

The study addressed the problem of developing a mechanism for introducing blockchain technology into the system of accounting and analytical support for public sector entities.

In the course of the research, the volumes and types of financial violations by public sector entities were analyzed. Identified violations were committed by public sector entities, and their significant share fell on the system of accounting and analytical support, in particular, financial reporting, budget execution. Legal restrictions on the introduction of blockchain technology for public sector entities were outlined. The absence of a number of acts in the field of digitization, protection of state secrets, cyber security, international standards, etc. in the legal field was established. The characteristics and mechanisms of blockchain technology were described, the types of blockchains based on permission models (open, closed) were defined. The technological characteristics of the use of blockchain platforms in the system of accounting and analytical support of public sector entities have been determined. The need to use blockchain applications such as smart contracts was indicated. It is noted that the use of smart contracts can be developed on blockchain platforms such as Ethereum, NXT, and Hyperledger; their key characteristics were described. A comparative description of transactions of state funds in the traditional accounting system and with the use of blockchain systems is given. The problem of the materiality of the transaction cost when transferring large volumes of data was outlined using the Ethereum platform as an example; its shortcomings were identified. The development of a mechanism for introducing blockchain technology into the system of accounting and analytical support using the Hyperledger platform, which has an open-source community focused on the development of a set of stable frameworks, tools, and libraries for deploying enterprise-level blockchains, was described. The advantages and disadvantages of introducing blockchain technology into the system of accounting and analytical support have been determined

Keywords: accounting and analytical support, information technologies, blockchain, transactions, smart contracts, public sector

IMPLEMENTATION OF BLOCKCHAIN TECHNOLOGY IN THE SYSTEM OF ACCOUNTING AND ANALYTICAL SUPPORT FOR THE PUBLIC SECTOR

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1. Introduction

Accounting information systems are open systems that depend on the environment in which they operate. Therefore, accounting information systems should work continuously and constantly use advanced technologies that are related to the nature of their work. Taking into account the numerous changes taking place in the IT environment, the expansion of its application and use in the accounting data system, it is necessary to investigate the possibility of introducing advanced technologies into the mechanism of accounting and analytical support.

Blockchain technology can be highlighted among the latest developments in the field of information technology.

Unlike traditional document management methods, blockchain provides a more efficient way to represent billing, documentation, processing, accounting, inventory, and payment systems. The technology allows institutions to simultaneously record transaction data in the general ledger in

real time. In the future, the need for traditional double-entry bookkeeping may disappear, provided it is fully automated. Blockchain technology has great potential to fundamentally change the profession of accountants and analysts.

One of the key elements of the effective activity of a business entity within the framework of a fraud prevention program is the assessment of the risk of fraud. It should be noted that the risk of fraud is always increased in an environment that is not effectively controlled, and that the use of standard verification methods alone is not sufficient to detect fraud.

Attention should be paid to fraud in financial reporting, which usually causes greater financial losses and has a negative impact on external users [1]. As this research has shown, the issue of detecting and eradicating fraud is relevant today, especially for the public sector. The analysis of average monthly losses of subjects from various types of economic fraud, shown in Fig.1, reveals that the biggest losses of the institution are caused by frauds that occur in the finance

and accounting department (20 %), where one of the types of fraud is the falsification of financial statements (11 %).

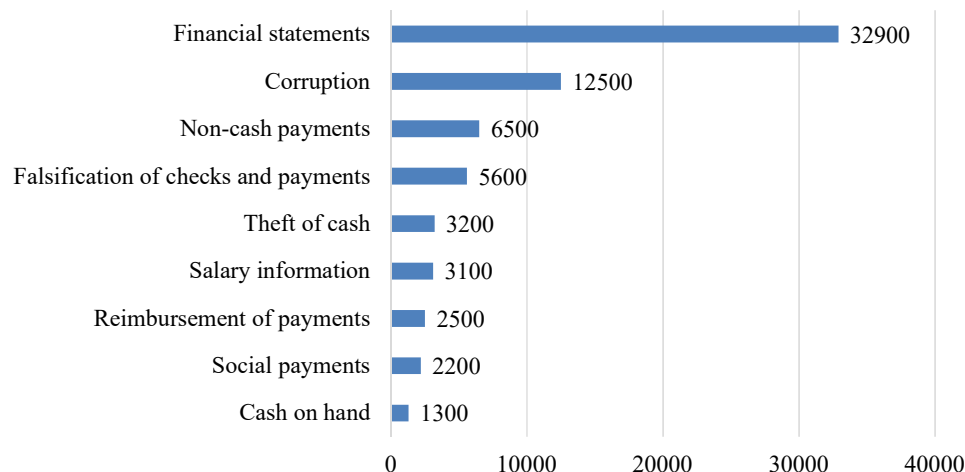


Fig. 1. Average monthly losses of institutions from various types of economic fraud, USD
 Source: systematized by the author based on Report to the Nation [2]

Innovative technologies, such as blockchain and others, can correct fraud investigations, warn about financial violations, misappropriation of public funds, and display reliable data in the accounting and analytical support system of the public sector. The use of blockchain technology has become a real revolution in working with financial data, which requires studying, knowing its impact and benefiting from the operation of accounting information systems in the modern IT environment

In most countries of the world, in the public sector, information systems are assigned the role of means of ensuring the openness of public information and public procurement. However, it is necessary to introduce innovative technologies, such as blockchain technology, to ensure the transparency of transactions of public funds, their distribution, redistribution, and effective use in accordance with their intended purpose.

Thus, the chosen research topic is extremely relevant and involves conducting a study on the feasibility of introducing blockchain technology into the system of accounting and analytical support for public sector entities.

2. Literature review and problem statement

In the work, it is important to study the experience of introducing blockchain technology in the business sector, which made a significant contribution to the computerization of the accounting and analytical support system. The impact of improving the efficiency of their activities, improving customer service, providing services, reducing budgets with the help of blockchain is determined to be significant. The most successful models are the Canadian PayPie project, which is being developed by such international companies as Microsoft, Citrix, Bosch, IBM, Deloitte, KPMG, Bank of America [3].

