DNIPRO UNIVERSITY
of TECHNOLOGY
1899

NAUKOVYI VISNYK

Natsionalnoho Hirnychoho Universytetu

Peer-reviewed
journal

5 2023
197

Geology

Mining

Solid State Physics, Mineral Processing

Geotechnical and Mining Mechanical Engineering, Machine Building

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Economy and Management

Bi-Monthly ■ Founded in September 1998

The journal has been included in SciVerseSCOPUS, Index Copernicus Journal Master List, ProQuest, EBSCOhost, Ulrichsweb Global Serials Directory, ResearchBib, Ukrainika naukova, Dzherelo.

Subscription for the journal can be done in post offices of the Ukraine (subscription index in Subscription Publication Catalogue is 89166) and in the subscription agencies Ukrinformnauka (index in Subscription Publication Catalogue is 10107) and Ideia (index is 17736)

Makeup T. A. Klimenko. Proofreading M. T. Sysun.
Passed for printing under recommendation of Academic Council of Dnipro University of Technology (transaction No. 10 dated October 19, 2023).

Certified by Ministry of Justice of Ukraine. Registration number KB No. 24305-14145PR dated December 27, 2019. Passed for printing October 26, 2023. Sheet size 60 × 90/8. Presswork 23.3. Offset paper. Number of copies printed 200. Order No. 1.

Founder and publisher Dnipro University of Technology, Dnipro
Certificate of Publisher ДК No.1842 dated June 11, 2004

Address of publisher and editorial office: 19, D. Yavornytskoho Ave., building 3, room 24a, Dnipro, 49005
Tel.: (056) 373 08 65, e-mail: nv.ngu@ukr.net, www.nvngu.in.ua; nv.nmu.org.ua

Production PP KF "Gerda". 60, D. Yavornytskoho Ave., Dnipro, 49000.
Certificate of Publisher ДК No.397 dated April 3, 2001

ДНІПРОВСЬКА
ПОЛІТЕХНІКА
1899

НАУКОВИЙ ВІСНИК

Національного гірничого університету

Рецензований
журнал

5 2023
197

Геологія

Розробка родовищ корисних копалин

Фізика твердого тіла, збагачення корисних копалин

Геотехнічна і гірнича механіка, машинобудування

Електротехнічні комплекси та системи

Технології енергозабезпечення

Екологічна безпека, охорона праці

Інформаційні технології, системний аналіз та керування

Економіка та управління

Виходить 6 разів на рік ■ Заснований у вересні 1998 р.

Журнал зареєстровано у Міністерстві юстиції України. Реєстраційний номер КВ № 24305-14145ПР від 27.12.2019. Наклад 200 прим. Зам. № 1. Підписано до друку 26.10.2023. Формат 60 × 90/8. Ум. друк. арк. 23,3. Папір офсетний.

Засновник та видавець Національний технічний університет «Дніпровська політехніка», м. Дніпро. «Свідоцтво суб'єкта видавничої справи» ДК №1842 від 11.06.2004

Адреса видавця та редакції: 49005, м. Дніпро, просп. Д. Яворницького, 19, корпус 3, к. 24а
Тел.: (056) 373 08 65, e-mail: nv.ngu@ukr.net; www.nvngu.in.ua; nv.nmu.org.ua

Виготовлення: ПП КФ «Герда». 49000, м. Дніпро, просп. Д. Яворницького, 60.
«Свідоцтво суб'єкта видавничої справи» ДК №397 від 03.04.2001

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"Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu" is included in the Category A of the "List of Scien c Professional Edi ons of Ukraine" on geological and economic sciences (Order of Ministry of Educa on and Science of Ukraine No. 612 dated May, 7, 2019) and technical sciences (Order of Ministry of Educa on and Science of Ukraine No. 975 dated July 11, 2019)

ЗМІСТ

„Науковий вісник НГУ“ включений до категорії А „Переліку наукових фахових видань України“ з геологічних та економічних наук (Наказ МОН України від 07.05.2019 р. № 612) і з технічних наук (Наказ МОН України від 11.07. 2019 р. № 975

https://doi.org/10.33271/nvngu/2023-5/186

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SMART CONTRACTS AND BUSINESS PROCESS AUTOMATION: THE TECHNICAL ASPECT

Purpose. To analyze the process of implementing smart contracts for the automation of business processes, aimed at achieving high reliability and cybersecurity during contract execution, optimizing transaction costs, and maximizing the productivity of the enterprise's internal operations.

Methodology. The research results were obtained using special and general methods of scientific knowledge, namely descriptive, comparative, strategic analysis, abstract-logical and generalization.

Findings. The study revealed the potential of smart contracts based on blockchain technology to improve business process efficiency, reduce costs, and ensure innovative development in the Ukrainian business environment.

Originality. A comprehensive analysis of the technical aspects of using smart contracts based on blockchain technology to automate business processes has been conducted; their impact on the business environment has been assessed; a comparison of popular programming languages and blockchain platforms for the development and deployment of smart contracts has been made; a SWOT-analysis of the implementation of smart contracts at Ukrainian enterprises has been carried out, which opens up prospects for innovative approaches to business practices and their optimization.

