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REVIEW

Exploring Blockchain Technology: Applications and Insights Across Multiple Fields

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ABSTRACT

Blockchain is a digital recording technology where each block contains encrypted data linked to previous blocks, forming an immutable and transparent sequence. This review systematically analyzes the applications and evolution of blockchain technology across multiple sectors from 2021–2023. peer-reviewed articles focused on key areas such as finance, healthcare, energy, and supply chain management. The findings highlight blockchain's transformative potential, including its ability to enhance security through encryption and decentralization, improve trust and data integrity, and eliminate intermediaries, enabling faster transactions and cost reduction. However, challenges such as scalability issues, high energy consumption in cryptocurrency mining, privacy concerns due to the immutability of records, and the need for regulatory adaptation remain significant barriers to widespread adoption. This review provides a comprehensive overview of blockchain's opportunities and limitations, offering valuable insights for researchers and practitioners aiming to leverage this technology in various fields.

Keywords: Blockchain, Industry 4.0, Transactive system, Transactions, Security

1. Introduction

According to [1], the Blockchain is defined as a chain of blocks that generates a record that cannot be traced is transparent, and protects, in the case of using it, the user's money. In its early days, Blockchain was mainly known for its use in cryptocurrencies, especially with Bitcoin, protecting its users and banking transactions. Users' transactions with Blockchain support have several advantages: they are highly reliable with their platforms, they are sure of their transparency, and the cybersecurity section is fully covered [2].

Several fields have made use of technology to shield their operations. In the security sector, Blockchain uses its technology to strengthen the database layer to secure users' information, their companies, and the corporate contacts with which it works. In the tourism sector, the security of the personal and banking data of tourists, in addition to tracking their bags and reservations. In the energy sector, it helps to manage energy consumption efficiently for the development of roadmaps and short-term energy planning referencing demand; in the agricultural sector, it helps to identify and prevent crop problems in real-time [2–4].

Many businesses implement this technology since it has innovated in information security, in opportunities to grow in competitiveness with other companies, given that Blockchain, in addition to specializing in the cybersecurity of companies, is implemented to improve authenticity and risk management, increasing efficiency, transparency and opening new income opportunities for them. This is how, in many sectors of information and commerce, Blockchain technology has been implemented. With it, better knowledge has been acquired about the advantages of working with this technology, increasing all the available

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documentation on its benefits in the computational, financial, and medical sectors [3, 5].

Blockchain technology has evolved into a versatile tool with applications spanning numerous sectors, from finance and healthcare to energy and supply chain management. This review adopts a deliberately broad scope to map the diverse applications of blockchain, highlighting its potential to address sector-specific challenges and uncovering trends that connect these fields. By providing an overview of blockchain's impact across multiple domains, this work aims to serve as a foundational reference for researchers and practitioners seeking to explore its applications in depth or identify opportunities for cross-sectoral innovation. Such a comprehensive perspective is essential in understanding how blockchain technology transcends traditional boundaries, fostering advancements reshaping industries and society. Blockchain technology has revolutionized numerous business and commercial sectors in recent years. Many businesses companieshave adopted this innovative technology due to its significant impact on information security and its ability to drive competitiveness in an increasingly aggressive market. Blockchain strengthening enterprise cybersecurity and excels at improving authenticity and risk management, resulting in greater operational efficiency and unparalleled transparency. In addition, it opens new revenue opportunities for companies that use it. This work aims to present the conceptual union on which Blockchain is based, the synergy between the concepts that give rise to it, and its use in different fields of engineering and science. With search engines and bibliographic software, the evolution in the number of works that use Blockchain is shown firstly and, secondly, the conceptual relationships that give support.

The novelty of this article lies in its comprehensive approach to mapping the applications of blockchain technology across multiple fields, supported by a systematic review of recent literature (2021–2023). Unlike prior reviews focusing on specific domains such as finance or healthcare, this work integrates insights from various sectors, emphasizing cross-disciplinary trends and shared challenges. By analyzing a diverse set of peer-reviewed articles, this study identifies emerging patterns, highlights underexplored areas, and provides a foundational reference for understanding blockchain's transformative potential. This integrative perspective allows for a broader understanding of how blockchain technology drives innovation and addresses challenges in an increasingly interconnected and digitalized world.

This review adopts a broad scope to explore the diverse applications of blockchain technology across multiple sectors, such as finance, healthcare, energy, and supply chain management. Doing so aims to provide a foundational understanding of the state of the art and highlight potential areas for specialized research. The document serves as a reference for further studies. The article is structured as follows: Section 2 shows the materials and methods used in this review. Section 3 contains the results; Section 4 contains the discussion; and finally, Section 5 contains the conclusions and references [2].

