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IMPLEMENTATION OF BLOCKCHAIN TECHNOLOGY IN AGRICULTURE: FASHIONABLE TRENDS OR REQUIREMENTS OF THE MODERN ECONOMY

Purpose. *The purpose is to reveal the theoretical and practical aspects of the implementation and application of blockchain technology in the economic activity of agricultural enterprises, taking into account the economic feasibility of their implementation and determining the system of elements of the implementation of blockchain technology in agriculture.*

Methodology / approach. *The following methods were used during the research: analysis and synthesis, scientific abstraction – when determining the goal and formulating research conclusions; comparative, calculation, statistical and graphic – when evaluating, analyzing, comparing and determining the current state of implementation of blockchain technology in the economic activity of agricultural enterprises. The method of surveying agricultural producers regarding their awareness of blockchain technology and the benefits of its application was also used. The research used: a theoretical approach (based on the analysis of theoretical aspects of blockchain technology and its application in agriculture) and a practical approach (on the basis of the proposed methodology, the economic feasibility of using blockchain technology in the economic activity of an agricultural enterprise was determined).*

Results. *The main areas of influence of blockchain technology in agriculture have been determined. It has been established that every year the amount of funding for the implementation of blockchain technology is increasing, and the reasons are identified. The world experience of implementing blockchain technology in the economic activity of agricultural producers is considered. The results of a survey of agricultural producers of the Mykolaiv and Kirovohrad regions regarding their awareness of blockchain technology and the benefits of its implementation are highlighted. The objective reasons that affect the implementation of blockchain technology in agricultural production are determined and ways of its popularization are proposed. An action algorithm for the introduction of blockchain technology for agricultural producers has been developed. Agricultural producers who are potentially ready and financially able to implement this technology in their activities have been identified. The main factors affecting the cost of implementing blockchain technology in agricultural production have been identified. A methodology for calculating the economic feasibility of implementing blockchain technology according to optimistic and pessimistic options is proposed, and the calculation of the net present value, payback period, discounted payback period of the project, internal rate of return and the rate of return on the example of a specific enterprise of the Mykolaiv region is carried out. Based on theoretical and practical approaches, a system of elements for implementing this technology in agriculture has been developed.*

Originality / scientific novelty. *The novelty consists in the implementation of a comprehensive theoretical study of the problems and prospects of the implementation of blockchain technology in agriculture; for the first time, a system of elements for the implementation of blockchain technology*

in agriculture was developed; an algorithm of actions for agricultural enterprises that plan to implement this technology was improved; a methodology for calculating the economic feasibility of implementing blockchain technology in an agricultural enterprise was proposed.

Practical value / significance. *The results can be used in the process of decision-making by business entities regarding the implementation of blockchain technology and the calculation of its economic feasibility, during the optimization of the processes of management of production, financing, supply chains, etc., as well as by scientists, government bodies and other entities that are interested in implementation of blockchain technology in agriculture.*

Key words: *blockchain technology, agricultural enterprise, system, economic justification, innovative project.*

Introduction and review of literature. In the modern world, in which the population is growing and the need for food is increasing, agricultural enterprises face the task of increasing the volume of production, provided that the volume of land resources does not change, and there is also a need to increase productivity, efficiency of economic activity and increase competitiveness. Under such conditions, agricultural producers should be aware of the importance and give preference to an intensive method of production.

Intensive production involves the use of advanced technologies, modern agrotechnical methods and effective management of business processes in order to achieve maximum productivity and optimal use of limited resources. Managers of agricultural enterprises must understand that intensive production cannot be based only on the introduction of the latest technology, this method of production also requires the improvement of management processes, the introduction of the latest information technologies, the use of analytics and monitoring for making informed decisions. One of the latest information technologies that can improve the efficiency of management of production processes, resources, financing processes at the enterprise, providing accurate accounting of the use of land, irrigation, fertilizers and other resources based on the impossibility of making changes to information, is blockchain technology. However, to date, the issue of prospects for the implementation and application of blockchain technology in agriculture and the justification of the economic feasibility of its implementation for agricultural enterprises remains insufficiently researched.

In accordance with the above, the statement of the problem can be formulated with the following questions:

1. Are there restraining factors that affect the implementation of blockchain technology in the activities of agricultural enterprises?
2. Does the implementation of blockchain technology in an agricultural enterprise affect the results of its economic activity?
3. Do domestic IT companies provide services for the development of solutions and applications based on blockchain technology, and are Ukrainian agricultural producers ready to spend financial resources on such applications?
4. Is the level of knowledge of Ukrainian agricultural enterprises about the possibilities of applying blockchain technology sufficient for its implementation?

5. Has the methodology and algorithm for implementing blockchain technology for agricultural enterprises been developed?

The issue of implementing blockchain technology is relevant, because blockchain technology is a new type of information storage, a decentralized database represented by a chain of interconnected blocks. In a short period of time, this technology has become a mega popular research topic. According to the free access search engine Google Scholar, more than 48,000 scientific studies related to blockchain technology and more than 7,000 related to the field of application of blockchain technology have been recorded, in most cases, scientific studies related to the financial sphere. Using the capabilities of the Google Search engine, we found that more than 70,000 publications relate to the implementation of blockchain technology in various areas of the economy. In addition, using one of the largest online collections of published scientific research – ScienceDirect, which belongs to the Dutch publishing house Elsevier and is a prototype of the Scopus database, the authors received more than 13,500 scientific articles and publications on this topic according to the request regarding blockchain technology. Considering the dynamics of publications on the topic of blockchain technology, it was established that its popularity began to grow in 2019 and the maximum number of publications was 4,064 units. recorded in 2022, but since the topic of implementing blockchain technology in agriculture is highlighted in only 1.5 % of the proposed articles, there is a clear need for additional research in this direction.

So, the works of L. M. M. Zayed & O. H. Othman [1] are aimed at studying blockchain technologies in the field of accounting, clarifying the principles of its operation, determining its advantages and disadvantages. In the course of the study, it was established that the blockchain technology allows to significantly reduce the costs of companies, ensures high stability and competitiveness. According to the authors, blockchain technology allows to increase the volume of information flows and reduce the amount of resources for data processing. The authors emphasize the possibilities and expediency of using blockchain technologies in the field of trade, which provides the possibility of tracking goods at all stages.

Works by A. Pólvora et al. [2] aimed at researching the possibilities of applying blockchain technology in various sectors. The main conclusions of the authors are based on a transdisciplinary approach and emphasize the possibilities for the development and implementation of blockchain in the conditions of expanding the boundaries of generally accepted practice.

Research by B. Thompson & S. Rust [3] aims to find out how social, cultural and institutional factors can lead to the promotion of digital technologies or resistance to them. These authors considered not only conceptual approaches to the development and implementation of blockchain technology, but also paid considerable attention to the issues of practical application when investigating the problems of implementing blockchain technology in the seafood supply chain. These researchers found that the literature on blockchain and food supply chains is dominated by conceptual publications, and only 17 % of publications are empirical,

of which only 1 % report survey results. The researchers came to the conclusion that the positive effect of the implementation of blockchain technology can be achieved only if the participants of the supply chains are aware of the value of these technologies and their confidence in the protection of information and its confidentiality.