Practical value. The results of the study can be used to develop and implement innovative strategies in a business environment based on the integration of smart contracts based on blockchain technology in order to improve the efficiency of business processes.

Keywords: *smart contracts, automation, business processes, blockchain, listing, SWOT analysis*

Introduction. The modern technological revolution is having a significant impact on all spheres of life, especially the business environment. Innovative technologies allow for a significant improvement in the technical and economic performance of enterprises. They not only provide increased productivity, but also open up new opportunities for efficient resource management and increased profits.

In a broader context, advanced technologies not only make our lives easier, but also significantly expand our understanding of the world. Thanks to innovative technologies, we can access new knowledge and approaches to solving global problems, which contributes to the development of science and technology and helps to ensure the sustainability of society. Innovative technologies allow for the rapid and efficient exchange of information, thus promoting the development of international cooperation and cultural diversity.

Due to the relentless progress of technology, the modern world is constantly moving forward. New opportunities are emerging in the business environment that contribute to the development of enterprises and ensure their competitiveness. One of the most promising areas of business development in the modern world is the automation of business processes through the integration of blockchain technology and "smart" systems based on artificial intelligence.

Given the significant benefits that blockchain and smart contracts can bring in the context of business process automation, their consideration and implementation becomes an obvious necessity. The use of blockchain technology and smart contracts can help businesses to simplify the contract signing process, ensure the fast and secure execution of contractual terms, improve the efficiency of business processes, and reduce the costs of their execution.

Literature review. There are many scientific papers by domestic and foreign economists devoted to the issues of digitalization and automation of business processes. Among the researchers who have dealt with these issues, the scientific works by representatives of the scientific school of Vinnytsia National Agrarian University deserve special attention. In particular, G. Kaletnik and S. Lutkovska define that digital technologies and business process automation play an important role in improving efficiency and productivity, reducing resource consumption and emissions, and creating new products and services that contribute to sustainable development [1]. G. Kaletnik, I. Honcharuk and Yu. Okhota argue that an innovative approach, which involves the integration of digital economy products, is the foundation for the development of a country in the context of globalization [2]. O. Golovnya explores the formation and development of smart entrepreneurship through the interactions between smart, information and innovation activities in the context of digital transformation of the economy [3]. A team of authors led by I. Honcharuk investigates the use of software for mathematical modeling [4]. In this context, we believe that a mathematical software tool helps to automate complex mathematical calculations and can become an important element of the digital economy, as it allows one to efficiently solve complex tasks and improve production and management processes.

The use of smart contracts in the modern world is an extremely topical issue that attracts the attention of both scientists and practitioners. In recent years, there has been a significant interest in studying and researching the potential of using blockchain technology and smart contracts in various industries, including finance, logistics, real estate, etc. Ukrainian scientists (O. Tomchuk, et al. [5], N. Zayed, et al. [6], Ya. Ma-

nuilov [7], M. Bortnikova and Yu. Chyrkova [8], V. Koibichuk and M. Rozhkova [9]) are paying significant attention to their research on the practical application of blockchain technology and smart contracts.

However, despite significant progress in the field of smart contract implementation, research shows that there are a number of issues that require further study. These include general technical aspects, security issues, scalability, and overall efficiency. Smart contracts have their own limitations and risks that require systematic analysis and resolution.

Purpose. To conduct an analysis of the process of implementing smart contracts for the automation of business processes, aimed at achieving high reliability and cybersecurity during contract execution, optimizing transaction costs, and maximizing the productivity of the enterprise's internal operations. To provide an example of a code listing for the implementation of a smart contract using the C# programming language for the automation of corporate processes.

Methods. The study used special and general methods of scientific knowledge: descriptive method in the analysis of literature sources for review of the existing experience of implementation and use of smart contracts in the automation of business processes; comparative method in the analysis of different programming languages and blockchain platforms for the development of smart contracts; strategic analysis method in the assessment of the strengths and weaknesses of the implementation of smart contracts in Ukrainian enterprises; abstract-logical method in the demonstration of the basic functionality of smart contracts by analyzing the code listing in the C# programming language; logical generalization method in the accumulation of information about the use of smart contracts for the automation of business processes on the basis of consideration of their technical aspects and features in comparison with traditional agreements.

Results. Blockchain is one of the most influential and innovative technologies of our time, opening up a wide range of possibilities in different spheres of activity. It has found its application in many areas, such as economic activity, finance, healthcare, law, etc. [5]. Blockchain technology provides a fast and seamless data transfer, allowing one to reduce process execution time and improve the interaction between system elements [6]. It also simplifies the interaction of external suppliers, customers and partners, which facilitates the rapid exchange of information and reduces delays in communication.

In a narrow sense, blockchain is a special form of database that runs on a network of computers known as nodes, on which smart contracts can be programmed and executed. The basic idea of the system is to create a sequence of blocks, each of which contains cryptographically linked data. Each block contains information about a certain number of transactions or events. When a new block is formed, it automatically references the previous block in the sequence, creating a chain that cannot be changed without making changes to all previous blocks.