Paper [4] predicts the transformation of accounting through the introduction of blockchain. The authors argue that blockchain technology will impact the database mechanisms of accounting information systems by digitizing current paper-based verification processes. The implementation

of blockchain technology in accounting information systems will reduce the number of errors, reduce the costs of confirming and tracking transactions, and the immutability of technical data will reduce the potential for fraud.

The authors of [5] conducted a study on the adoption and implementation of blockchain technology in accounting practice, identifying advantages and some threats, which allowed them to identify new risks and future challenges.

It is shown that the public sector has also become a field of application of blockchain technology. According to the European Blockchain Observatory, as of November 2020, more than two hundred use cases were registered in the

public sector worldwide [6]. Blockchain technology has been found to be used for transparency in government services, including payments, land registration, health care, education, social services, identity management, taxation, etc.

But the issues related to ensuring the transparency of the movement of state funds, their distribution, redistribution, effective management of state finances by public sector entities remained unresolved. The reason for this may be problems related to the imperfection of state regulation in the field of digitalization, accounting, control, and transparent management of public finances [7].

Numerous studies on the use of blockchain technology in the public sector solved specific problems, the main focus was on increasing the transparency of certain public services, public procurement, etc. [8]. The lack of a general concept of effective management of state finances, the formation of an information base in the system of accounting and analytical support actualizes the introduction of advanced technologies, namely blockchain technology.

Numerous studies have emphasized the importance of implementing blockchain technology for public finance management [9] but practical implementation of the solution to this problem has not been achieved.

The introduction of blockchain technology into the accounting and analysis system will ensure the transparency of the use of public funds, the traceability of public payments between public sector entities, and their intended purpose. Blockchain technology fundamentally changes the rules of accounting as it ensures the integrity of records, providing access to a complete cycle of all economic transactions without the possibility of corrections. Innovative blockchain technology will help build an accounting ecosystem that will ensure transparency of all transactions conducted by public sector institutions.

3. The aim and objectives of the study

The purpose of our work is to develop a mechanism for introducing blockchain technology into the system of accounting and analytical support for the public sector. This

will make it possible to build a single information and analytical database of the full cycle of the movement of public funds between public sector entities.

To achieve the goal, the following tasks were set:

- to analyze the volumes and types of financial violations by public sector entities in the system of accounting and analytical support (the sample is given on the example of Ukraine);
- to outline legal restrictions and ways of solving the introduction of a unified information technology system for public sector entities;
- to describe the general characteristics and mechanism of operation of blockchain technology in the system of accounting and analytical support;
- to determine the technological characteristics of the use of blockchain platforms in the system of accounting and analytical support of public sector entities;
- to determine the advantages and disadvantages of introducing blockchain technology in the system of accounting and analytical support;
- to determine the possibilities of using the blockchain and their potential impact on the system of accounting and analytical transactions of state funds.

4. The study materials and methods

The object of this study is the accounting and analytical support of public sector entities.

The research hypothesis assumes that the introduction of blockchain technology will make it possible to build a single information and analytical database of the full cycle of the movement of public funds between public sector entities.

The introduction of blockchain technology into the system of accounting and analytical support is evidence of a serious transformational potential in the control of financial flows between public sector institutions. There are reasons to assume that blockchain technology will become one of the most important components of digitalization owing to innovations that will bring the development of the accounting and analysis system to a fundamentally new level.

In the research process, the necessity and mechanism of introducing blockchain technology into the system of accounting and analytical support for the public sector is substantiated.

A set of general scientific methods of cognition was used to conduct the research. The theoretical analysis, comparison, generalization, and synthesis methods were used in the study of the theoretical provisions and current state of the blockchain and its application in the system of accounting and analytical support, justification of the feasibility of using this technology in the activities of public sector entities. Attention is paid to the analysis of the volumes and types of financial violations in the accounting and financial reporting system. A comparison of the use of blockchain technology with the traditional accounting system is made, the advantages of

introducing blockchain technology into the accounting and analytical support system are substantiated. Owing to the use of analysis methods in the study of smart contracts as a blockchain application, their main functions and prospects for use in the accounting and analytical support system were studied. A comparison of blockchain platforms, such as Ethereum, NXT, and Hyperledger Fabric, was performed, the distinguishing features of different types of blockchain and their practical application were determined. The use of methods of generalization and synthesis made it possible to justify the impracticality of using the Ethereum platform while the Hyperledger platform is preferred.

5. Results of investigating the mechanism of introduction of blockchain technology into the system of accounting and analytical support for the public sector

5.1. Analysis of volumes and types of financial violations by public sector entities in the system of accounting and analytical support

The volumes and types of financial violations by public sector entities were analyzed using the example of Ukraine. Last year, the Accounting Chamber inspected 355 objects, as a result of which 39 reports/conclusions were approved. The volume of public finances audited by the Accounting Chamber in 2022 amounted to EUR 9.2 billion. Financial violations related to misuse of budget funds and deficiencies in the amount of 1.5 billion euros were revealed [10].

The most significant number of violations were found in the system of accounting and analytical support, in particular during the preparation and submission of reports, violations during the formation and execution of state and local budgets, as well as violations during the implementation of public procurement (Fig. 2).

32,619 violations of budget legislation committed by managers and recipients of state and local budget funds for a total amount of 6,565.1 million euros were prevented [12].