Investigating the impact of blockchain technology on ensuring transparency of information on quality, bias, distortion and unauthorized access, L. Zhao [4] emphasizes the positive characteristics and provides examples of biased sales of low-quality products and withdrawal of some products due to the use of blockchain technology even by powerful market players.

In their work, Q. Zhang et al. [5] outline the motivation for research into blockchain query technology and consider three aspects that need improvement in blockchain query technology: query efficiency, query reliability, and query security. The paper examines the practical aspects of the application of blockchain-based query technology in various fields, researches modern blockchain query processing technologies in order to identify future trends and challenges.

In addition to the above-mentioned researchers who study the impact of blockchain technology on the economy, this issue was studied by such scientists as O. Grybyniuk et al. [6], V. Rutytska [7], T. Moroz [8], M. Yakovchuk et al. [9], A. Di Vaio, L. Varriale [10], Z. Zhang et al. [11], O. Ali et al. [12], C. Zheng et al. [13], R. Komulainen, S. Nätti [14], S. Köhler, M. Pizzol [15], H. Xiong et al. [16], G. A. Motta et al. [17], L. Kucher [18], H. Patel, B. Shrimali [19], A. Marchese et al. [20], and others [21–28].

But despite the large number of scientific studies and periodical publications on the issues of blockchain technology, the system of elements of the implementation of blockchain technology in accordance with the characteristics of agriculture still requires further research, and it is necessary to substantiate the approaches to the calculations of the economic feasibility of its implementation in the economic activity of an agricultural enterprise.

Having studied the scientific works of the above-mentioned scientists, the authors hypothetically assume that:

- the association of blockchain technology with cryptocurrencies does not allow the owners and management of business entities to realize the advantages of using this technology in other areas, including in agriculture;

- the lack of information about the practical experience of implementing and using blockchain technology by Ukrainian enterprises, the lack of a methodology for calculating their economic feasibility, as well as the inability to estimate the cost of their implementation, are factors that slow down these processes.

The purpose of the article is to reveal the theoretical and practical aspects of the implementation and application of blockchain technology in the economic activity of agricultural enterprises, taking into account the economic feasibility of their implementation and determining the system of elements of the implementation of blockchain technology in agriculture.

Results and discussion. With the development of industrialization and the spread of new technologies, the world is entering a new digital age. This era is characterized by the rapid development of high technologies that permeate all spheres of human life. The proliferation of technologies such as cloud technologies, the Internet of Things (IoT), virtual and augmented reality, 3D printing, the development of quantum technologies and robotics are the result of the Fourth Industrial Revolution, also known as Industry 4.0. Modern scientists are already investigating the problems of the formation of the Fifth Industrial Revolution with the "IGen" generation, whose representatives associate their entire conscious life with advanced technologies.

Blockchain technology is one of the promising technologies that increases trust and transparency in business processes. After all, with the growing need for transparency in information exchange, blockchain is becoming a better technology in all areas of human life. The possibility of using decentralized smart contracts, which contain transaction rules for participating parties and a transparent mechanism for their monitoring, contributes to the implementation of blockchain technology in various sectors of the economy. Today, blockchain technology is not limited to financial services and digital currencies, but is actively used for tracking goods, keeping records, managing supply chains, and processing large volumes of information about the various activities of business entities.

The use of information data is becoming an increasingly important factor in increasing the efficiency of operational activities in the agricultural sector. Information and communication technologies increase the efficiency of data collection, storage, analysis and use by agricultural enterprises. Information and communication technologies have made it easier for agricultural enterprises and interested parties to obtain up-to-date information for making effective management decisions in everyday economic activities. For example, remote sensing data on soil conditions helps agricultural producers during planting; gadgets with access to the Internet reduce the cost of obtaining information; facilitating farmers' access to financial assistance on financial markets and various government programs, ensuring mobility in the quick processing of subsidies for enterprises; the development of GPS facilitates field mapping and equipment management; allows to receive real-time data about the harvest.

The use of blockchain technology provides the opportunity to find partners based on the principles of the circular economy in the context of the implementation of the Sustainable Development Goals. After all, the UN Global Sustainable Development Goals for 2015–2030, adopted in 2015, determined the main directions for the formation of future food security in the world [29]. Of the seventeen points highlighted in the Sustainable Development Goals, three directly relate to global food security:

- Goal No. 1 "Overcoming poverty" – overcoming poverty in all forms and everywhere [29]. According to World Statistics, in 2015, almost 737 million of the world's population lived on less than USD 2.0 per day, of which almost 75 % lived in

rural areas [30]. Most of them worked in agricultural production, therefore, the introduction of technological innovations and innovative projects into agriculture should stimulate economic growth and lead to a decrease in the level of poverty in rural areas;

- Goal No. 2 "Overcoming hunger, development of agriculture" [29]. According to the World Food Program, released in August 2022, the number of people in urgent need of food has increased dramatically over three years, from 135 mln people in 2019 to 345 mln people in 2022. In total, more than 868 mln people [31] in the world do not have enough food and "go to bed hungry at night" [30]. The increase in the level of hunger in the world is connected with the military actions taking place in various countries of the world, including in Ukraine. According to the Ministry of Agrarian Policy and Food of Ukraine, "the Ukrainian agro-industrial complex annually fed more than 400 mln people around the world" [32].

- Goal No. 3 "Strong health and well-being" – ensuring a healthy lifestyle and well-being of people of any age [29]. This goal includes not only increasing the quantitative indicators of the well-being of the global population, but also improving the quality of nutrition, which depends on human health, because without regular, high-quality nutrition, a person cannot live, learn, fight diseases and live a full life.

Today, the number of people on the planet is constantly growing. According to World Statistics, about 8 bln people are recorded [32], according to World Bank estimates, a constant population growth is expected, which will reach 9.7 bln by 2050 and 11.2 bln by 2100. This trend necessitates an increase in production volumes food products. Accordingly, agricultural producers need to apply progressive methods of growing agricultural crops and implement innovative projects to increase the volume of production of agricultural products and its quality. The use of modern digital technologies helps to achieve this.

Despite large-scale digitalization of the economy, most enterprises in the agricultural sector do not have access to the services of IT specialists, do not use cloud computing services, etc. [33]. This is due to the fact that in the structure of agricultural enterprises, the largest specific weight belongs to small ones, which are territorially distant from the centers of civilization (labor market, Internet resources, etc.) [34]. However, today's requirements require the use of digital technologies, among which blockchain technology has a number of advantages. It is appropriate to consider the advantages of using blockchain technology in agriculture in four main directions.

In the first direction, the food industry will benefit from decentralized digital smart contracts that will allow automatic processing and authentication of transactions between participants in the supply chain. Smart contracts can also help automate the role of regulators and information sharing in the agri-food sector, but there are growing concerns about the quality of reporting data, accuracy and consistency of smart contracts.