Considering this system more broadly, blockchain is an innovative technology that is based on a distributed database and cryptographic algorithms. It provides an opportunity to replace the traditional approach to data processing, offering an alternative paradigm that is based on decentralization, reliability, and immutability [7, 8]. Understanding these key characteristics of blockchain is essential to understanding the essence and potential of this technology, and the logic of smart contracts in particular.

The difference between blockchain technology and traditional centralized systems is that the data and the mechanism for managing it are distributed among a multitude of nodes, rather than being concentrated in a central authority. Each node in the network has a copy of the full database and can participate in the confirmation and verification of transactions.

Blockchain networks are divided into public, private, and hybrid. Public networks do not require permission to access and allow anyone to join. Private blockchain networks are controlled by a specific organization that determines the participants and their rights. Hybrid blockchain networks are a combination of public and private networks. In them, the controlling organization has access to the primary data and determines who can modify it, while public participants have general access to other data that allows them to verify its correctness. The hybrid type of network is used in smart contracts, which allows public participants to verify both the execution of transactions and their correctness.

The reliability of a system is a derived criterion that follows from the features of a decentralized system. Specifically, this manifests itself in the fact that data is stored on a multitude of nodes in the network, rather than in a single central location. This means that even if several nodes fail or are compromised, other nodes will continue to store and maintain a copy of the database. This makes the system resilient to failures and attacks, providing high data reliability. Immutability, in turn, is the impossibility of modifying any data, which is ensured by the operation of special cryptographic mechanisms. Thus, each block contains a hash sum of the previous block, which makes it impossible to change the previous data without changing all the subsequent blocks in the chain. Moreover, changing any data in the block will lead to a change in its hash sum, which will be obvious when checking the block by the network nodes [9, 10]. This mechanism ensures that any information that is "trapped" in the blockchain is immutable and unforgeable. Due to these features, systems built on blockchain algorithms form a reliable and transparent basis for storing data and performing various operations. However, blockchain technology, like any other, has its advantages and disadvantages, especially when we consider it in the context of mass integration into already functioning business processes. Understanding these aspects is an important prerequisite for the successful use of its potential [11, 12] (Table 1).

Thus, the integration of blockchain technology allows for the creation of safe and tamper-proof systems that promote trust and reliability in business relationships. AI-based "smart" systems can analyze large amounts of data, identify patterns, and make managerial decisions, primarily in uncertain conditions. However, despite the existing shortcomings, blockchain technology can be considered an extremely efficient system that opens up a lot of opportunities for the development of business and various fields of activity. The combination of innovative solutions allows enterprises to implement innovative strategies that change the perception of the functioning of business processes in the modern business environment – this

Table 1

Advantages and disadvantages of blockchain technology

Advantages	Disadvantages
Decentralization and data security	High energy consumption and the need for powerful computing resources
Data immutability and transaction immutability	Limited scalability and transaction speed
Transparency and openness for all participants	Potential privacy and data confidentiality issues
Performance efficiency and process automation	Complexity of technical integration with existing systems
The ability to create decentralized applications and smart contracts	Legal uncertainty and lack of regulatory framework
Auditing and inaccessibility to data manipulation	Vulnerability to technical errors and attacks on cryptographic security
The potential to eliminate intermediaries and reduce transaction costs	Need for widespread adoption and understanding of the technology

opens up a lot of new opportunities for enterprises that strive to improve the efficiency of their business processes, ensure a high level of security and reliability in their activities.

Today, business process automation is a natural strategic solution for the progressive development of enterprises. It plays a special role in optimizing approaches to resource use, reducing costs and increasing employee productivity. This strategy is based on the use of advanced information technologies and algorithms to automate routine and repetitive tasks, such as document processing, reporting, inventory tracking, etc., which allows one to increase efficiency, reduce costs, improve quality and free up employee time for strategic development. It allows using resources more efficiently, reducing costs and increasing employee productivity.

We agree with the opinion of scientists S. Kyrychenko and M. Barannikov that the essence of automation is to replace a worker who performs primarily template work with a computer complex, which will allow one not only to increase the stability of the enterprise's operation, but also to significantly reduce labor costs, since world practice reflects the significant economic efficiency of the software application compared to a person [13]. Here, automation of business processes through the use of blockchain technology is becoming a necessary step for businesses that are looking to achieve high productivity, resource optimization, and maximum efficiency in their operations.

The use of advanced technologies such as artificial intelligence, machine learning, and blockchain allows businesses to standardize and automate a variety of processes, helping to reduce the need for manual labor [14]. However, the real potential of the latter is revealed as a platform for a more innovative solution – smart contracts. Smart contracts, as an "extension" of blockchain technology, allow automating the execution of contract terms without the need for third-party mediation. They use blockchain algorithms to ensure data immutability, as well as to ensure transparency and security of contract execution. Therefore, blockchain and smart contracts in synergy act as a powerful tool for creating innovative solutions for automating routine tasks in many sectors of the national economy.