2. Materials and methods

The methodology used in this article is a classic literature review, where articles corresponding to a time window of the years 2021–2023 were used. The search time is justified since a previous review is fruitless because until then, the concept had not been used. The database to be used is Scopus and Web of Science, where keywords are used to search for articles related to the topics related to the topics named in this article. Fig. 1 shows the work flowchart, three large stages previously fed with processes associated with the review.

The flowchart shown in the figure consists of 4 stages. The first stage is the definition of the related keywords. A preliminary literature search determines the relevant keywords in the investigations. The keywords used were: Blockchain, the key technology in this article; COVID-19, stage, and scenario where the technology took force worldwide in all commercial and non-commercial sectors; Artificial Intelligence, Cryptocurrencies, bank accounts, security, algorithms, and privacy. With these keywords, we searched in specialized engines such as Scopus, Science Direct, and Web of Science; the time window was between 2021 and 2023. The conceptual correlation between keywords, the areas where this type of technology is used, and its use as an advantage or disadvantage within the reviewed literature. The results obtained are shown below.

3. Results

The strategic selection of the time window for our literature review covers 2021 to 2023. It emerges as a critical element in the contextualization of the results of this research. During this period, there was a dizzying expansion in the adoption and understanding of blockchain technology in various sectors. The growing relevance of Blockchain as a disruptive innovation has redefined paradigms in areas ranging from data management to cybersecurity. The literature review is presented as a deep dive into relevant

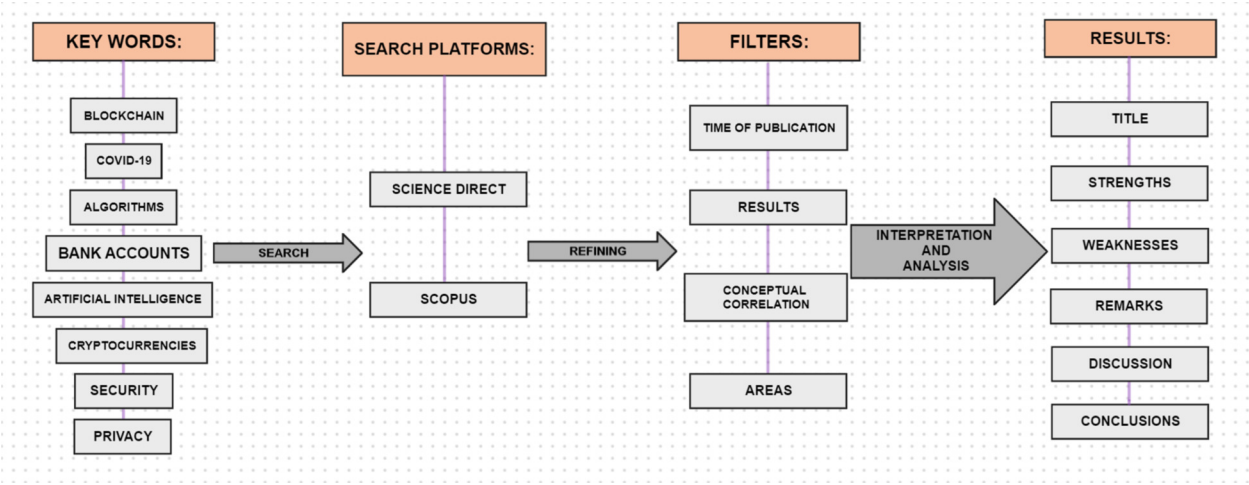

Fig. 1. Flowchart of revising the state-of-the-art. *Source*: Authors.

