технологій нового покоління, що передбачає перехід економіки до цифрової області. Розкриття механізмів реалізації технології блокчейн засноване на застосуванні сучасних баз даних і однорангових пірінгових комп'ютерних мереж, що дозволило детально висвітлити основні механізми протиріч, реалізації та впровадження технології блокчейн.

Результати. Основні результати даних досліджень отримані в області розвитку цифрової економіки. У роботі показано, що цифрові технології відкривають величезний спектр можливостей для різних секторів економіки. Дослідження спрямовані на висвітлення особливостей і принципів застосування технології розподіленого реєстру (блокчейн). Показано, що технологія блокчейн, як децентралізований реєстр даних, є найбільш обговорюваною та актуальною темою розвитку цифрової економіки.

Наукова новизна. У роботі отримала подальший розвиток основна складова цифрової економіки, що найінтенсивніше розвивається: технології розподіленого реєстру (блокчейн). Аналізуються такі її сильні сторони, як зниження витрат, підвищення рівня безпеки та прозорість транзакцій, що притягнуло до себе увагу різних секторів економіки. Представлено авторський підхід для усунення виявлених механізмів протиріч, реалізації та впровадження технології блокчейн. Для чіткості й визначеності розуміння проблем децентралізації управління господарчих суб'єктів удосконалено визначення цифрової економіки, цифрових технологій в економіці та «наскрізних» цифрових технологій. Це дозволило показати, що цифрова економіка відрізняється рядом тонкощів, пов'язаних і з недостатньою вивченістю, і з розумінням технічної реалізації та гнучкістю.

Практична значимість. Результати досліджень будуть корисними в частині розширення уявлень про процеси впровадження технології блокчейн в різні сектори економіки, що супроводжується зниженням витрат, підвищенням рівня безпеки та прозорості діяльності господарчих суб'єктів, а також забезпечує підвищення їх економічної ефективності управління й розвитком в умовах застосування цифрових технологій. Упровадження технологій блокчейн на підприємствах гірничо-металургійного комплексу дозволить зробити виробництво та продажі продукції більш ефективними та прозорими, а вплив людського фактору при цьому суттєво зменшити.

Ключові слова: *цифрові технології, контракти, інвестиції, блокчейн, безпека, прозорість, транзакції, реєстр даних, програмне забезпечення*

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