The essence of business process automation is the use of computer systems, software, and algorithms to automatically perform tasks related to information processing, data management, reporting, and other aspects of business activity. In this context, smart contracts act as a leading tool for automating and optimizing business processes.

In 1994, Nick Szabo, a cryptographer and legal expert, introduced the concept of smart contracts. The basic idea was to use electronic contracts that could be automatically executed through the use of an electronic decentralized ledger [15]. However, the idea of smart contracts remained conceptual for a long time, without finding wide application. It was only in 2008, with the advent of blockchain technology, that the concept of smart contracts became a practical reality.

Blockchain, as a distributed technology, has opened up new possibilities for the implementation of the concept of smart contracts. This technological breakthrough has allowed moving from an idea to real programmable and self-organized "smart" contracts. It has become the basis for the safe and reliable deployment and execution of agreements.

As a result of the progress of IT technologies, a new form of agreement has emerged – smart contracts, also known as "smart" agreements. They work on blockchain algorithms and demonstrate the potential to rethink traditional approaches to the conclusion of agreements and contracts, as well as the implementation of financial transactions. This is a new type of contract that provides security, trust and automation of agreements without the need for mediation by traditional institutions such as banks or law firms [16].

Smart contracts reduce the time and financial costs of contract execution by providing an automated process for executing agreements. Additionally, smart contracts provide a high level of reliability, as their execution is built on the logic of blockchain, which guarantees transparency and inaccessibility to third-party intervention. As a result, the use of smart contracts allows to make the process of contract execution more transparent, efficient and safe for all participants.

Smart contracts, with their unique combination of intelligent automation and smart algorithms, have already found wide application in various business areas. So, one of the most obvious areas of application for smart contracts is the financial sector. They can be used to securely and automatically execute financial transactions, such as money transfers, dividend payouts, or other financial calculations. Smart contracts provide reliability and transparency in financial transactions, allowing parties to quickly enter into agreements without the need for intermediaries [17]. In the field of logistics and supply chain management, smart contracts can automate the processes of delivery, cargo tracking, and settlement between parties. They provide accuracy and transparency in the execution of contracts, thereby reducing the risks of delays or potential errors in the supply chain. Smart contracts have also found application in the real estate sector, where they can automatically execute agreements for the purchase, sale, exchange, or rental of real estate. This ensures the security and speed of transactions, as well as reduces the costs of intermediary services [8]. Other areas where smart contracts have already found their application include intelligent contracts in the insurance sector, automation of transactions in the energy sector, and use in loyalty programs, etc. In essence, there are no limits to the use of smart contracts – they are flexible and versatile tools that can be applied in different industries and in a variety of scenarios. Their potential is being seized both in traditional industries such as finance, logistics, real estate, and insurance, and in rapidly developing areas such as decentralized finance, supply chain management, digital assets, and intellectual property. The flexibility of smart contracts allows them to be used in virtually any context where it is necessary to establish clear rules and automate the execution of agreements.

The implementation of smart contracts in Ukrainian enterprises is one of the most topical issues that attracts the attention of the business community and experts in innovative technologies [10, 13]. Smart contracts offer new opportunities for automating business processes, which allows companies to focus on more important tasks and improve their productivity. In addition, the implementation of smart contracts opens up new opportunities for Ukrainian businesses in the context of ensuring their competitiveness in the context of globalization. Accordingly, it is important to properly research the strengths and weaknesses of smart contracts, as well as to identify the opportunities and threats that they can create in their practical implementation [11, 13] (Table 2).

A SWOT analysis is an important tool for a detailed analysis of the strengths and weaknesses of smart contracts, opportunities and threats, which provides a basis for further improvement of these valuable tools and ensures their safe and successful use. Thus, smart contracts are aimed at providing a new level of automation. This technology can reduce the likelihood of errors, as well as reduce the cost of transactions and increase their speed. However, it is important to remember that smart contracts are technically complex, which can make them inaccessible to a wide audience. It is also worth considering that smart contracts are a new technology, and therefore there are no clear standards or regulatory provisions yet. This can create certain risks for its use.

The above allows forming the advantages and disadvantages of smart contracts compared to traditional agreements [18, 19] (Table 3).

As mentioned above, smart contracts are computer programs that automatically control and execute agreements, and manage the conditions that have been recorded in them [20, 21]. From the perspective of the functionality of a smart contract, its execution mechanism is similar to the mechanism of the letter of credit. First of all, their common feature is the