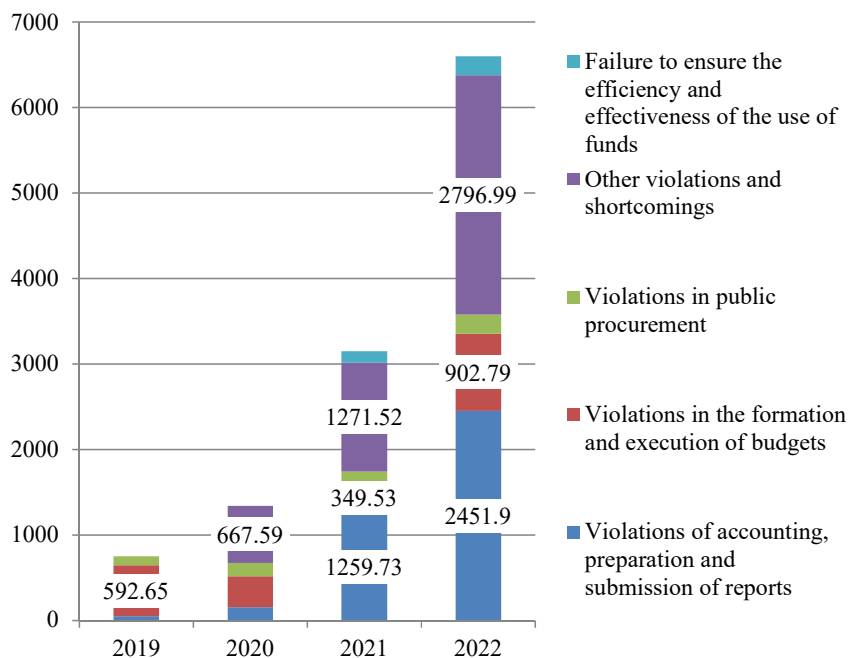


Fig. 2. Identified violations according to unified classification features, 2019–2022, UAH million [11]

Financial violations were committed by public sector entities, in particular, bodies of executive power, local self-government, management of state extrabudgetary funds, and unitary enterprises (Fig. 3). Thus, there is a need to form a set of measures to prevent violations that would correspond to the specifics of the functioning of state entities.

Based on the results of the analysis of the detected violations, it was established that a significant share of them annually falls on the system of accounting and analytical support for financial reporting and budget execution.

Thus, in order to increase the transparency of the management of state funds, it is proposed to carry out measures to unify all databases. This can be implemented by introducing a unified information technology system with the aim of automating accounting and analytical procedures, treasury service of budget execution and targeted use of state funds. Such measures will ensure real-time monitoring of the flow of state and local budget funds, assessment of budget liabilities, accounting, and analysis of expenditures according to their intended purpose.

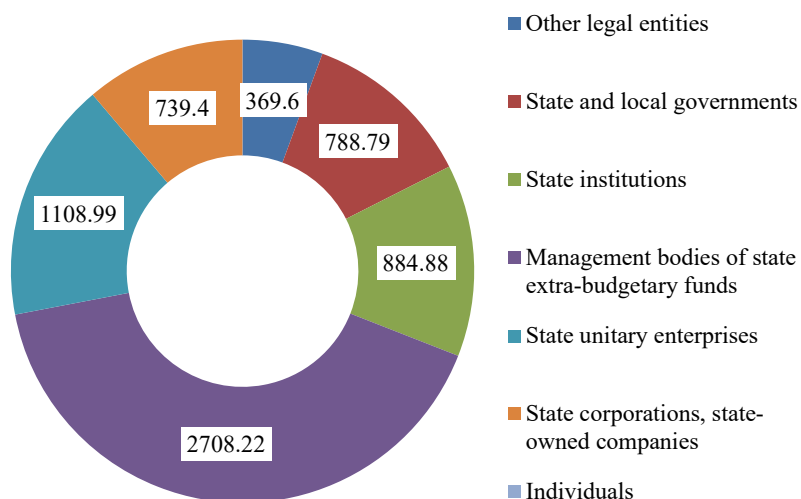


Fig. 3. Amounts of detected violations by types of control objects for 2022, UAH million [13]

5.2. Determination of legal restrictions on the introduction of a single information technology system for public sector entities

First of all, when implementing a unified information technology system, public sector entities will face legal restrictions, namely the absence of a number of acts in the field of digitization in the legal field. There is a need to comply with the legislation in the field of protection of state secrets, international standards in the area of combating money laundering and financing of terrorism (hereinafter – CML/FT), currency regulation, transparency of financial reporting, etc.

Legal restrictions related to compliance with legislation in the field of state secrets can be resolved by bringing the technological characteristics of distributed registers into line with the regulations in this field [14]. That is, the very functionality of the state distributed register, namely the exclusive type with restrictions on access to network information, can be considered as one of the tools of the state secret protection system. Cash flows that may constitute a state secret in the military sector, in the fields of economy, science and technology, in the field of foreign policy, as well as in intelligence, counterintelligence and operational-research activities will be cryptographically protected. In the case of protection of

state secrets during the transition to an improved system of accounting and analysis, the security mechanism will work similarly. The main difference is only that the authorized state bodies will be able to gain access not to the financial statements of a separate state institution but to a whole chain of blocks in which all counterparties are marked [15].

With regard to international aspects, it is necessary to ensure the operation of the state platform in accordance with all standards and recommendations in the field of CML/FT, currency regulation.

5.3. General characteristics and mechanism of operation of blockchain technology in the system of accounting and analytical support

Blockchain provides a transaction model based on the collective knowledge and trust of the participants themselves, without intermediaries, allowing all participants to view the information available to them, which not only gives legitimacy to the transaction, but also allows for the verification and recording of the transaction.

Each block has a digital signature of its owner and contains relevant transaction data, a timestamp, and a hash of the previous block, which connects all the blocks that make up the chain.

It is important to understand how the algorithm that creates the hash of each block works. Regardless of the content of the data, the algorithm applies a mathematical function that converts this content into a 256-bit hash. This hash has two very important characteristics: non-iterativeness and uniqueness of the fingerprint. If there are changes in the data, the result of the algorithm will also change, and therefore the prints will be different, as illustrated in Fig. 4.

Since the hash of the previous block is added to each block of data before the hash of the previous block is calculated, the hash of the previous block cannot be changed either. Thus, each block is connected to the previous block. This iteration is performed systematically over a period of time, resulting in successive generation of linked blocks identified by sequence numbers. To establish control over the ownership of digital assets and prevent the risk of double spending, each block also records a transaction date, which determines which transaction occurred first.