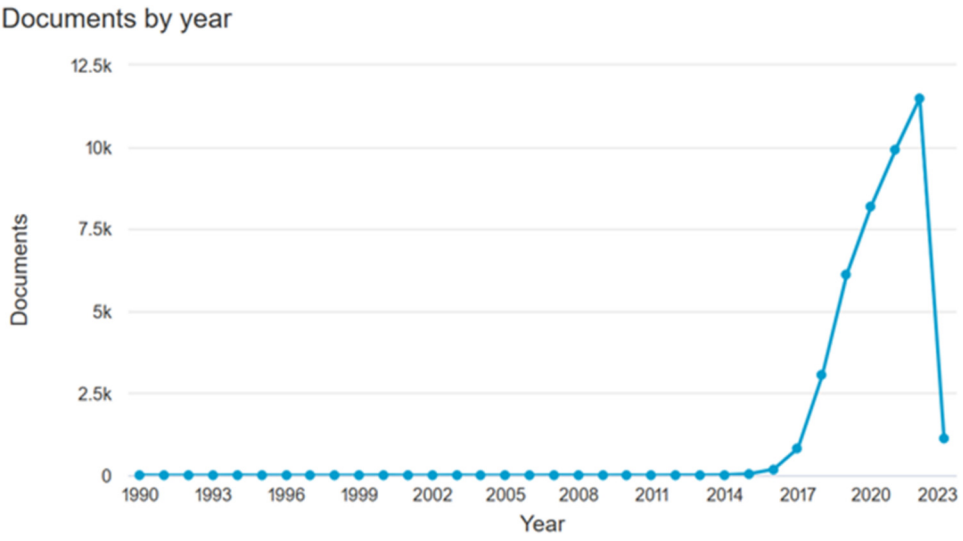

Fig. 2. Documents by year with central theme Blockchain. *Source*: Authors.

literature, addressing the advances and challenges in implementing and evolving Blockchain in the global technological and business landscape.

Fig. 2. shows the number of works with Blockchain as the primary research topic. From 1990 to 2011, blockchain technology was not used systematically. Blockchain technology became known through cryptocurrency transactions due to its security and reliability, and subsequently (2021) became one of the safest technologies for application in various existing business sectors.

The upward trend in Blockchain-related jobs since 2018 and its increase from 2021 can be attributed to several key factors:

Cryptocurrency boom: In 2018, cryptocurrencies such as Bitcoin and Ethereum gained significant global attention. These digital currencies use blockchain technology as a foundation, which led to an increased demand for professionals who understand this technology to develop and maintain these networks.

Expansion of use cases: Blockchain technology proved helpful beyond cryptocurrencies. Applications began to be explored in various sectors, such as logistics, healthcare, supply chain management, and electronic voting. This generated a growing demand for Blockchain experts who could apply this technology in various contexts.

Investment and financing: Companies, investors, and Blockchain technology projects received considerable investments. Large corporations and startups embarked on blockchain development projects,

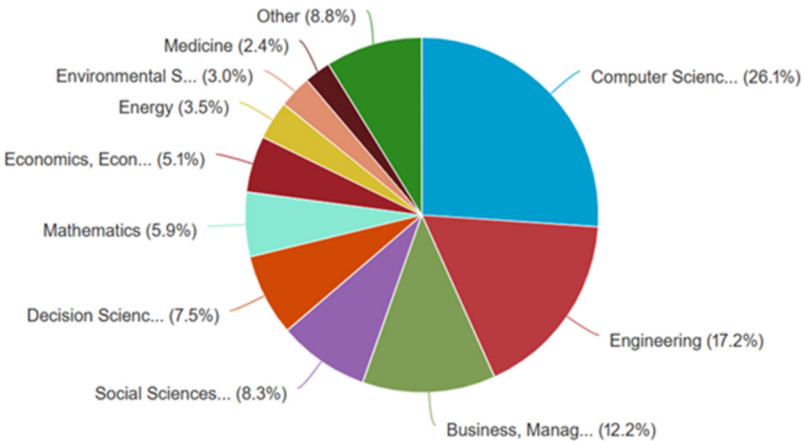

Fig. 3. Percentage of jobs using Blockchain in different disciplines. *Source adapted from Web of Science*: Authors.

which increased the need for skilled professionals in this field.

Technological maturity and regulation: As blockchain technology matured and governments established more explicit regulatory frameworks, greater confidence in its adoption was generated. This attracted more commercial players towards Blockchain technology, further driving the demand for specialized talent.

Pandemic crisis: The COVID-19 pandemic highlighted the importance of digitization and data security in various industries. This further drove the adoption of technologies such as Blockchain to ensure records' integrity and transactions' security in an increasingly digital environment.

In terms of the areas where Blockchain is applied, there is a broad spectrum of applications and generation of investigative documents such as research articles, book chapters, and books. Fig. 3 shows the percentages of the sectors in which Blockchain is applied. The sector that best seizes this technology is computer science, with 26.1%, followed by engineering, with 17.2%. This indicates that innovation and documentation focus on technology, Artificial Intelligence, robotics, and transactions.

The figure shows the different sectors in which Blockchain technology is used in the field of industrial engineering, software, communication, and systems (17.2%), business, management and accounting (12.2%), in social sciences such as telecommunications policy and its applications in society (8.3%), in decision science and strategies for better decisions (7.5%), in the different fields of mathematics (5.9%), economics and finance (5.1%), among other commercial sectors (18%).