In the second direction, the use of blockchain technology facilitates the integration of hardware and software, potentially contributing to better system

integration and productivity.

In the third direction, blockchain technology will provide an immutable record of transactions in chains of information accessible through a peer-to-peer network. Accordingly, this technology can be considered as a tool to increase trust between participants in the supply chain of quality agricultural products by simplifying the verification of records.

According to the fourth direction, the application of blockchain technology provides an opportunity to improve tracking and ensures transparency of the process of promoting goods in the supply chain from production to final consumption. For example, retail managers have the opportunity to access data and, accordingly, plan deliveries or production "long before the grain is delivered to the processing plant and reaches the store shelves" [35]. Many companies that ensure food safety through the sale of food in stores, for example, retail giants such as Walmart, Alibaba and JD.com, have shown interest in the application of blockchain technology for several years, the main interest is specifically in the tracking of food supply chains [8]. Sellers such as Auchan Retail and Carrefour Italia emphasize that the implementation of blockchain technology is implemented specifically to track food quality [8].

According to World Statistics, in 2017, the volume of funding for the implementation of blockchain technology in agriculture amounted to about USD 32.2 mln, this figure is expected to grow to approximately USD 1.4 bln by 2028 [31] (Figure 1).

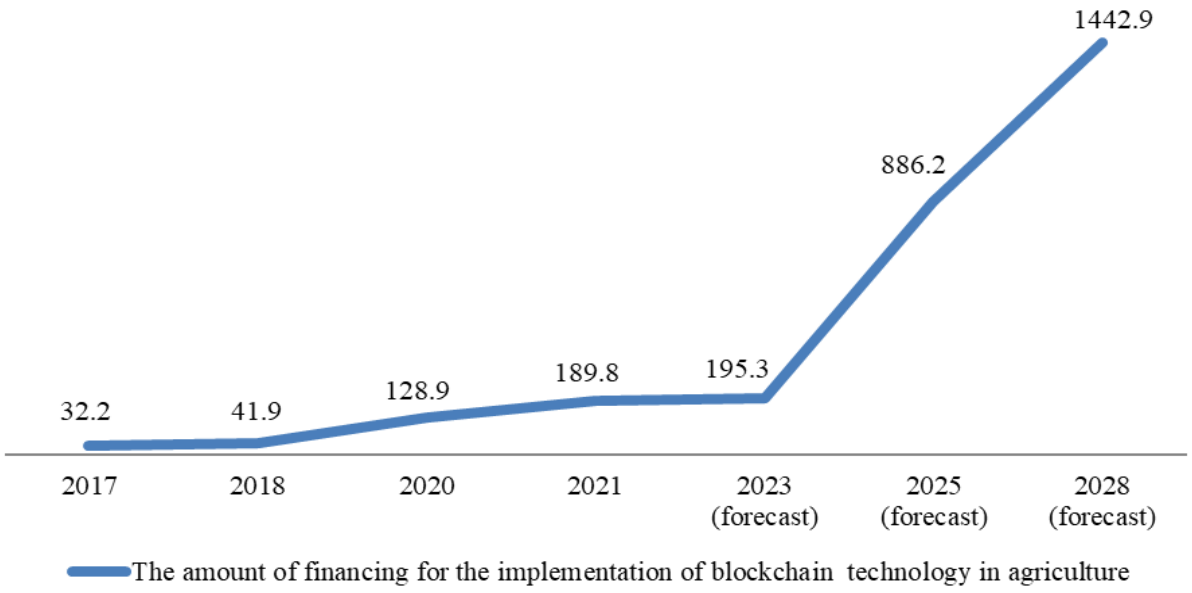

Figure 1. Estimated volume of funding for the implementation of blockchain technology in agriculture in the world, mln USD

Source: grouped by authors based on [22].

Forecast indicators shown in Figure 1, included according to the data of Reportlinker.com, which is indicated in the document "Global Agricultural and Food Chain Market Blockchain Report 2021: Growth and Changes Due to COVID-19"

[33]. The amount of funding for blockchain technology in agriculture is expected to increase from USD 128.9 mln in 2020 to USD 195.3 mln in 2023. That is, the increase in volumes is 51.5 %, which is a high growth rate.

The growth of investments of financial resources in blockchain technology in agriculture and the production and promotion of food products is due to the interest of participants in this technology and offers from companies that have the opportunity to develop effective solutions for agricultural enterprises. The most famous global company, which has long been engaged in the implementation of solutions for managing the production of agricultural products using artificial intelligence and blockchain technology, is the Indian company CropIn [36]. This company started functioning in 2010 and develops solutions for data analysis, monitoring and forecasting of harvest. With the help of their solutions, it is possible to automatically collect and analyze information from various sources, including the collection of data using agricultural sensors, the capture of images from satellites and the analysis of data from weather stations. With the help of the received data, the owners of agricultural enterprises have the opportunity to make more informed decisions regarding further changes in their economic activity. Due to the implementation of the development from the CropIn company, agricultural producers can remotely monitor the condition of their fields and crops. This allows more efficient use of resources and reduces the likelihood of crop loss. CropIn also uses blockchain technology to secure and ensure the objectivity of data stored in a decentralized database and linked together in a chain of blocks.

Currently, CropIn successfully cooperates with more than 250 clients from 92 countries, including large agricultural companies such as Loacker, Synthite, East-WestSeed, CosechaPartners, AmbujaCementFoundation and Mahindra&Mahindra [36]. CropIn is also known for its partnership program with Microsoft, which allows them to use the Microsoft Azure cloud service to store and process data more efficiently. In addition, CropIn has several other partnership agreements with leading players in the agricultural market, including Syngenta and ITC Limited.

In addition to the Indian company CropIn, which is constantly developing effective solutions for digitalization and decentralization of agricultural enterprises and their transparency, such multinational companies as Bayer Crop Science, together with Ant Financial, in 2019 started joint development of solutions using blockchain technology. Within 10 years, Bayer Crop Science plans to invest in developments related to agriculture, including in blockchain technology more than EUR 25 bln [37]. In addition to the above-mentioned companies that are engaged in the development of solutions for managing "smart agricultural production" using blockchain technology, it is worth noting the following ones that will gain popularity in 2023, such as IDEASOFT, Blockchain-X, Boosty Labs, Evacodes and 4irelabs [38; 39].

Ukraine is a country with a high level of digitization and implementation of technological innovations. According to the data of the Blockchain Association of Ukraine [40], about 30 % of companies use blockchain technology, but do not make

this information public, so it is very difficult to find company data to determine the effectiveness of the implementation of this technology. Based on the analysis of the Ukrainian market of companies that provide services for the development of solutions and applications based on blockchain technology, it is possible to note that the most famous are Bitfury, Attic Lab and Bloqly [38; 39] (Table 1).