Table 2

SWOT analysis of the implementation of smart contracts in Ukrainian enterprises

STRENGTHS	WEAKNESSES
1. Automation of contract execution processes. 2. High accuracy and reliability of contract execution. 3. Ability to automatically execute contract terms. 4. Data security and uniqueness of smart contracts. 5. Creation of new opportunities for automation of business processes	1. Complexity of technical integration with existing systems. 2. Limited liability of smart contracts in case of unforeseen circumstances. 3. High cost of developing and implementing smart contracts. 4. Limited scalability for large volumes of transactions. 5. Vulnerability to technical errors and attacks
OPPORTUNITIES	**THREATS**
1. Reduce operating costs. 2. Improve transaction speed. 3. Provide greater transparency and trust in business relationships. 4. Increase the efficiency of accounting and auditing. 5. Expand the market for smart contract and blockchain technology developers	1. Risk of cyberattacks and abuse in the field of smart contracts. 2. Legal uncertainty and lack of regulation in the field of smart contracts. 3. Potential errors in the smart contract's code. 4. Incomplete compatibility with existing systems and protocols

Table 3

Advantages and disadvantages of smart contracts

Advantages	Disadvantages
Automatization and execution of contract terms without intermediaries	Vulnerability to technical errors and vulnerabilities in the program code
High accuracy and reliability of contract execution	Limited liability of smart contracts in case of unforeseen situations
Efficiency and transparency of the contract execution process	Complexity of technical integration with existing systems and protocols
Ability to automatically execute contract terms without the need for additional actions	High cost of developing and implementing smart contracts
Security and immutability of data provided by blockchain algorithms	Incomplete compatibility with legal frameworks and legal uncertainty
Speed of contract execution and reduction of time and costs for operational activities	Potential data privacy and confidentiality issues
Ability to automatically keep accounting and audit records	Limited scalability for large volumes of transactions

conditionality of execution. In other words, the fulfillment of a certain obligation or contract is dependent on the occurrence of certain conditions or events and is technically expressed by a branching operator (Fig. 1).

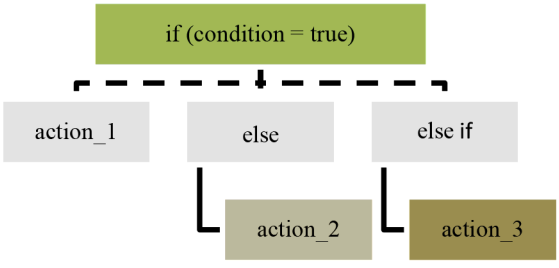

Fig. 1. Logic of conditionality of smart contracts

The conditional operator is used to check a condition and select a path of execution based on the result of the check. If the condition meets the specified criteria, a certain sequence of actions is executed. Otherwise, an alternative sequence of actions is executed. This approach is the basis of all functioning smart contracts, where a module is required to check the execution of conditions and select different paths of action depending on the result of the check.

Smart contracts are typically programmed in languages specifically designed for blockchain platforms. The most popular programming languages for creating smart contracts are listed in Table 4.

The choice of programming language for smart contracts is an important step in the development of blockchain applications. Different languages have their own features, syntax, and capabilities, which can affect the efficiency, security, and scalability of smart contracts [22, 23].

The most illustrative example of the use of smart contracts is their application in the context of the conclusion of asset purchase and sale agreements. Smart contracts can be used to create a program that automatically executes agreements between buyers and sellers, checks the availability of goods, calculates payments, controls delivery, and ensures the resolution of disputes. All of this logic can be embedded in a smart contract and executed directly on the blockchain.

To demonstrate the principle of conditional execution of smart contracts, below is a listing of code in the C# programming language, which is popular in other programming spheres and is syntactically similar to Solidity, which is the most popular for developing applications on the Ethereum platform (Fig. 2).

In the example, the SmartContract class represents the logic of a smart contract for the sale of a product. It contains properties such as Seller (seller), Buyer (buyer), IsSold (boolean field that determines whether the product has been sold), Product (name of the product) and Price (price of the product). The Buy method simulates the process of buying a product by checking if the product has not yet been sold (IsSold). If the product has not been sold, the Buyer and IsSold properties are updated to identify a successful purchase. Otherwise, a message is displayed that the product has already been sold.

It is worth noting that this is just a simple example of a C# smart contract that simulates the process of selling a product. For real-world smart contracts, it is necessary to use specialized programming languages and tools that are supported by a specific blockchain platform, such as Ethereum.

The use of smart contracts in the business environment has the potential to change the paradigm of interaction, allowing one to automate and optimize business processes. Smart contracts open up wide opportunities for automating business processes and optimizing interaction models. They can be used to automatically execute payments, control quality, manage logistics, register contracts, etc. The use of smart contracts allows enterprises to ensure the efficiency, transparency and accuracy of the execution of agreements, minimizing risks and costs. Smart contracts allow for effective management of information and resources, ensuring the accuracy, speed and security of the execution of agreements [24].

The use of smart contracts has the potential to simplify and accelerate the interaction between government and business. They can automate the processes of registration, licensing, taxation, and delivery of government services, avoiding bureaucratic procedures and unnecessary delays. Additionally, smart contracts can help to improve transparency, clarity, and trust in the interaction between government and business, by providing automatic execution of terms without the need for manual intervention.