Using heat maps and tools like VOSviewer provides a valuable advantage in analyzing data and visualizing key relationships in complex information sets. These heat maps, often used in bibliometric and network data analysis, visually highlight patterns and trends in data, allowing for a deeper and more efficient understanding of information. With VOSviewer, a tool specially designed to analyze and visualize networks and relationships in bibliometric data, the most relevant keywords and connections between research topics or areas of interest can be identified. This makes it easier to identify emerging trends, spot academic collaborations, and make informed decisions. In addition, the ability to adjust heatmaps according to user preferences and needs makes this combination of tools a powerful ally in research, strategic planning, and decision-making in various fields, from science to business. Below are different heat maps that reference the conceptual relationship between Blockchain and 4.0 technologies and IoT.

According to Fig. 4, heat map. You can see the purpose of this type of graph and the incidence of the keywords that are most used when writing about Blockchain and banking activities. Words such as transparency, banking systems, financial service, digitalization, electronic money, and accounting, among others. The relationship between these words is that, by providing greater transparency, efficiency, and security, Blockchain has the potential to alter the banking and financial industry significantly. These figures were made with the VOSviewer Software, choosing the keywords most used in the literature, and linking Blockchain with different topics you want to study. Blockchain technology has evolved thanks to Bitcoin, the security in the transactions of cryptocurrencies to other users. This technology has advanced since it expanded to different commercial sectors, being the most reliable technology known today due to characteristics that stand out from other computer technologies.

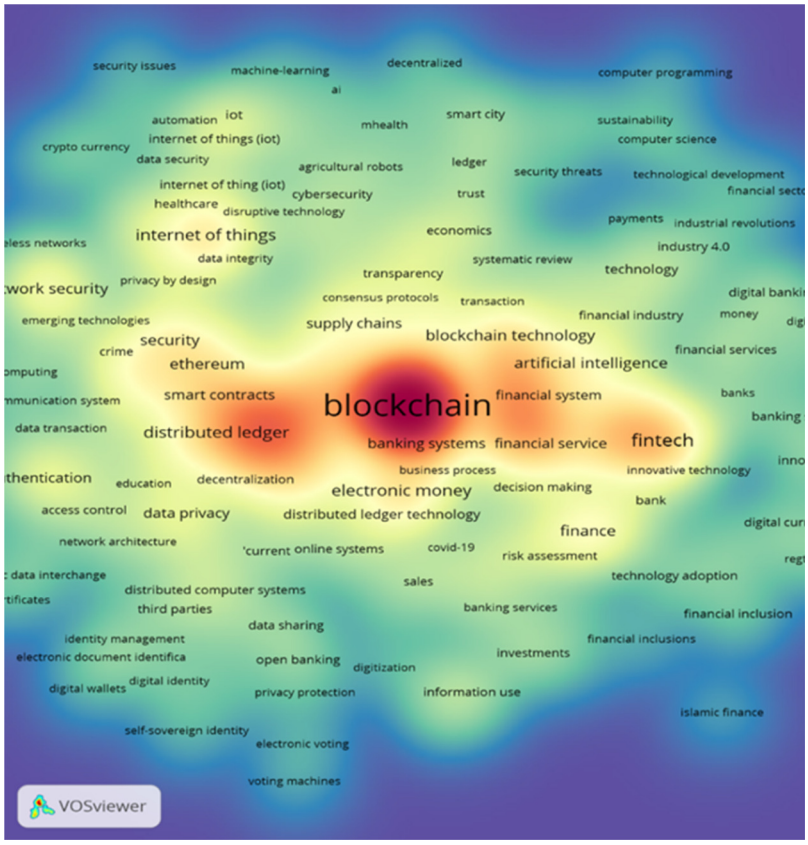

Fig. 4. Conceptual heatmap and related keywords: Blockchain and Banking. *Source*: Own.

Fig. 5 shows how Blockchain technology extends comprehensively to various fields, ranging from real-time systems to complex simulations and diagnostics, as well as computer security, cybersecurity, and data analysis. As a result of these qualities, it is not surprising that Blockchain technology has managed to stand out today.

According to Fig. 6, the most related words when talking about Blockchain and the economy are observed. Blockchain technology is also based on the application of the digital economy that facilitates the optimization of the commercialization of economic goods and services, such as the transaction of cryptocurrencies, political economy, and automation for the optimization of processes to minimize fraud and corrupt processes, to improve the tourism industry and modernize the digital world.

According to Fig. 7 and Fig. 8, artificial intelligence, together with Blockchain, has helped the automation of all health sectors, such as computer sectors; many of these machines and the technology that correlates with AI have supported the optimization of various human activities and facilitated them.

During the COVID-19 pandemic, society had to adapt to the digital age, which implied significant changes in daily life. One of these remarkable changes occurred in the field of medicine. A few years ago, it was hard to imagine that we could work from home, take classes through a computer, or even have a doctor's visit through a mobile device. However, the confinement made these situations become a palpable reality. Life as we knew it underwent a radical transformation, and during this change, Blockchain technology, innovation, and people's creativity played a pivotal role.