Table 1

Basic information on Ukrainian companies engaged in the provision of solutions and application development services based on blockchain technology

Company	Founder	The year the company was founded	The number of developed projects in the field of agriculture	Advantages of the company
Bitfury	V. Vavilov	2011	Has no specific specialization in agriculture	Has extensive experience in the implementation of blockchain technology and cooperates with many participants of the business environment
Attic Lab	A. Dubins-kyi	2018	Has several projects in the field of agriculture	Has an individual approach to each client who is interested in implementing blockchain in their business activities
Bloqly	R. Novak	2018	Has several successful projects related to the implementation of blockchain in agriculture	Has its own platform for blockchain implementation, provides its customers with a high degree of data security

Source: grouped by authors based on [38; 39].

Within the framework of this study, the authors conducted a survey of agricultural producers of the Mykolaiv region regarding their awareness of blockchain technology and the possibility of its implementation in an agricultural enterprise. Taro Yamane's formula (standard error 10 %) was used to determine the minimum sample size [41]:

$$n = \frac{N}{1 + N \times e^2} = \frac{3439}{1 + 3439 \times 0{,}1^2} = 97\ items\ ,$$

where N – the number of active agricultural enterprises of the Mykolaiv region as of November 1, 2022;

e – sampling error – 10 %;

n – the minimum sample size.

Thus, in order for the survey to be reliable, it is necessary to survey 97 representatives of agricultural enterprises. The survey took place in two stages: The first stage was conducted in the period from April 1 to April 30, 2023, during which 36 representatives of agricultural enterprises were interviewed; the II stage was conducted in the period from June 15 to June 30, 2023, during which 65 representatives of agricultural enterprises were interviewed. The questionnaire was conducted online, by providing answers in the Google Form prepared by the authors. The profile of the interviewees is given in Table 2.

Table 2

Profile of interviewees

Indicators	Characteristics	Share, in % of the total number of interviewed representatives of agricultural enterprises during the 1st stage	Share, in % of the total number of interviewed representatives of agricultural enterprises during the II stage
Gender of interviewees	Men	75.0	56.9
	Women	25.0	43.1
Age	18–25	15.4	10.8
	26–34	23.1	20.0
	35–44	15.4	10.8
	45–54	15.4	15.3
	55–64	26.9	38.5
	65–74	3.8	4.6
Organizational and legal form	Individual entrepreneur	15.4	3.0
	Limited liability company	15.4	20.0
	Private enterprise	7.7	7.8
	Farming	57.7	63.1
	Household	3.8	4.6

Source: grouped by the authors on the basis of processed questionnaires of respondents.

As a result of a survey on the awareness of agricultural producers of the Mykolaiv region about blockchain technology and the possibility of its implementation, the authors of the study obtained the following results:

- 60.1 % of respondents had not previously come across information about blockchain technology;

- 42.3 % of respondents know that "Blockchain is a decentralized database used to store and transfer information. Information in the blockchain is built according to certain rules and has a continuous, sequential chain of blocks containing information from previous blocks";

- 65.6 % do not know that blockchain can be used not only in the field of cryptocurrencies (Bitcoin and Ethereum);

- 81.4 % of respondents do not know that blockchain technology can be used in agriculture;

- 65.2 % do not know about the advantages of implementing blockchain technology in various areas of the economy, and especially that the efficiency of the enterprise will increase from 20 % to 40 %;

- 85.2 % do not know and were not interested in the cost of introducing blockchain technology into economic activity;

- 49.4 % of respondents would implement blockchain technology in their own production activities if the cost of its implementation would be from UAH 120,000 to 500,000.

In order to clarify the results of the survey and the possibility of spreading its results to other regions, a survey of agricultural enterprises – clients of the

Kirovohrad Regional Agricultural Advisory Service (98 farms) was conducted. The results of the survey are generally identical, but there is a difference regarding the respondents' awareness of the possibilities of application in the practice of agricultural enterprises and the potential possibility of increasing production efficiency as a result of the implementation of blockchain technology. Thus, only 32.3 % of respondents do not know that blockchain technology can be used in agriculture, and 52.0 % do not know about the benefits of implementing blockchain technology in various areas of the economy, and especially that the efficiency of the enterprise will increase from 20 % to 40 %. Such a difference in results, in our opinion, is due to the fact that the consultants-advisors familiarized the clients with the potential possibilities of using blockchain technology. At the same time, 82.2 % of respondents answered that they would implement blockchain technology in their own production activities if the cost of its implementation would be from 120,000 to 500,000 UAH. In our opinion, it would be appropriate to introduce a norm at the level of legislation, according to which, along with taxes and costs that reduce the minimum tax payment of agricultural enterprises [42], documented costs for the implementation of blockchain technology should also be taken into account. Accordingly, 76.6 % of the surveyed clients of the Advisory Service noted that such a norm of tax legislation would have a positive impact on their decision to implement blockchain technology.

Based on the analysis of the organizational conditions of economic activity of agar producers, the authors believe that there are objective reasons for slowing down the implementation of blockchain technology in economic activity (Figure 2).

In order to overcome these factors, it is advisable to create favorable conditions and use appropriate mechanisms. Specifically, the authors of this study believe that it is necessary:

1. Legislatively regulate the issue of the application of start-contracts in the economic activity of agrarian enterprises and their tax consequences;
2. Create agricultural cooperatives for the implementation of blockchain technology, with the aim of reducing the cost of its implementation and further maintenance throughout the entire period of use;
3. Increase the readiness of enterprises to implement blockchain technology by developing instructions and conducting targeted training courses for enterprise owners and operatives (it is advisable to conduct them in cooperation with advisory services and scientists of higher educational institutions);
4. Develop standards for the application of blockchain technology, taking into account the specifics of agricultural business;
5. Create business hubs for the dissemination of positive practical experience of implementing innovative technologies by agricultural enterprises and companies that directly develop business management solutions using blockchain technology. The modern innovative direction of the development of the agrarian economy is agrarian-industrial integration, which should cover not only large economic

entities, but also small personal peasant farms [43]. For such structures, the implementation and application of blockchain technology will help ensure competitiveness.

Insufficient readiness for innovation and lack of sufficient knowledge about blockchain technology

- in agriculture, a small share of entities using innovative technologies; insufficient level of awareness regarding the expediency and implementation algorithm and benefits of using blockchain technology;

High cost of implementation

- the implementation of blockchain technology is a high-cost project for an agricultural producer, especially for micro and small enterprises that cannot invest in technological projects from 10,000 USD and more, depending on the size of the given project; it is difficult to calculate the expected profits from the introduction of blockchain technology;

Lack of proper regulatory framework

- blockchain is a fairly new technology, many countries do not have a regulatory framework for its use in the economy, including in agriculture, which potentially affects the emergence of legal complications;

Problems of standardization

- the lack of standardization in the blockchain can lead to difficulties in the interaction between producers and processing enterprises, which is an obstacle to the implementation of the technology

Figure 2. Objective reasons that affect the implementation of blockchain technology in the activities of an agricultural enterprise

Source: grouped by authors [6; 9; 25; 27].