Smart contracts have a programmable "logic" that determines the conditions for their activation and execution. The conditions for activating a smart contract can be different, and depend on how the contract was programmed. The condition

Table 4

Advantages and disadvantages of programming languages for writing smart contracts

Programming language	Blockchain platform	Advantages	Disadvantages
Solidity	Ethereum	- broad application due to the platform's popularity; - large developer community	- need to learn the specific principles of Ethereum
Vyper		- the most secure programming language for smart contracts	- limited functionality compared to Solidity; - need to learn the specific principles of Ethereum
Michelson	Tezos	- fast code verification; - high smart contract security	- difficult to learn and understand programming language; - limited programming capabilities compared to Solidity and Vyper
Chaincode (Go)	Hyperledger Fabric	- powerful programming language with a large developer community; - large developer community	- need to learn the features of the Hyperledger Fabric platform
Cadence	Flow	- simple and easy-to-understand module-writing syntax; - focus on smart contract security	- low popularity among programmers due to the complexity of code scaling; - designed for writing applications on the Flow platform, and therefore requires a thorough study of this platform

can be related to a specific date or time when the smart contract should be activated. The condition can also be the result of other actions being performed or the state of the system at a certain point in time. For example, a smart contract can be programmed to activate after receiving a certain number of

```
using System;
public class SmartContract
{
    public string Seller { get; private set;}
    public string Buyer { get; private set;}
    public bool IsSold { get; private set;}
    public string Product { get; private set;}
    public int Price { get;private set;}
    public SmartContract(string seller, string product, int price)
    {
        Seller = seller;
        Product = product;
        Price = price;
    }
    public void Buy(string buyer)
    {
        if (!IsSold)
        {
            Buyer = buyer;
            IsSold = true;
            Console.WriteLine("The product has been successfully
            sold");
        }
        else
        {
            Console.WriteLine("The product has already been sold");
        }
    }
}
public class Program
{
    public static void Main()
    {
        string seller = "Seller_1";
        string product = "TV";
        uint price = 500;
        SmartContract contract = new SmartContract(seller, pro-
        duct, price);
        string buyer_1 = "Name_1";
        contract.Buy(buyer_1);
        string buyer_2 = "Name_2";
        contract.Buy(buyer_2);
    }
}
```

Fig. 2. A listing of code in the C# programming language

confirmations from other network participants or after reaching a certain value of certain variables in the system. When the conditions are met, the smart contract is automatically activated and executes actions, depending on the purpose of the smart contract.

Among the possible actions that a smart contract can perform are the following:

1) transfer of assets – a smart contract can have built-in logic that allows it to automatically execute a transaction from one address to another. For example, this can be used to automatically pay for services or transfer funds after certain conditions are met;

2) data storage – smart contracts can record and store data on the blockchain. This can be useful for creating decentralized databases or for recording important information that requires trust and immutability;

3) interaction with other smart contracts – a smart contract can have the functionality to launch other smart contracts. This allows for the creation of complex chains of actions, where the execution of one contract automatically triggers other contracts. Such chains can include sequential or parallel execution of different contracts;

4) contract fulfillment – a smart contract can contain conditions that need to be checked before the underlying contracts are executed. For example, the contract can check whether certain conditions have been met in external systems or whether certain pre-set parameters are met;

5) event logging – a smart contract can perform the function of logging events or transactions. This allows storing a history of interactions with the contract and creating auditable data registries;

6) access control – a smart contract can be used to manage access rights to certain resources or functionality. For example, a contract can establish rules for access to certain data or system functions.

The operation of a smart contract is similar to other transactions that are made through blockchain and are characterized by the execution of several important steps that are aimed at ensuring effective and safe interaction with this tool. Each of these steps has its own unique features and requirements that need to be considered for the successful use of a smart contract. These include:

1) requirements definition – the first step is to define all of the terms, rules, and requirements for the smart contract. This may include the terms of performance, required actions, dates, and any other important aspects of the contract;

2) smart contract development – the smart contract itself is developed on the basis of the formed requirements. This can be implemented using programming languages such as Solid-

ity (for Ethereum contracts) or other similar languages, depending on the blockchain platform in use;

3) deployment on blockchain – a smart contract must be deployed on the relevant blockchain platform. After deployment, the contract becomes available for interaction. During interaction with the contract, parties can call functions and pass parameters, which activates the execution of certain actions or conditions, specified by the contract;

4) verification and confirmation – operations performed in a contract are verified by the blockchain network. After transaction execution is confirmed, they become immutable and irreversible;

5) distribution of results – according to the terms of the contract, the results may be distributed between the parties. This may include the transfer of funds, the performance of certain actions, or assets that are transferred in accordance with the terms of the contract.

Therefore, a smart contract is an automated protocol that runs on blockchain and is based on the programming of executable actions. It sets the rules and conditions for the execution of transfers and automatically ensures their implementation. Instead of involving intermediaries, the parties can "program" their relations in a smart contract. Thus, after defining the terms and conditions of the contract, the execution of the agreement becomes a fully automated process.