When discussing modernization or the digitalization of the world, it is inevitable to go back a little and remember how the COVID-19 pandemic forced society to make significant adjustments. Online learning modalities emerged telemedicine was adopted, and work from home was encouraged. Of course, this process created challenges and destabilized many economic and social countries. However, it also led to solutions that allowed people to keep their jobs, continue their studies, and maintain effective communication. Below is the literature review carried out to address the strengths and weaknesses of the research to date that addresses Blockchain in different topics.

Table 1 shows articles about Blockchain, how Blockchain technology was applied in these projects,

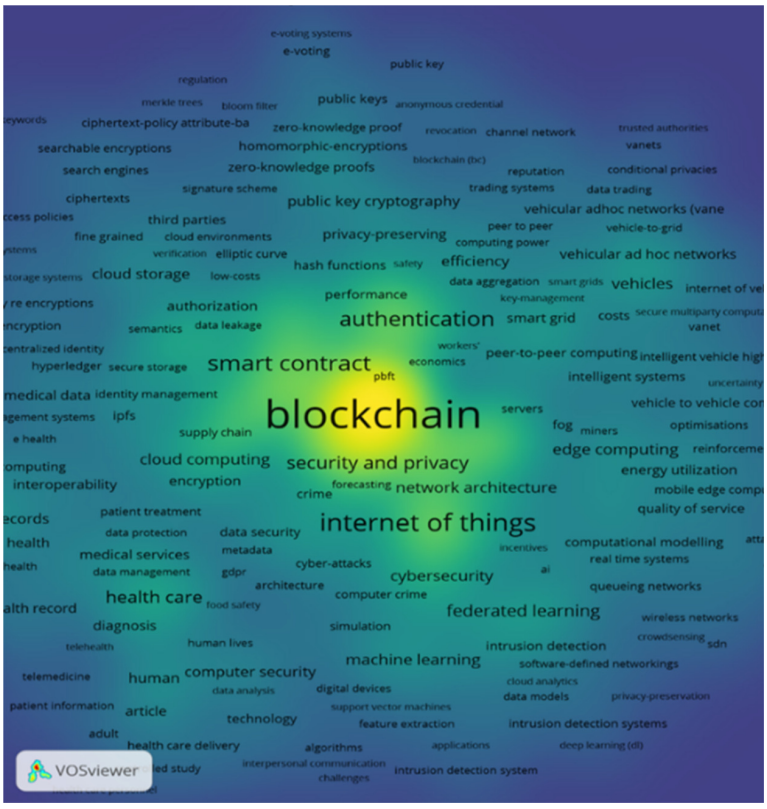

Fig. 5. Conceptual heatmap and related keywords: Blockchain, privacy and security. *Source*: Own.

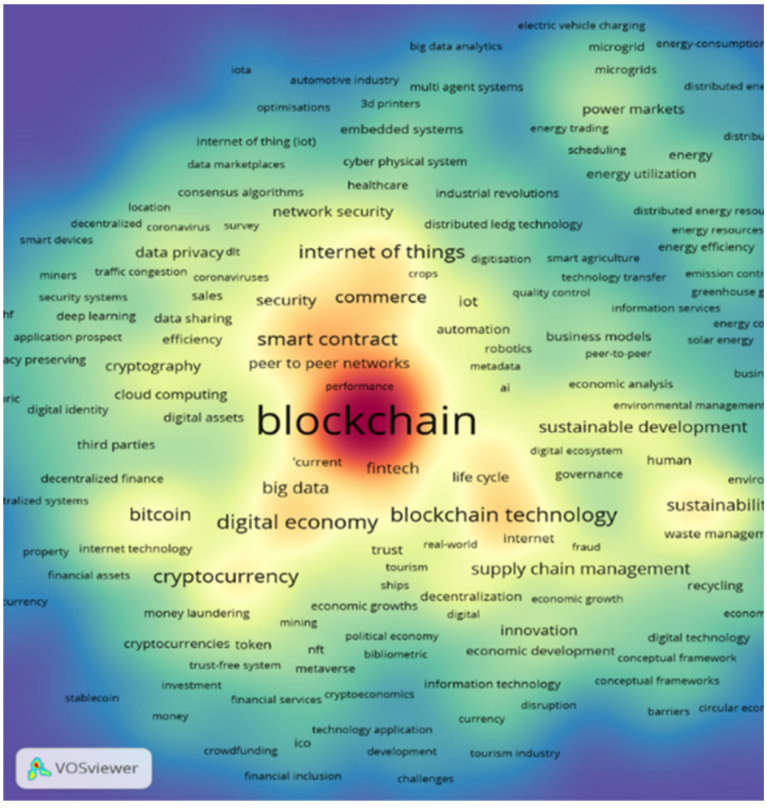

Fig. 6. Conceptual heatmap and related keywords: Blockchain and economy. *Source*: Own.