The blockchain operating model involves many participants, each of which can store and exchange information from blocks in the network, called nodes. These actors can work simultaneously with virtually no coordination, and they do not need to be identified because messages are not directed to a specific location. This creates a decentralized network without intermediaries, which increases the reliability of the model. However, since these blocks are copied between different nodes, changing a completed block theoretically requires the changes to be applied to all members of the network.

The use of hashing algorithms makes it extremely difficult for an attacker to falsify data. This is because an attacker must control a significant portion of the network's computing power to defeat the accumulated power of honest nodes, which is possible if these nodes are limited or extremely vulnerable. (In cyber security jargon, this phenomenon is called a "sybil attack") [17].

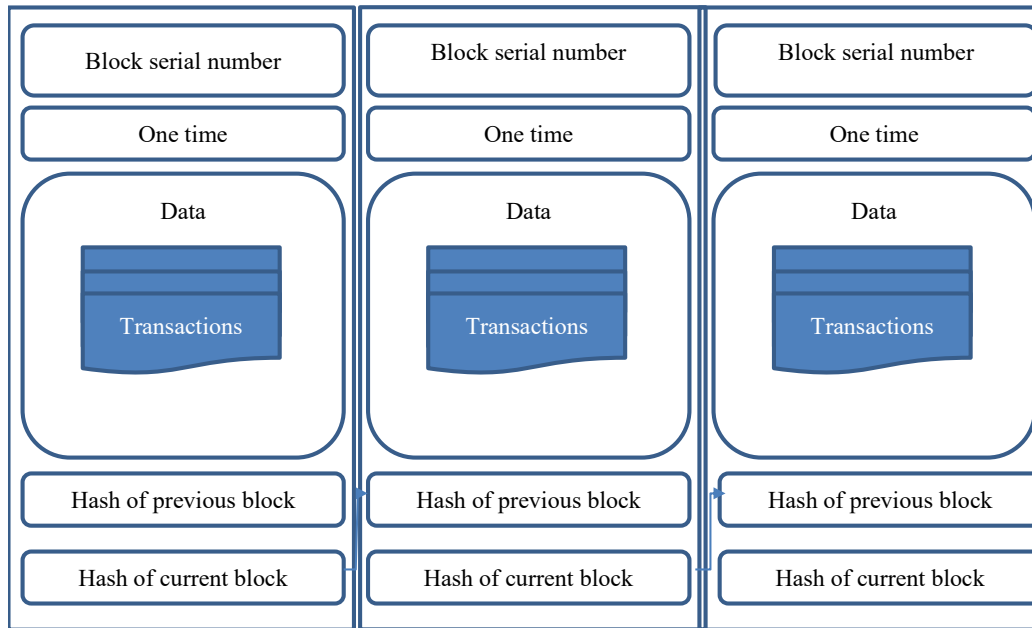


Fig. 4. Mechanism of operation of blockchain technology [16]

A blockchain is “open” if all nodes in the chain can freely view the information. A blockchain is “closed” if a node requires authentication to read the block. Nodes participating in the blockchain can read, write, and transact according to their authority.

Table 1 describes the types of blockchains based on permission models.

Blockchain types based on permission models

Permit type		Possibilities		
		Read	Write	Implement
Open	Public without permission	All participants	All participants	All participants (requires high computing power)
	Public permission	All participants	Authorized members	All members or authorized members
Closed	Consortium	Authorized members	Authorized members	Authorized members
	Private permission	Private participants	Network (admin only)	Network administrator

Source: [18]

The main characteristics of blockchain are decentralization, openness, traceability, protection from third party interference, security, data reliability and anonymity. The system uses peer-to-peer (P2P) network technology, which means there is no centralized control center. Every node in the network has equal status, and all nodes record and store transaction data. The openness of the blockchain system means that anyone can request access to information via a hash value in the blockchain header. The information system is not stored in one place, and the keys are distributed among computers. This ensures system security and minimizes the risk of data leakage. To make changes to the information, it is necessary to make an entry in the next block, but other users must confirm this operation. Traceability means that records added to the blockchain are permanently stored in the system and that each transaction record contains data about the trader. You can fully trace the route of the subject of the transaction.

Blockchain technology encrypts data using asymmetric cryptography and uses consensus algorithms to protect against external attacks, thus ensuring security and preventing information forgery. Alert schemes can be built into the blockchain to detect unverified transactions in a timely manner or to monitor the financial status of an organization and help decision-makers develop new control mechanisms [19].

Table 1

Therefore, consensus algorithms will allow each member of the group to make and support joint decisions. Consensus is necessary to ensure fairness and equality in the blockchain. The first algorithm used in the Bitcoin network, called “Proof of Work” (PoW), involves solving a very complex mathematical puzzle, which, after solving, is very easy to repeat on the rest of the nodes. In particular, PoW is a very useful consensus algorithm but it does not require significant computing power (hardware) to run in a reasonable amount of time, making it inconvenient for chains with high transaction rates and short transaction times. Therefore, to solve these problems, various consensus algorithms have been developed, mainly using private networks, to reduce the complexity and reduce the required computing power and time [20].

5. 4. Determination of the technological characteristics of the use of blockchain platforms in the system of accounting and analytical support of public sector entities

Accounting and analytical information about transactions of state funds, goods, and services must be displayed in a single database of the information technology system.

Blockchain applications such as smart contracts deserve special attention. Based on blockchain technology, a computer protocol was created that makes it possible to enter transactions and control their execution using mathematical algorithms. It acts as a constructor that makes it possible to create smart contracts. New smart contracts are placed on the blockchain by calling the constructor function via a transaction. The sender of this request becomes the owner of the smart contract and only he can call this function to

destroy the contract. Some functions call other smart contracts. Each smart contract contains states (a variable that stores the address where certain data resides) or a smart contract (the owner’s wallet address). There are two types of states: persistent states, which can never be changed, and writable states, which store states in the blockchain. This is a piece of code that makes it possible to read information and change state [21].