Conclusion. Smart contract is an innovative algorithm developed on the basis of decentralized blockchain technology, designed to conclude and ensure the execution of commercial contracts. This concept allows one to automate the processes of concluding deals, storing data and ensuring their security using a distributed network and appropriate algorithms and encryption mechanisms. Blockchain technology provides fast and uninterrupted data transmission, which allows reducing the execution time of processes and improving communication between different parties. It also simplifies the interaction of external suppliers, customers and partners, which contributes to the rapid exchange of information and reduces delays.

Smart contracts are computer programs that contain rules that are automatically executed when certain conditions are met. This provides transparency and immutability to agreements, as any changes or transactions are recorded using cryptographic algorithms. The use of this technology can provide significant benefits in many areas, including banking, trade, real estate, and more.

Therefore, smart contracts can be a powerful tool for automating and simplifying the contracting process. However, like any new technology, smart contracts require further research and development to ensure their effective and safe use in the future.

The prospects for further research in the context of smart contracts reveal a wide range of opportunities for improving and applying this innovative technology. One of them is the development of protocols that ensure data privacy. This includes the search for new approaches to privacy management, such as combining public and private blockchain platforms or applying intelligent data masking methods. In addition, the issue of blockchain application standardization is also acute, where an important research direction is the development of standards and protocols that will allow smart contracts to interact and collaborate with other blockchain platforms. Further research may also include the study on the possibilities of integrating smart contracts with other technologies, such as artificial intelligence and the Internet of Things (IoT).

References.

1. Kaletnik, G., & Lutkovska, S. (2020). Innovative Environmental Strategy for Sustainable Development. *European Journal of Sustainable Development*, *9*(2), 89-98. https://doi.org/10.14207/ejsd.2020.v9n2p89.

2. Kaletnik, G., Honcharuk, I., & Okhota, Yu. (2020). The Waste-Free Production Development for the Energy Autonomy Formation of Ukrainian Agricultural Enterprises. *Journal of Environmental Management and Tourism*, *3*(43), 513-522. https://doi.org/10.14505/jemt.v11.3(43).02.

3. Ostrovska, H., Tsikh, H., Strutynska, I., Kinash, I., Pietukhova, O., Golovnya, O., & Shehynska, N. (2021). Building an effective model of intelligent entrepreneurship development in digital economy. *Eastern-European Journal of Enterprise Technologies*, *6*(13(114)), 49-59. https://doi.org/10.15587/1729-4061.2021.244916 .

4. Honcharuk, I., Kupchuk, I., Yaropud, V., Kravets, R., Burlaka, S., Hraniak, V., Poberezhets, Ju., & Rutkevych, V. (2022). Mathematical modeling and creation of algorithms for analyzing the ranges of the amplitude-frequency response of a vibrating rotary crusher in the software Mathcad. *Przeglad Elektrotechniczny, 98*(9), 14-20. https://doi.org/10.15199/48.2022.09.03.

5. Trachova, D., Belova, I., Stender, S., Tomchuk, O., & Danilochkina, O. (2022). Rationale for the need to use blockchain technology to record and control operations for the export of grain (the example of Ukraine). *Independent Journal of Management & Production*, *13*(3), 347-360. https://doi.org/10.14807/ijmp.v13i3.1980.

6. Zayed, N.M., Edeh, F.O., Darwish, S., Islam, K.M.A., Kryshtal, H., Nitsenko, V., & Stanislavyk, O. (2022). Human resource skill adjustment in service sector: Predicting dynamic capability in post COVID-19 work environment. *Journal of Risk and Financial Management*, *15*(9), 402. https://doi.org/10.3390/jrfm15090402 .

7. Manuilov, Ya. (2021). Use of blockchain technology in telecommunications. *Scientific notes of Taurida National V.I. Vernadsky University, series "Technical Sciences"*, *3*, 123-128. https://doi.org/10.32838/2663-5941/2021.3/20.

8. Bortnikova, M., & Chyrkova, Yu. (2022). Features of the formation and implementation of smart contracts in Ukraine. *Economic Scope*, *181*, 79-83. https://doi.org/10.32782/2224-6282/181-13.

9. Koibichuk, V., & Rozhkova, M. (2020). Research for application of blockchain technologies in the world's enterprises activity: methodical approach. *Pryazovskyi economic herald*, *4*, 118-123. https://doi.org/10.32840/2522-4263/2020-4-20.

10. Chikov, I. (2022). Digital transformation of the economy: essence, problems, features. *Entrepreneurship and Innovation*, *25*, 97-102. https://doi.org/10.32782/2415-3583/25.16.

11. Pantelieieva, N. (2018). Innovative blockchain technology in the public finance management system. *Scientific Bulletin of Uzhhorod University, Series "Economics"*, *1*, 363-369.

12. Pravdiuk, N., & Obniavko, M. (2021). Blockchain technology in accounting: advantages and disadvantages of application. *Black Sea Economic Studies*, *71*, 177-182. https://doi.org/10.32843/bses.71-28.

13. Kyrychenko, S., & Barannikov, M. (2023). Automation of the core business processes as a basis for increasing the efficiency of enterprise functioning in modern conditions. *Agrosvit*, (9-10), 106-112. https://doi.org/10.32702/2306-6792.2023.9-10.106.