Despite the reasons that hold back the implementation of blockchain technology in economic activities, some large agricultural holdings are already working towards the implementation of blockchain technology and have a positive result from its implementation. For example, in 2018, the Agrox company expressed its intention to implement blockchain technology during the conclusion of contracts for the purchase and sale of agricultural products, which is used by the multinational company "NCH Capital". A good example is the practical experience of PJSC "Myronivskyi Hliboprodukt", which in 2020 started cooperation with Ambrosus on the introduction of blockchain technology into the system of control and improvement of the quality of chicken meat [44]. Australian agricultural company AgriDigital notes that after implementing blockchain technology,

administrative costs decreased by 60 % and the efficiency of payment processing increased by 50 % [44]. The Hungarian company TE-FOOD also records an increase in the efficiency of economic activity and a decrease in costs for the settlement of problems with the supply of goods and raw materials, as well as an increase in customer confidence [44].

We suggest that agricultural enterprises that plan to implement blockchain technology use the following action algorithm (Figure 3).

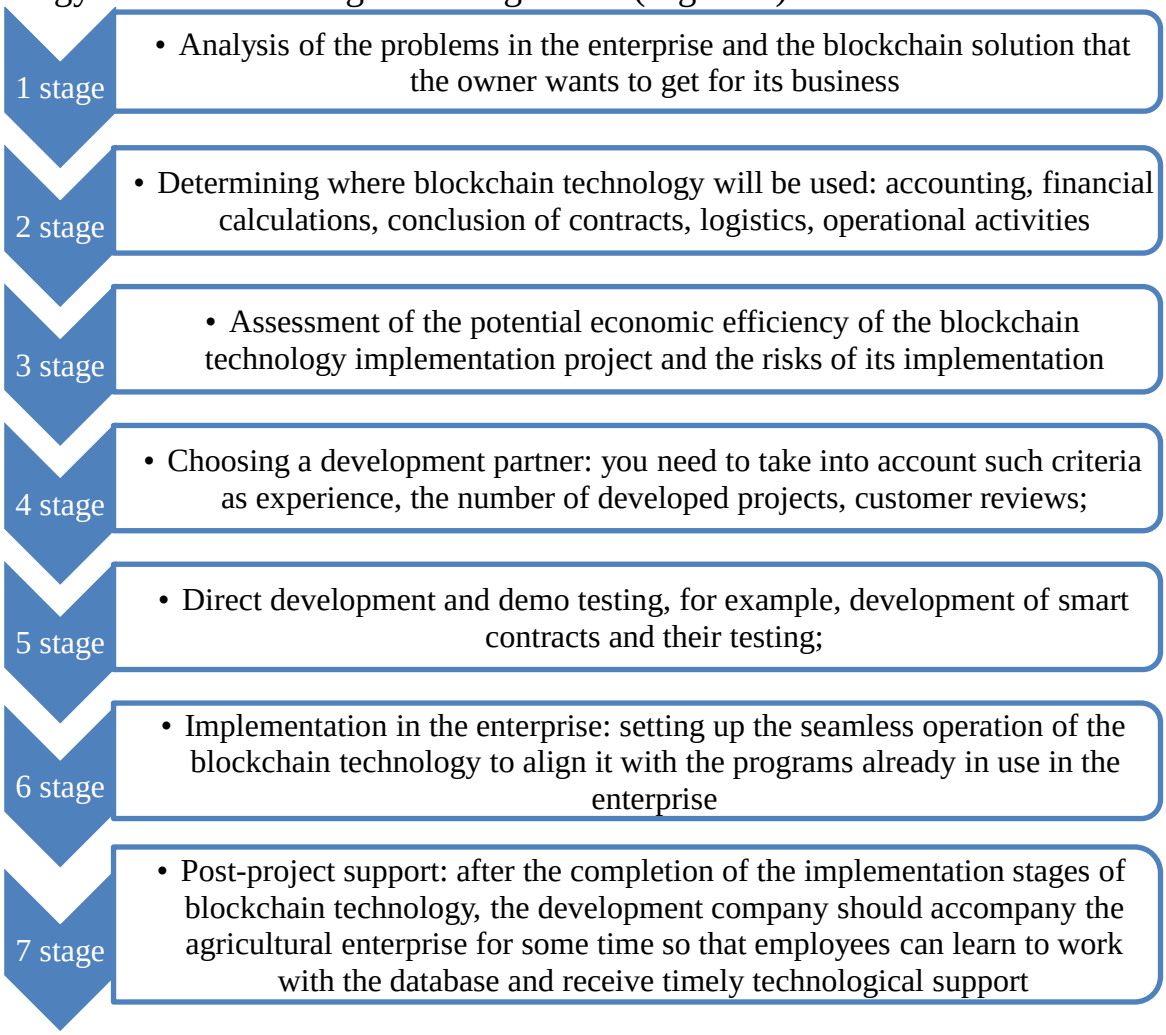

Figure 3. Algorithm for introducing blockchain technology into the economic activity of an agricultural enterprise

Source: developed by the authors.

Decision-making regarding the introduction of blockchain technology should be considered from the point of view of the economic feasibility of the innovative project. To determine potential business entities that are ready to implement blockchain technology, it is worth taking into account such factors as the total amount of land and the amount of sold products. According to the data of the State Statistics Service of Ukraine [33], as of January 1, 2023, 72,475 agricultural producers of legal entities and 18,315 individual entrepreneurs whose economic activity is agriculture were registered:

- the number of operating enterprises in terms of volumes of sold products in

2021 was: up to EUR 1 mln – 35,934 units; from EUR 1 to 2 mln – 1,954 units; from EUR 2 to 5 mln – 1,479 units; from EUR 5 to 10 mln – 375 units; from EUR 10 to 20 mln – 156 units; from EUR 20 to 50 mln – 78 units; from EUR 50 to 200 mln – 31 units;

- the number of operating enterprises by the size of land plots in 2021 was: from 0 to 100 ha – 28,155 enterprises; from 100 ha to 500 ha – 6300 units; from 500 ha to 1000 ha – 3433 units; from 1,000 ha to 10,000 ha – 1,854 units; from 10,000 ha or more – 265 units [33].

In the study of L. Kucher et al. [45] regarding the readiness of agricultural enterprises to implement innovative projects, it is stated: "8.7 % of enterprises reached a high and very high level of the integral indicator of readiness to implement innovative projects, the same number had an average level, while 82.6 % is a very low level. According to the method using the sigmoid function, 67.4 % of enterprises had a very low and low level of readiness, 21.7 % had an average level, and 10.9 % had a high and very high level" [45]. That is, the authors of the study assume that of the total number of enterprises engaged in agricultural activities, only 4,360 units have a high level of readiness for the implementation of innovative projects, which include the implementation of blockchain technology in economic activity. According to the authors, the most financially capable of implementing this technology in economic activity are enterprises with a volume of sales from 10 to 200 mln euros and which have 1,000 to 10,000 ha of land under cultivation, but in order for blockchain technology to enter mass use it is necessary to pay attention to enterprises whose volume of sold products is from EUR 1 to 10 mln (their total number is 3,808 units). It is these enterprises that will be able to afford financial costs related to the introduction of blockchain technology, its further support and the purchase of additional Internet of Things for collecting information in real time about the condition of soils, agricultural crops and animals, including record their growing season, the presence of diseases and pests, tracking supply chains, etc. In addition to the development of blockchain solutions, the enterprise needs to have the appropriate human resources to use the technology in its current activities.