When entering into a smart contract, each party prescribes the terms of the transaction, penalties for non-performance, and their digital signatures. The smart contract makes or fulfills the terms and decides whether to close the deal, fine the participants, or close access to the assets. This type of transactional contract is stored, duplicated, and updated on distributed blockchains. In the case of traditional contracts, they must be centrally executed by a trusted third party, which involves late execution and additional costs. Companies that implement blockchain with smart contracts can improve compliance and risk management. They can be developed and deployed on blockchain platforms such as Ethereum, NXT, and Hyperledger Fabric.

The characteristics of the mentioned blockchain platforms are summarized in Table 2.

Table 2

Key features of Ethereum, NXT and Hyperledger Fabric blockchain platforms

Name of the blockchain platform	Characteristic
Ethereum	A virtual machine called the Ethereum Virtual Machine (EVM) is used to support advanced and personalized smart contracts. The Solidity programming language is used to write smart contracts, which fully complies with the Turing principle, and the contract code is compiled into EVM bytecode and deployed on the blockchain for execution. The record of an Ethereum smart contract consists of its code, the contract address, the state, which consists of a private storage, and the balance of virtual coins (ether). Smart contracts cannot be changed after being placed on the blockchain, in particular developers must include security guarantees in their coding
NXT	The platform contains a set of active smart contracts. However, it is not Turing complete, so only existing templates can be used, and personalized smart contracts cannot
Hyperledger Fabric	The Hyperledger Fabric architecture supports a wide range of enterprise use cases with plug-and-play components. The transaction is executed by a specific executor and signed only by network participants. Upon receiving a transaction request, each member of the network executes the transaction independently by calling the chain code referenced by the transaction

Source: [22]

It should be noted that the Ethereum platform is the first and most popular blockchain platform for developing smart contracts. NXT is an open source blockchain platform based entirely on a consensus protocol. Hyperledger Fabric is enabled by groups of organizations that can join its membership provider.

The largest blockchain platforms are Ethereum and Hyperledger Fabric, which differ from each other in many parameters. For example, Hyperledger Fabric supports programming languages such as Go, Java, and JavaScript. To execute a transaction in Ethereum, a code is included in the transaction that is distributed in the peer-to-peer network, and the participant who received the transaction can execute it on a local virtual machine. In Hyperledger Fabric, a transaction is executed by a specific executed and signed only by network participants.

A comparison of money transfers in accounting and blockchain systems is as follows. In a traditional money transfer system, the sender initiates a transfer request to an intermediary (in this case, a bank or treasury). Next, the bank checks the legitimacy of the request, the availability of funds, and the transaction limit. If the bank or treasury approves the request, the funds are transferred from the sender to the recipient. The sending bank (Treasury) records the transaction in its accounting records and notifies the sender. The recipient’s bank registers the transfer in its books and informs the recipient about it. It should be noted that the use of intermediaries may result in delays in the execution of transactions, as well as errors or discrepancies in the registration pages. The part illustrates the execution of the first transaction using the blockchain. In this system, the person who wants to transfer value creates an encrypted message. The message contains information about the amount and the recipient’s network address and is then distributed throughout the network. Users can verify the authenticity of the message by comparing the amount with the sender’s last balance recorded in the blockchain. After checking the message, the transaction is completed.

Blockchain has proven efficient in working with financial data. Blockchain has the potential to transform the accounting profession and change business systems. Some experts believe that its implementation in accounting will endanger employment and have a negative impact on cyber security, financial planning, and analysis [23]. On the other hand, the main function of accountants and analysts is shifting from the usual filling of documents and entering data about operations into information systems to independent formulation of business decisions.

Accountants can perform analytical procedures in real time, check data, participate in inspections, enter data into the information infrastructure, spend less time recording events, prepare their own professional judgment, explain the economic content of operations, spend more time on the correctness of the display of transactions in accounting and reporting. To achieve this, accountants need to improve their qualifications and be professional analysts who know how to implement economic processes in the organization.

To avoid keeping separate records of transactions, companies can record them simultaneously in a single block of records, thus creating an interconnected system of records. Also, since all records are decentralized and cryptographically protected, they are less likely to be destroyed or tampered with by covert actions. In the accounting system using the blockchain platform, there is an opportunity to reduce the number of errors, perform accounting functions automatically and increase the efficiency of accountants, making accounting less costly and its correctness less verified.

Despite all the advantages that blockchain offers, the technology has a serious problem, significant costs when transferring large volumes of data. Basic summaries of information may not give the end user a complete picture of the situation. Excessively detailed descriptions also increase the complexity of information and lead to additional costs for its storage.

The problem described above can be illustrated using the example of the Ethereum network. Assuming that the description of one data block, which stores data about payment transactions at a certain stage of product development, requires approximately 2,500 characters (that's about half of an A4 sheet of Times New Roman font). Text, for example, is encoded in UTF-8, the Universal Character Encoding Standard (Unicode), and uses the Latin alphabet (representing English characters) or the Cyrillic alphabet, requiring no more than 2 bytes per character or 5000 bytes for the entire text.

In the Ethereum system, one word is 32 bytes in size, so 157 words are needed to store 5000 bytes. To simplify calculations, it can be assumed that the number of characters in each word is different from zero. According to [24], storing one word (Gsset operation) requires 20,000 gas. Every transaction in Ethereum requires computing resources, and therefore every transaction requires a fee. Gas is the fee required to successfully complete a transaction in Ethereum [25].