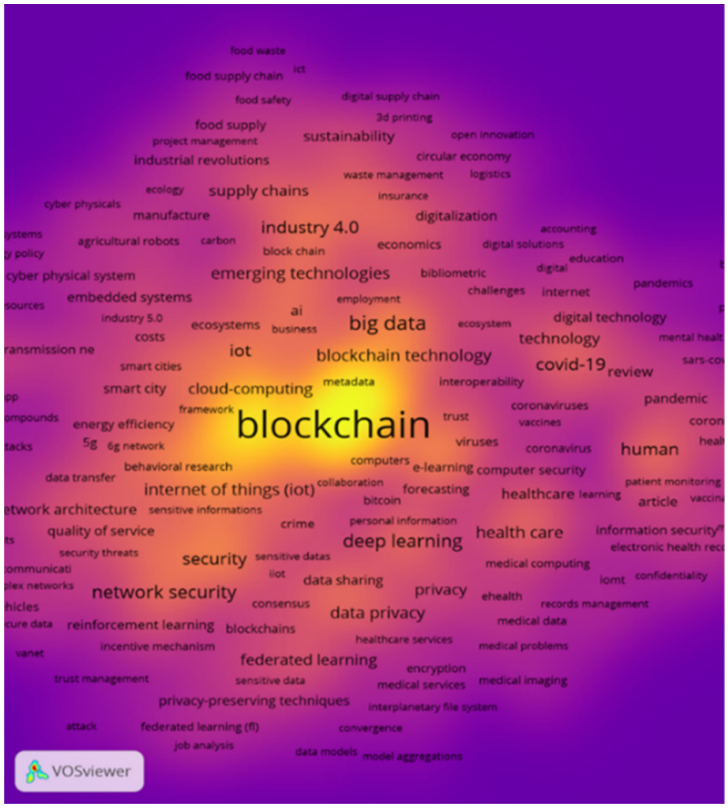

Fig. 7. Conceptual heatmap and related keywords: Blockchain and artificial intelligence. *Source*: Own.

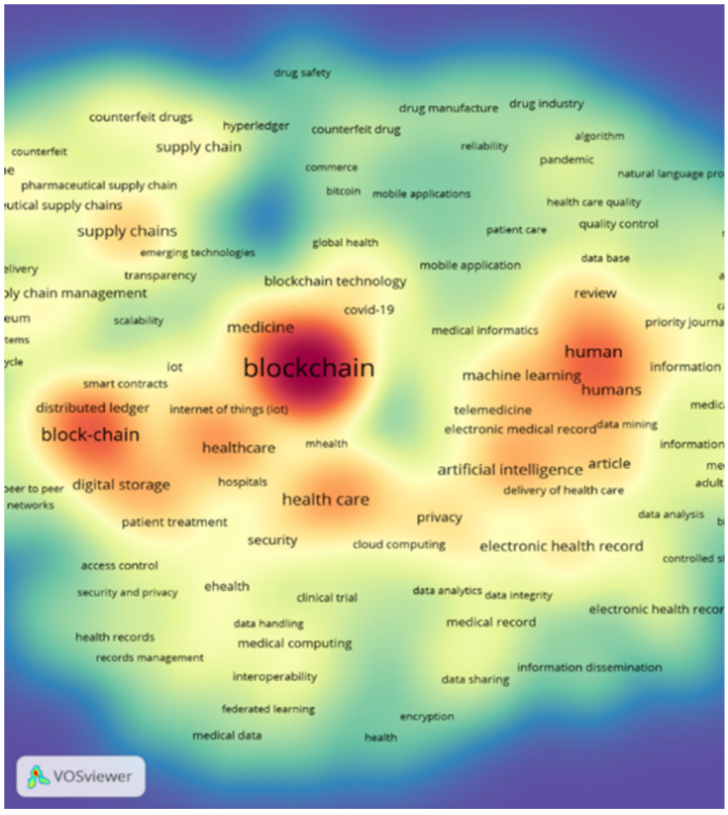

Fig. 8. Conceptual heatmap and related keywords: Blockchain and medicine. *Source*: Own.

Table 1. List of works that make use of Blockchain technology.