For the owners and management of the agricultural enterprise, the question of the cost of introducing such technology into economic activity and its effectiveness is relevant. The calculation of economic efficiency allows to determine the expected profitability of the project, in particular, to estimate the costs of implementing blockchain technology and the expected income from its use.

There is no unequivocal answer to the cost of implementing blockchain technology, because each project is individual and various factors influence the formation of the project cost (Figure 4).

The practical experience of implementing and using blockchain technology shows the economic feasibility of developing and implementing innovative projects of "blockchain technology". However, for every enterprise that makes a decision on the implementation and application of blockchain technology, it is necessary to calculate the economic efficiency.

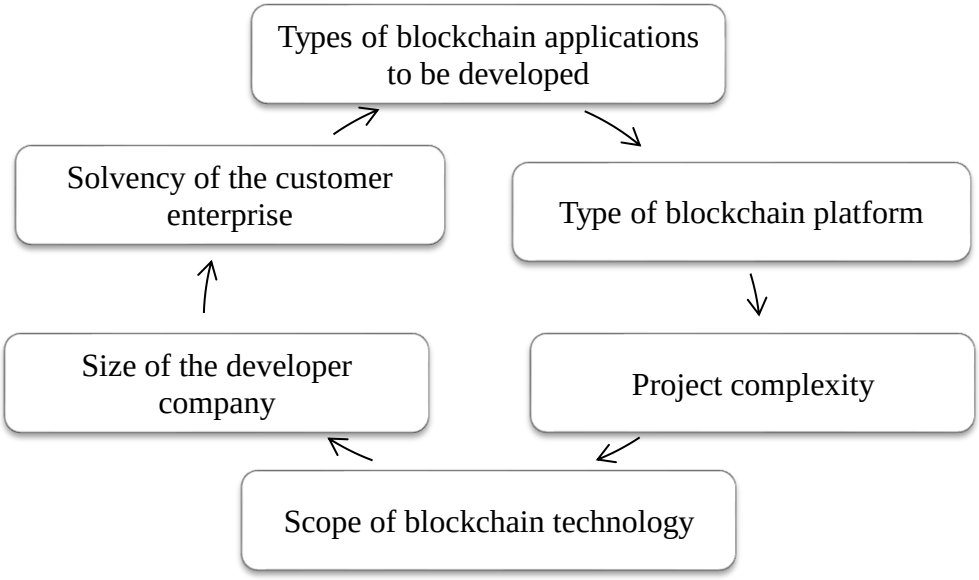

Figure 4. Factors affecting the cost of implementing blockchain technology in an agricultural enterprise

Source: grouped by authors based on [38; 39; 43].

Methodical approaches to such a calculation are tested on the example of agricultural limited liability company "X", which is located in the Pervomaisky district of the Mykolaiv region, which actively implements innovative technologies in economic activity. Based on the analysis of information on the farm's website, it was found that the company has been using "smart agricultural production" with the use of the Internet of Things for many years. The official website states that "increasing production volumes is our main task for the future. The planned improvement of the infrastructure and the use of modern technologies will help create more comfortable working conditions for all employees, improve their qualifications" [46]. Therefore, it will be much easier for such an innovative enterprise to implement blockchain technology in its own production activities. To calculate the payback of the implementation of blockchain technology, the results of Accenture research were used, which found that as a result of the implementation of this technology, administrative costs in agriculture are reduced by 25 % [47]. According to the results of the study A. Sharma et al. [48] – the use of blockchain technology in the agricultural sector leads to an increase in the profitability of agricultural enterprises by 25–30 %. According to a Deloitte study, the implementation of this technology combined with the Internet of Things can increase the yield of agricultural crops by 30 % [49].

The positive experience of introducing blockchain technology into the business practice of foreign enterprises indicates the possibility of using the results of research by foreign scientists at domestic enterprises to assess the potential result of the introduction of technologies. This is due to the fact that there are currently no studies by domestic scientists on the impact parameters of the introduction of blockchain technology. The authors calculated according to two options:

- according to the optimistic – calculation of economic efficiency from the

introduction of blockchain technology under the condition of increasing profitability by 30 %;

- according to the pessimistic option – increase in profitability by 10 %.

On the basis of the financial reporting data of STOV "X" for previous years, the economic feasibility of introducing blockchain technology into the business practice of the enterprise was calculated. For the reliability of the obtained results, the calculation was carried out in Microsoft Excel using financial functions. In the Table 3 shows the initial data for the calculation.

Table 3

Initial data for calculating the economic feasibility of implementing blockchain technology

Year	Net financial result			Deviation	
	Without implementation of blockchain technology, thsd UAH	Optimistic option (profitability will increase by 30 %), thsd UAH	Pessimistic option (profitability will increase by 10 %), thsd UAH	Optimistic version, thsd UAH	Pessimistic version, thsd UAH
2018	7432.00	7432.00	7432.00	0	0
2019	7640.00	7640.00	7640.00	0	0
2020	7569.00	7569.00	7569.00	0	0
2021	29505.00	29505.00	29505.00	0	0
2022	2256.00	2256.00	2256.00	0	0
2023 (estimated)	14334.30	14334.30	14334.30	0	0
2024 (estimated)	15485.60	20131.28	17034.16	4645.68	1548.56
2025 (estimated)	16636.90	21627.97	18300.59	4991.07	1663.69
2026 (estimated)	17788.20	23124.66	19567.02	5336.46	1778.82
2027 (estimated)	18939.50	24621.35	20833.45	5681.85	1893.95
2028 (estimated)	20090.80	26118.04	22099.88	6027.24	2009.08
2029 (estimated)	21242.10	27614.73	23366.31	6372.63	2124.21
2030 (estimated)	22393.40	29111.42	24632.74	6718.02	2239.34

Source: calculated by the authors.

For further calculation, the size of the required initial investment is determined. According to the official information of the Ukrainian company Bitfury [50], the estimated cost of the project is UAH 3,500,000 (the cost may vary depending on the specific requirements and needs of the enterprise, on the need for personnel training, increasing the amount of data storage, making changes to the system in the future, integration with other systems, etc.).

Table 4 shows the main results of calculating the economic efficiency of the project and its payback period.

Analyzing the obtained results according to the optimistic version, it is possible to conclude that the project is effective. In particular, the net present value (NPV) is UAH 16,097.0, which means that the amount of net income from the project exceeds the costs of its implementation. The payback period of the project (PP) is 1.88 years, which also indicates its effectiveness.