This means that 157 save operations need to be called and used, requiring 20,000 gas for each operation. The total cost of gas is as follows:

$$\begin{aligned} \text{Total gas consumption} &= \\ &= Gsset * k - \text{number of words} = \\ &= 20000 * 157 = 3140000. \end{aligned}$$

According to calculations, one block of data requires 3,140,000 gas per transaction. At the time of writing, the price of 1 ETH is USD 2,675. And the average price of one gas is 66 Gwei, or 0.000000066 ETH. Thus, the cost of storing one block of data in USD is as follows:

$$\begin{aligned} \text{Total cost} &= \text{total cost gas} \times \\ &\times \text{average price for 1 gas} = 3140000 * 10^{-9} = \\ &= 0.20724 \text{ ETH} * 2675 \text{ USD} = 554.37 \text{ USD}. \end{aligned}$$

Based on the calculations above, it will take USD 554.37 and approximately 1274 seconds, or 22 minutes, to add a block to the Ethereum blockchain. It is also worth noting that gas prices are volatile and the Ethereum exchange rate is highly volatile. Under such conditions, as with any continuous production process in an institution, the feasibility of storing large amounts of data is questionable.

One way to solve this problem is to create a blockchain that is not based on Ethereum. The implementation of the "own" system of adding data to the blockchain will allow

us to abstract from the capabilities of Ethereum and use the company's nodes to calculate data. However, this approach has additional costs.

Therefore, the use of the blockchain platform in the system of accounting and analytical support is impractical.

It should be noted that in 2016, the Linux Foundation founded Hyperledger, an open-source community focused on developing a stable framework, tools, and libraries for enterprise-level blockchain deployments. It is a global collaboration that spans finance, government, banking, supply chains, manufacturing, and technology. Within this framework, supported by the Linux operating system, data stored on the blockchain, tools have been developed to manage privacy. The channel approach deserves special attention, according to which a node can access information only in the channel to which it belongs or to which it has access rights. Fig. 5 illustrates this architecture and how information privacy is protected from other nodes outside the channel by distributing blocks only among nodes belonging to the same channel.

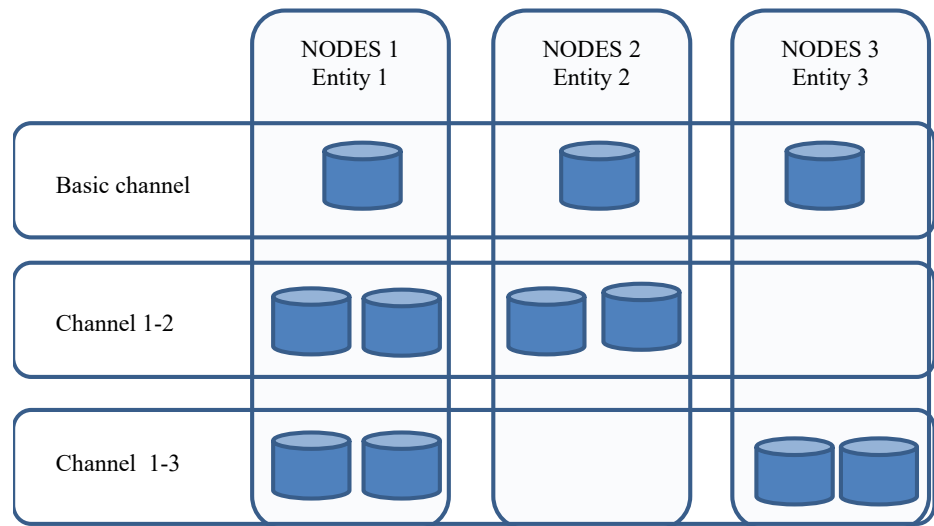


Fig. 5. The mechanism of operation of the Hyperledger Fabric blockchain platform
Source: [26]

In the same year, Walmart developed a proof-of-concept project using the Hyperledger platform to analyze the advantages of the technology in the accounting system. Where "traditional" accounting tools took weeks to find transactional errors in the food procurement process, blockchain has made it possible to do so in a matter of minutes, depending on the number of nodes and the complexity of the product's value chain.

5.5. Advantages and disadvantages of introducing blockchain technology in the system of accounting and analytical support

Blockchain technology offers significant opportunities to significantly improve the country's public and economic sectors. Countries that are at the stage of digital development need to pay attention to all the features of the digitalization process, taking into account both positive and negative aspects (Table 3).

Thus, blockchain has the potential to fundamentally change the country's economy, increase the efficiency and security of financial transactions, particularly in the public sector.

Table 3

Advantages and disadvantages of introducing blockchain technology in the system of accounting and analytical support

Advantages	Drawbacks
<ul style="list-style-type: none"> - avoiding deliberate manipulations and errors in calculations; <ul style="list-style-type: none"> - reduction of costs for accounting and analysis; - increasing the working capital of the company; - simplification of international operations and transactions; <ul style="list-style-type: none"> - emergence of a new class of assets - digital property; - reliable and up-to-date accounting reporting, i.e., more transparent, and less time-consuming; - the evolution of the role and functions of accountants and analysts in companies and the growth of their expertise; - quick online response, provision of reliable and open information about transactions; <ul style="list-style-type: none"> - the ability to manage transactions from any device; - ensuring information transparency and reducing the number of accounting errors. <ul style="list-style-type: none"> - automated processing and storage of documents; - ensuring transparency of information; automation of document processing and storage; <ul style="list-style-type: none"> - reduction of risks; - protection of information against fraud, loss, and destruction; - ensuring close cooperation and mutual relations with debtors and creditors; <ul style="list-style-type: none"> - creation of new opportunities and models; - focusing on operations with high added value; - the ability to monitor, analyze, edit, and report in real time; - increasing the speed of access to information, its completeness, evidence and saving time; - promote the emergence of new types of accounting and analytical services; - integrate different levels of accounting, create a single database, and synchronize accounting records 	<ul style="list-style-type: none"> - a description of the legal framework and transaction regulation standards reflected in blockchain technology; - the need to transfer all commercial transactions to a virtual environment, which is not always possible; - lack of understanding of technology, lack of acceptance by employees, low qualification of accountants and analysts; <ul style="list-style-type: none"> - change of business processes at enterprises; - the need to invest in the purchase of equipment and its capital repair, introduction and development of technology, training of personnel, etc.; - the need to integrate existing accounting systems with blockchain technology; - irreversibility of operations, increase in information volumes and media overload, where it is practically impossible to make changes in case of incorrect data entry; - technical problems (low bandwidth, 51 % threat of attacks); - the level of privacy and confidentiality of data related to the institution's activities; - the impossibility of accurately measuring the benefits at the blockchain implementation stage; <ul style="list-style-type: none"> - experience of successful application in other companies; - immaturity; - a large amount of misinformation about blockchain technology; <ul style="list-style-type: none"> - issues of cyber security; - high energy consumption, damage to the environment; - statements about legal responsibility for maintenance of distributed databases; - statement of legal responsibility for database maintenance