	Title	Strengths	Weaknesses	Remarks	Year
1	Estimation of the success probability of a malicious attacker on the blockchain-based edge network. [1]	The strengths we found are that these investigations assure us that 51% of the possible types of attacks that occur in this medium and on these platforms are covered, as well as finding solutions to these cyber-attacks.	However, the weaknesses are that we find a puzzling percentage (49%) of possibilities of cyberattacks that are not covered and that they do not know how much impact on the security of the platforms it may have.	This type of research and studies make Blockchain platforms more secure over time; thanks to these studies, we can trust the reliability of what is done on these platforms, although we cannot be sure of the security they provide today.	2022
2	What Blockchain can and cannot do: Applications to marketing and privacy [6]	The strength of this research varies greatly, as this study identifies that this Blockchain increases its ability to protect the privacy and control of users, as well as the security of Bitcoin transactions.	The weaknesses and strengths vary in the sector that this is used since, in marketing applications, these benefits are not applied much.	This research is mainly focused on identifying how, from an economic perspective, they can find a technological solution to the implementation of Blockchain in the use cases in cryptocurrencies and an incentive system ("consensus rules").	2022
3	An empirical study for blockchain-based information sharing systems in electronic health records: A mediation perspective. [7]	The strength of this system is that it is safer than what is always used in hospitals, the EHT system. This, being Blockchain technology, is more reliable, safer, and more reliable.	The weakness is that it is just a study that's in mockup.	This research goes beyond the financial sector; it is more focused on the health industry, well, not directly, but indirectly, with personal and confidential data of that sector.	2022
4	Blockchain technology and gender equality: A systematic literature review. [8]	The strength of this prototype is that it helps centralize the Blockchain system in the social sphere, managing gender equality and inclusion processes guiding corporate governments.	It is a prototype.	This research is focused on potentiating the social field that Blockchain can do in systems; this prototype can become proof of the progress of Blockchain beyond financial or economic systems.	2022
5	A novel fraud detection and prevention method for healthcare claim processing using machine learning and blockchain technology. [9]	The strength of this study is that it goes beyond the ordinary since it specializes in avoiding and preventing health fraud, and the best thing is that it has an accuracy of 97.96%, innovative and accurate.	The weakness is that it is not found in all countries, although we want to reach these developed and developing countries.	This research would be beneficial in all countries where it is applied.	2022
6	Role of blockchain technology in the transactive energy market: A review. [10]	The strengths are that this perspective is complete, direct, and focused on efficiency, safety, and transparency.	The weakness is that it is a prototype and has not been implemented for energy transactions.	In addition to being innovative, this system connects with other types of technology, IoT and Blockchain technology, showing the objectives and solutions of various approaches used in the energy market.	2022
7	Does the corporate social responsibility of the service based on Blockchain technology affect the consumer's actual behavior? [11]	The strengths are that the results of this research positively influence the consumer's attitude, behavior, and behavioral intent.	Its weaknesses are that the study is incomplete since it does not specify how this influences companies.	This research studies the company's behavior, the consumer, responsibility, and the relationship between them and Blockchain technology.	2022

(*continued on next page*)

Table 1. Continued.

	Title	Strengths	Weaknesses	Remarks	Year
8	High interest, low adoption. A mixed-method investigation into the factors influencing organizational adoption of blockchain technology. [12]	The strengths we found are that the research results are good from the perspective of Blockchain since many factors positively influence the implementation of this technology.	Its weaknesses are that the research, besides being positive, is minimal for the global context.	This research studies the factors that influence the implementation of Blockchain technology and the results that drive companies to implement this technology.	2022
9	Blockchain technology for efficient data management in healthcare system: Opportunity, challenges, and future perspectives. (Singh et al., 2022)	Strengths are the positive characteristics of implementing Blockchain in any scope or environment.	Its weakness is that it has no development goal to advance this research.	This research focuses on studying how Blockchain technology helps in different environments.	2022
10	6G technology and taxonomy of attacks on blockchain technology. [13]	The strengths of this research are the studies they conducted to discuss the attacks, vulnerabilities, and possible solutions of blockchain technology.	Its weakness is that it has not been tested in different environments to define the appropriate solutions to these vulnerabilities.	This research studies Blockchain technology in aspects of human life and in the applications in which it is applied.	2021
11	Survey of security supervision on Blockchain from the perspective of technology. [14]	The strengths of this study are the protective measures to prevent cyber-attacks on Blockchain technology and identify these attacks.	Its weakness is that it has not been tested in different environments to define the appropriate solutions to these attacks.	This research studies attacks on financial transactions and cyber-attacks.	2021
12	Blockchain in healthcare and health sciences—A scoping review. [5]	The strength of this study is that it shows the advancement of Blockchain technology in the healthcare environment and areas within it.	Its weakness is that it has not been implemented to notice its shortcomings and benefits.	This research is focused on the advancement and use of Blockchain in the healthcare environment.	2019
13	A review of Blockchain Technology applications for financial services. [3]	The strength of this study is that it identifies the positive characteristics of Blockchain technology in the financial and economic field, in addition to the significant impact on the financial life of users.	Its weakness is that the limits of this research are that its Blockchain technology cannot adequately handle some of the essential problems related to each application (citation).	This research focuses on Blockchain technology and its importance for financial services.	2022
14	A survey of Layer-two blockchain protocols. [15]	The strengths of this research help systematize knowledge dispersed in the domain and will help readers better understand the field of Blockchain layer two protocols.	Its weakness is the prone attacks on the security and privacy of different layer two protocols.	This research created a broad taxonomy of protocols and implementations, as well as their approaches and outstanding characteristics.	2022