Table 4

Calculation of the economic efficiency of the blockchain technology implementation project, thsd UAH

Indicators	2023	2024	2025	2026	2027	2028	2029	2030
Optimistic version								
Initial cash costs	-3500	-	-	-	-	-	-	-
Operating cash flow	-3500	4645.7	4991.1	5336.5	5681.9	6027.2	6372.6	6718.0
Cumulative cash flow	-3500	1145.7	6136.8	11473.2	17155.1	23182.3	29554.9	36273.0
Discount rate, %	20	20	20	20	20	20	20	20
Discount factor	1	0.833	0.694	0.579	0.482	0.402	0.335	0.279
Discounted cash flow	-3500	3871.4	3466.0	3088.2	2740.1	2422.2	2134.2	1874.9
Net discounted cumulative flow	-3500	371.4	3837.4	6925.7	9665.7	12088.0	14222.1	16097.0
Net Present Value (NPV)							16097.0	
Project payback period (PP), years							1.88	
Discounted project payback period (DPP), years							1.95	
Internal rate of return (IRR), %							139.4	
Profitability index (PI), coef.							4.6	
Pessimistic version								
Initial cash costs	-3500	-	-	-	-	-	-	-
Operating cash flow	-3500	1548.6	1663.7	1778.8	1894.0	2009.1	2124.2	2239.3
Cumulative cash flow	-3500	-1951.4	-287.8	1491.1	3385.0	5394.1	7518.3	9757.7
Discount rate, %	20	20	20	20	20	20	20	20
Discount factor	1	0.833	0.694	0.579	0.482	0.402	0.335	0.279
Discounted cash flow	-3500	1290.5	1155.3	1029.4	913.4	807.4	711.4	625.0
Net discounted cumulative flow	-3500	-2209.5	-1054.2	-24.8	888.6	1696.0	2407.4	3032.3
Net Present Value (NPV)							3023.3	
Project payback period (PP), years							3.17	
Discounted project payback period (DPP), years							4.02	
Internal rate of return (IRR), %							46.1	
Profitability index (PI), coef.							0.86	

Source: calculated by the authors.

The project's discounted payback period (DPP) is 1.95 years, that is, the project will pay off within the estimated period. The internal rate of return (IRR) is 139.4 %, which also confirms the profitability of the implementation. The profitability index (PI) is 4.6. Therefore, it can be argued that the implementation of blockchain technology in an optimistic version is promising and effective for agricultural enterprises. According to the results of calculations based on the pessimistic version of the project, the NPV is UAH 3,023.3 thousand, the PP is 3.17 years, and the DPP is 4.02 years, which indicates the efficiency of the project. Internal the rate of return is 46.1 %. However,

the profitability index has a value of 0.86, which also indicates insufficient profitability of the project under the pessimistic option. In general, the project under optimistic option is profitable and has a short payback period, which is arguments for a positive decision regarding its implementation.

The methodology for calculating the potential economic efficiency of the blockchain technology implementation project can be used by other agricultural enterprises in order to substantiate decisions regarding the feasibility of its implementation. At the same time, before making a decision to invest in the project, a detailed analysis of possible risks that may arise in the process of its implementation should be carried out.

The main potential risks associated with the implementation of blockchain technology can be grouped as follows: 1. Financial risks: the cost of project implementation may increase depending on external and internal factors; 2. Technical risks: equipment malfunction, hacker attacks, incompatibility of software for implementing blockchain technology with what is already used by the enterprise; 3. Organizational risks: arise if necessary when introducing blockchain technology to make radical changes in business processes, the company's corporate culture and relationships with partners; 4. Legal risks: in connection with the uncertainty of the legal status of blockchain technology and its further regulation; 5. Personnel risks: insufficient level of knowledge, skills and experience of working with the new blockchain technology of employees of the agricultural enterprise, who in the future may not use the received information correctly.

Based on the substantiation of the benefits of application and the potential effectiveness of the implementation of blockchain technology in an agricultural enterprise, the authors proposed a system of elements for the implementation of blockchain technology, taking into account the characteristics of agricultural enterprises (Figure 5).

The implementation of blockchain technology in agriculture should ensure an increase in the efficiency and productivity of the enterprise’s economic activity, reduce costs, improve product quality and ensure production safety. It is important to note that the implementation of blockchain technology requires interaction between various business entities, including agricultural enterprises, suppliers, processors, trade networks and consumers.

At the end, it is appropriate to compare our results with the results of scientists who were engaged in research in this direction. Thus, based on a survey of accounting staff of Jordanian enterprises regarding the awareness of the possibilities of blockchain technology and the readiness of enterprises to implement this technology, L. M. M. Zayed, & O. H. Othman [1] established the following results: 56 % of respondents do not know what blockchain is; 47 % – how to use blockchain technology outside the financial sphere; 98 % of respondents noted that the companies they work for do not implement blockchain technology in their business activities. The results obtained by the above scientists are similar to the results of our research. This confirms the author’s position regarding the ignorance of most

employees of business entities regarding the benefits of implementing blockchain technology and its opportunities for business.