Source: [27]

5. 6. Possibilities of using blockchain and their potential impact on the system of accounting and analytical transactions of state funds

Each transaction with state funds in the system of accounting and analytical support starts hundreds of processes, which, after completion, are registered in the system of each participant. Throughout the supply chain, this data is replicated in each member's system, where it is often re-entered into the new system. An estimated 75 % of exporters re-enter data into the system and submit paper documentation to relevant trade authorities (IDB, 2020). The existence of numerous records often leads to errors, delays in information, delays, inefficiencies, fraud.

Given that blockchain contains a single version of data that is shared and verifiable, proper implementation of this technology can ensure the same information for all participants, reducing the use of paper (paperless transactions), time, cost, and complexity of communication between multiple parties. This can reduce the amount of time, cost, and complexity of communication between different parties. In addition, the use of advanced cryptographic methods (data in the blockchain is not encrypted by default) in addition to encrypted electronic communication between parties when storing information in the blockchain can provide a more secure service that can track and analyze data dynamics [28].

Five general cases of blockchain use and their potential impact on the accounting system of transactions of public funds are summarized, as shown in Table 4.

Therefore, the proper implementation of blockchain can improve the efficiency and security of the accounting of operations related to transactions of public funds. This technology has the potential for important changes in the system of accounting and analytical support, in particular, payment

operations (transactions) between public sector entities. In particular, it will lead to the ability to track the movement of public funds across blocks, starting with the blockchain, to ensure data integrity and purpose – determining ownership of assets and completion of a particular transaction – through a single system using a shared ledger.

Table 4

The possibilities of using blockchain and their potential impact on the accounting system of transactions of public funds

Possibilities of use	Potential impact on the accounting system in the public sector
The origin of the transaction of state funds and their traceability	It will offer advantages and greater accuracy in the management of transactions of public funds, reducing the risks of fraud and counterfeiting
Streamlining of business operations	It will facilitate secure information exchange, will facilitate secure paperless transaction
Automation and smart contracts	Increase transaction efficiency through faster processes and lower administrative costs
State funding	It will make public financing simpler and more transparent, especially in terms of efficiency and security of processes
Facilitating the detection of discriminatory measures	It will encourage transactions of public funds to be made more transparent and ethical

Source: summarized by the author based on [29]

Based on these characteristics, it is expected that the accounting system for transactions with public funds will soon change and include new programs, technologies, and services to meet the increasingly complex requirements for security, traceability, and transparency of public funds management.

6. Discussion of results of determining the mechanisms of introducing blockchain technology into the system of accounting and analytical support

In order to make a comprehensive justification for the use of blockchain technology in the system of accounting and analytical support, it is important to note the limitations and prospects of the introduction of this modern technology.

Blockchain technology is widespread in the accounting and analysis system. However, experience is limited to proof-of-concept and blockchain adoption initiatives, which cover only a small fraction of real-world public sector volumes.

The lack of a comprehensive analysis of the features and requirements for the implementation of blockchain technology can lead to erroneous conclusions. One of the factors restraining the use of blockchain technology in the system of accounting and analytical support is the need, for reasons of transparency, to create a number of specific and ideal conditions for the use of this technology. For example, the technology is not responsible for the authentication measures applied to participants. In the public sector, this means that a method of verifying the digital identity of chain participants should already be implemented. In this case, the use of third-party platforms will make the model centralized and not suitable for blockchain technology.

As for the adoption of blockchain technology in the public sector, there are currently commercial platforms that claim to be “blockchain-based”, meaning that they use this technology to process and store data in some of their operations. However, the advantage of the decentralized model offered by blockchain is based on the number of participants in the network, and this advantage is lost when one participant in the technology is responsible for all data processing.

Given the analyzed cases and the current application of blockchain technology in the public sector, there are technical challenges that arise before the introduction of blockchain platforms.

The standards established by Hyperledger can solve many of these problems with new permission schemes, appropriate consensus algorithms and a channel architecture that ensures that information is shared between nodes authorized to access it in advance of enabling blockchain networks that can solve many of these problems. However, the ecosystem has not yet reached the scale expected from distributed ledger technology. The main advantage is the absolute freedom to choose the method of connecting nodes, whether through cloud services from cloud service providers, or through mechanisms created and managed by the organizations themselves, in particular, state institutions.

Persuasive arguments in favor of the use of blockchain in the accounting system have been identified. Using the example of a shipping company, the cost of developing and implementing blockchain into their system was significantly lower than the fees and costs associated with one of the most common customs delays. In addition, as a result of this research, the paper describes three types of blockchains and recommends how each of them can be implemented in specific cases: the first is an open public blockchain, an open network in which anyone can participate (for example, Bitcoin and Ethereum). This type allows all users to read, write, and perform transactions, thereby replacing the role of a trusted third party. Permissioned public blockchains are closed networks in which verified and trusted nodes can participate (e.g., Hyperledger Fabric, Multichain, Eris). All members can view data,

but only authorized users can confirm transactions. Private blockchains are closed networks where only authorized users can read, send, and confirm transactions (examples include Hyperledger Fabric and Corda). The same blockchain application can run in multiple types, such as Hyperledger Fabric. They can also be used to secure authorized public blockchains or authorized private blockchains [30].