14. Chikov, I., Radko, V., Marshalok, M., Tepliuk, M., Petrenko, O., Sharko, I., & Sitkovska, A. (2022). Economic development of agricultural food enterprises on an innovative basis. *Financial and credit activities: problems of theory and practice*, *1*(42), 98-106. https://doi.org/10.55643/fcaptp.1.42.2022.3672.

15. Rossokha, V., & Bocharov, P. (2019). Using the "blockchain" technology in political marketing. *Herald of Khmelnytskyi national university. Economic sciences*, *5*, 211-215. https://doi.org/10.31891/2307-5740-2019-274-5-213-217.

16. Tyshchenko, O., Humen, T., & Trapezon, K. (2019). Investigation of the characteristics of blockchain technology in data transmission information systems. *Scientific notes of Taurida National V.I. Vernadsky University, series "Technical Sciences"*, *2*, 77-81.

17. Bondarenko, L., Moroz, N., & Lashchyk, I. (2019). Functional features of blockchaine technology implementation in the financial sector. *Investytsiyi: praktyka ta dosvid*, *3*, 21-25. https://doi.org/10.32702/2306-6814.2019.3.21.

18. Rossokha, V., & Petrychenko, O. (2019). Formation of contractual relations in the dairy industry on the principles of smart contracts and blockchain technology. *Innovative economy*, (3-4), 133-140.

19. Zayed, N.M., Mohamed, I.S., Islam, K.M.A., Perevozova, I., Nitsenko, V., & Morozova, O. (2022). Factors Influencing the Financial Situation and Management of Small and Medium Enterprises. *Journal of Risk and Financial Management*, *15*, 554. https://doi.org/10.3390/jrfm15120554.

20. Mironova, N., Koptieva, H., Liganenko, I., Sakun, A., & Chernyak, D. (2022). Modeling the selection of innovative strategy for development of industrial enterprises. *WSEAS Transactions on Business and Economics*, *19*, 278-291. https://doi.org/10.37394/23207.2022.19.26.

21. Yuldashev, O. K., Khomiachenko, S. I., & Yuldashev, S. O. (2022). Organizational and Legal Model of Competency-Based Education as a Means of the Transition to Innovative Economy. *Danube*, *13*(2), 107-118. https://doi.org/10.2478/danb-2022-0007.
22. Sytnyk, H. P., Zubchyk, O. A., & Orel, M. H. (2022). Conceptual Understanding of the Peculiarities of Managing Innovation-Driven Development of the State in the Current Conditions. *Science and Innovation*, *18*(2), 3-15. https://doi.org/10.15407/scine18.02.003.
23. Kalina, I., Khurdei, V., Shevchuk, V., Vlasiuk, T., & Leonidov, I. (2022). Introduction of a corporate security risk management system: The experience of Poland. *Journal of Risk and Financial Management*, *15*(8). https://doi.org/10.3390/jrfm15080335.
24. Semenets-Orlova, I., Rodchenko, L., Chernenko, I., Druz, O., Rudenko, M., & Poliuliakh, R. (2022). Requests for Public Information in the State Administration in Situations of Military Operations. *Anuario De La Facultad De Derecho.Universidad De Extremadura, 38*, 249-270. https://doi.org/10.17398/2695-7728.38.249.

Смарт-контракти та автоматизація бізнес-процесів: технічний аспект

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Мета. Провести аналіз процесу впровадження смарт-контрактів для автоматизації бізнес-процесів, спрямованих на досягнення високої надійності й кібербезпеки під час виконання угод, оптимізацію транзакційних витрат і максимізацію продуктивності внутрішніх операцій підприємства.

Методика. Результати дослідження отримані із використанням спеціальних і загальних методів наукового пізнання, а саме дескриптивного, порівняльного, стратегічного аналізу, абстрактно-логічного та узагальнення.

Результати. У процесі дослідження розкрито потенціал смарт-контрактів на базі блокчейн-технології для підвищення ефективності бізнес-процесів, зниження витрат і забезпечення інноваційного розвитку в українському бізнес-середовищі.

Наукова новизна. Проведено комплексний аналіз технічних аспектів використання смарт-контрактів на основі блокчейн-технології для автоматизації бізнес-процесів; оцінено їх вплив на бізнес-середовище; здійснено порівняння популярних мов програмування та блокчейн-платформ для розробки й розгортання смарт-контрактів; проведено SWOT-аналіз упровадження смарт-контрактів на українських підприємствах, що відкриває перспективи для інноваційних підходів до бізнес-практик та їх оптимізації.

Практична значимість. Результати дослідження можуть використовуватися для розробки та впровадження інноваційних стратегій у бізнес-середовищі на основі інтеграції смарт-контрактів на базі технології блокчейн із метою підвищення ефективності функціонування бізнес-процесів.

Ключові слова: *смарт-контракти, автоматизація, бізнес-процеси, блокчейн, лістинг, SWOT-аналіз*

The manuscript was submitted 04.06.23.