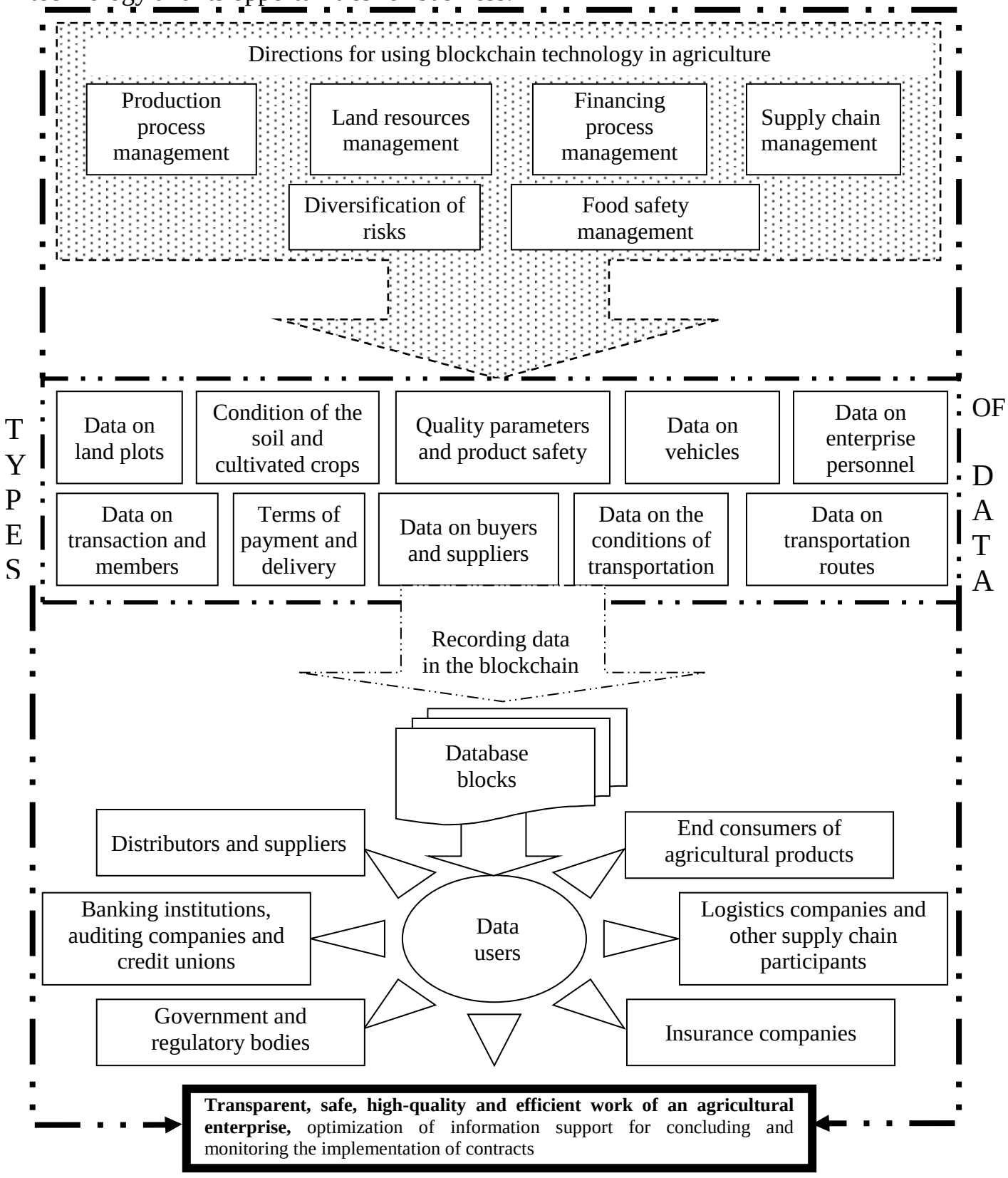

Figure 5. The system of elements of implementation of blockchain technology according to the peculiarities of agriculture

Source: developed by the authors.

Having studied the blockchain technology from the point of view of the sustainable productivity of the business entity, scientists A. Di Vaio & L. Varriale [10] proved the possibility of increasing the efficiency of management decision-making at the enterprise through the implementation of the A-CDM system, which works on the basis of blockchain technology.

In turn, our study also developed methodical approaches for calculating the economic feasibility of implementing this technology at the enterprise, which were tested on the example of an agricultural enterprise in the Mykolaiv region. In our research, an algorithm for implementing blockchain technology for agricultural enterprises was developed. A system of elements for the implementation of blockchain technology is also proposed in accordance with the characteristics of agricultural enterprises, which has not had a place in the research of other scientists. After conducting an empirical study on the various factors that influence blockchain adoption in SSVN, R. Komulainen & S. Nätti [14] found that there are four groups of factors:

1) internal psychological barriers (not understanding the benefits of implementing innovation in activities, limited knowledge about the possibilities of blockchain technology, not knowing its cost, etc.);

2) intra-functional barriers (not understanding exactly how this technology functions and how to apply it);

3) external psychological barriers (public distrust of cryptocurrencies that work on the basis of blockchain technology and the transfer of this distrust to the technology itself);

4) external functional barriers (absence of regulatory and legislative regulation of the use of technology).

In our research, we also focused on the objective reasons that hold back the implementation process of blockchain technology; in most cases, the reasons are similar, but we added to the valid reasons the lack of standardization and the unreadiness of domestic agricultural producers for technological innovations, as well as reasonable directions for overcoming these restraining factors.

Conclusions. The implementation of blockchain technology is an urgent requirement of the modern economy, its application creates prospects for the further development of the potential of enterprises and increasing its competitiveness. The implementation of blockchain technology in agriculture is especially relevant, given its role in providing quality food.

Blockchain technology provides effective management and monitoring of data on the general state of agricultural production, helps reduce risks and costs. The use of blockchain technology ensures security and transparency in relations with suppliers and buyers of products, which positively affects the reputation of the enterprise, its business relations, helps attract investments, increase investment attractiveness, etc. However, the implementation of blockchain technology in agriculture has significant barriers, which is primarily due to the low level of familiarity with it (more than 60 % of owners and managers of agricultural

enterprises do not know about the benefits of implementing blockchain technology and its impact on the company's activities).

In order to create favorable conditions for the introduction of blockchain technology, the need for:

- legislative regulation of issues of application of start-contracts in the economic activity of agrarian enterprises and their tax consequences;
- creation of agricultural cooperatives for the implementation of blockchain technology, with the aim of reducing the cost of its implementation and further maintenance during the entire period of use;
- increasing the readiness of enterprises to implement blockchain technology by developing instructions and conducting targeted training courses for enterprise owners and operatives (which is expedient in cooperation with Advisory Services and scientists of higher educational institutions);
- development of standards for the application of blockchain technology, taking into account the specifics of agricultural business;
- creation of business hubs for the dissemination of positive practical experience of implementing innovative technologies by agricultural enterprises and companies that directly develop solutions for managing enterprises using blockchain technology.

An algorithm for the implementation of blockchain technology in the economic activity of an agricultural enterprise was developed and methodical support for its implementation was provided, in particular, in the part of the methodology for assessing the potential economic efficiency of the project of implementing blockchain technology and the risks of its implementation, the factors that affect the cost of implementing blockchain technology in an agricultural enterprise were determined, and a system was proposed elements of the implementation of blockchain technology in accordance with the specifics of agriculture. As a result of the study, it was established that the implementation of blockchain technology in agriculture is effective. In connection with the above, the authors believe that the hypotheses put forward at the beginning of the study are proven and confirmed.

Characterizing the limitations, we note that this study concerned the survey of a small number of representatives of agricultural enterprises of the Mykolaiv region; according to the calculation of representativeness of the sample – the survey is reliable (taking into account 10 % error). In addition, the results in other regions may differ from the results in Mykolaiv region; as shown in the article, the results of the survey of representatives of agricultural enterprises of the Kirovohrad region. slightly different from the results of the Mykolaiv region. The survey was limited in time, so the authors assume that in the future the awareness of economic entities may change for the better with the growing popularity of the application of this technology in the production sphere. The study does not cover the state of domestic funding for the implementation of blockchain technology, as statistical data are currently unavailable, as the vast majority of enterprises are private, so access to empirical data is limited. But the authors paid more attention to methodological recommendations and the

algorithm for implementing blockchain technology. Using the example of a real agricultural enterprise of the Mykolaiv region, the author's idea regarding the economic feasibility of introducing blockchain technology into economic activity is methodically reflected.

Prospects for further research are the evaluation of causal relationships using correlation and regression analysis to determine the relationship between the implementation of blockchain technology and the performance indicators of agricultural enterprises, such as increased yield, reduced production losses, or optimization of resource use. Targeted development of methodological support for the implementation of blockchain technology for agricultural enterprises of various sizes may be the direction of further research; at this stage of research for small and medium-sized enterprises, it is worth focusing on the creation of cooperatives for the purpose of implementing and using blockchain technology. In the future, it is also worth focusing on the researched role and influence of the state on the introduction of blockchain technology at enterprises, the use of blockchain technology in the field of transportation and logistics of agricultural products. Such studies may include calculating the efficiency and economic feasibility of using blockchain technology in logistics supply chains.

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