Although solutions are available today that can solve many problems, they all exist in an environment where policy and regulation do not always facilitate cooperation between actors. As a result, each institution must strive to maintain multiple interfaces, which leads to technical complexity, monitoring, and maintenance, and is a potential source of cybersecurity and significant costs.

Data security and privacy, technology adoption and deployment factors, and some specific considerations for accounting and analysis were analyzed. In its current form, blockchain cannot meet the specific needs of accounting information systems. While blockchain technology can provide a number of useful functions, especially in the area of data reliability and financial reporting transparency, several factors have been identified that question the possibility of large-scale integration of this technology into accounting functions. The main obstacle is the cost of the technology. Although significant investments have been made in the development of blockchain and its business applications, we believe that the widespread use of this technology is not yet fully justified. Researchers have also raised concerns about blockchain’s ability to address data security and privacy risks [31].

Unresolved issues related to blockchain technology were identified, including scalability, flexibility, appropriate architecture, and cybersecurity. The researchers noted that the full integration of blockchain into real-world accounting systems will require consensus from regulators, audiences, and other stakeholders. Nevertheless, the document confirms the high potential of technology to improve the quality of information exchange and accounting [32].

The main problems that cause concern for the implementation of blockchain technology in the system of accounting and analytical support are the complexity of implementation, lack of qualified experts, data processing time, and cyber security. Among the challenges to bear in mind are the heterogeneity of existing information systems, as well as significant differences between open and closed blockchain implementations, which may lead to additional costs to achieve interoperability between systems.

It is important to develop initiatives for training public sector employees to understand the tools for using blockchain technology and acquire the necessary skills to actively participate in the digitalization of the accounting and analytical process. This includes addressing broadband, cost, and speed issues, as well as providing digital security knowledge that can unlock the full potential of digital transformation in accounting and analytics.

In itself, blockchain is not a direct benefit for government agencies. The technology should be analyzed based on the needs and industry specifics of the activities of public sector entities.

7. Conclusions

1. The volumes and types of financial violations by public sector entities were analyzed. With the indication of the

quantitative indicators of the results of the study, financial violations were identified regarding the non-targeted use of budget funds in the amount of UAH 6.6 billion. 32,619 violations of budget legislation committed by public sector entities for the total amount of UAH 16,565.1 million were warned over 2022. It was established that the detected violations were committed by public sector entities, and their significant share fell on the system of accounting and analytical support for financial reporting, budget execution.

2. Legal restrictions on the introduction of a unified information technology system for public sector entities have been outlined. With the indication of the qualitative indicators of the research results, the absence of a number of acts in the field of digitization, protection of state secrets, international standards, etc. in the legal field was established. The purpose of adapting the legal field in the field of state secret protection is to bring the technological characteristics of distributed registers into line with regulatory acts. In particular, the functionality of the state distributed register, namely the exclusive type with restrictions on access to network information, can be considered as one of the tools of the state secret protection system. When implementing the state information technology system, compliance with international standards and recommendations in the field of combating money laundering and terrorist financing, currency regulation is a necessity.

3. It is determined that blockchain means a database structure that stores information in the form of blocks forming a chain in which new blocks are connected to previously formed blocks. The main characteristics of blockchain are decentralization, openness, traceability, protection from third party interference, security, data reliability, and anonymity. The blockchain operating model involves the simultaneous involvement of many participants who can store and exchange information from blocks in a network called a node. Nodes can be both open and closed, it all depends on the permission model. The types of blockchains based on authorization models that can be used in the system of accounting and analytical support are summarized. Nodes participating in the blockchain can read, write, and perform transactions depending on their permissions.

4. Features of the development of the mechanism for introducing blockchain platform technology into the system of accounting and analytical support of public sector entities have been outlined. In particular, the expediency of using blockchain applications, such as smart contracts, is substantiated. In particular, a new smart contract can be placed in the blockchain by calling the constructor function through a transaction, the sender of this request becomes the owner of the smart contract. When entering into a smart contract, each party prescribes the terms of the transaction, penalties for non-performance, and their digital signatures. Companies that implement blockchain with smart contracts can improve compliance and risk management. It is noted that the use of smart contracts can be developed on blockchain platforms such as Ethereum, NXT, and Hyperledger; their key characteristics were described. A comparative description of transactions of state funds in the traditional

accounting system and with the use of blockchain systems is given. In summary, blockchain has the potential to revolutionize the accounting profession and change the business system. It is noted that the blockchain technology has one significant problem – the significant cost of the transaction when transferring large volumes of data. Visually, the problem is considered on the example of using the Ethereum platform. Based on the results of the analysis of costs and data volumes, a conclusion was made about the impracticality of using this platform in the accounting and analytical support system. The preferred platform is Hyperledger, which has an open-source community focused on developing a set of stable frameworks, tools, and libraries for deploying enterprise-grade blockchains. It is noted that the Hyperledger platform detects errors in the accounting system in a matter of minutes, unlike the traditional accounting system.

5. The advantages and disadvantages of introducing blockchain technology into the system of accounting and analytical support have been determined. In particular, countries that are at the stage of digital development need to pay attention to all the features of the digitalization process. Blockchain technology opens up great opportunities that can significantly improve the state and economic sectors of the country. Blockchain has the potential to fundamentally change the country's economy, increase the efficiency and security of financial operations, particularly in the public sector.

6. The possibilities of using the blockchain and their potential impact on the system of accounting and analytical support for transactions of state funds are summarized. Five types of blockchain usage opportunities and their potential impact on the system of accounting for transactions of public funds were summarized. Thus, the proper implementation of the blockchain can lead to important changes in the accounting of transactions of public funds, in particular: reaching consensus and establishing international standards that allow the interoperability of systems related to the certification of origin; the ability to track transactions of public funds across blocks, starting with the data immutability block and their destination – by using a single shared ledger to determine ownership of an asset or the completion of a given transaction.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

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Data availability

All data are available in the main text of the manuscript.

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