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Table 1. Continued.

	Title	Strengths	Weaknesses	Remarks	Year
15	Blockchain's roles in strengthening cybersecurity and They are protecting privacy. [2]	The strengths of this research are the analysis and detailed description of Blockchain's functions to track the sources of insecurity related to Lot devices.	Its weakness is that it is a study that has not transcended more since the year of its study.	This research evaluates the functions of Blockchain to strengthen cybersecurity and protect users' privacy, in addition to comparing the performance of Blockchain in the cloud in various aspects of security and privacy.	2017
16	Copyright in the blockchain era: Promises and challenges. [16]	There are several strengths, among which we find the ability to combine the simplicity of the application of commons / open licenses, facilitating the compensation of authors.	This study has weaknesses as well as strengths. Its weaknesses are that a proper balance cannot be found between the immutable nature of blockchain records and their necessity.	This study reveals several legal aspects of the application of Blockchain technologies in the field of copyright.	2018
17	The Impact of Profit Uncertainty on Miner Decisions in Blockchain Systems. [17]	Its strengths are that this study demonstrated uncertainty about the cost of transactions, although they could not demonstrate the impact of this uncertainty.	Its weaknesses are that, in any product, it has its limitations, which in this case are limitations in its transactions.	The main objective of this project is to investigate the uncertainty of miners' income and the cost of executing transactions and their impact.	2018
18	Blockchain energy: Blockchain in future energy systems. [4]	Its strengths are that this paper highlights the transition's performance potential by offering decentralized interfaces and systems and its alternative approach to organization.	Its weakness is that it has not been implemented, although it is a complete study.	This study analyzes the applicability and prospects of blockchain-based technologies in the energy sector (Blockchain energy).	2019
19	Blockchain, business and the fourth industrial revolution: Whence, whither, wherefore, and how? [18]	The strengths of this study are that it takes broad approaches in analyzing the perspectives on Blockchain in its various development functions and reflects on how to make the most of this technology.	Its weakness is that it has no development goal to advance this research.	The objective of this study is to review the literature to understand the shortcomings and opportunities presented by Blockchain in some business functions.	2020
20	Blockchain breeding grounds: Asia's advance over the USA and Europe. [19]	This study's strengths include examining the scenarios of Blockchain patents in the United States and Asia, their differences, the advances in each, and the results.	Its weakness is that it has no development goal to advance this research.	This study will study the potential that Blockchain has demonstrated over time and throughout its application.	2021

Source: Own.

and the observations of the articles and their year of completion.

Table 1's main objective is to provide a preliminary view of the advantages and disadvantages associated with implementing Blockchain technology in a wide range of commercial and non-commercial sectors. Its usefulness lies in the fact that it allows us to see the areas in which this innovative technology can offer substantial added value and the indications that could arise in its application in different contexts. In addition, this tool allows us to make projections about the future growth and expansion of blockchain technology's advantages. As blockchain technology continues to evolve, the advantages will likely expand and intensify, making its tracking essential to stay current in an increasingly digital, efficient, and transparency-oriented world.

To support the comprehensive analysis of blockchain applications across various fields, a curated selection of key references has been compiled.

These references encompass diverse areas such as engineering, healthcare, and exact sciences, providing a broad perspective on the advancements, challenges, and potential of blockchain technology. The selected studies highlight theoretical foundations, practical implementations, and interdisciplinary applications, offering valuable insights into the transformative impact of blockchain. The following table categorizes these references by their objectives, strengths, and weaknesses, facilitating a structured understanding of their contributions to the field.

Additional studies reinforce the transformative potential of blockchain across various domains. For instance, [50] explores blockchain's role in enabling decentralized applications beyond cryptocurrencies. [51] investigate blockchain's application in enhancing cybersecurity frameworks. [52] delves into the scalability challenges of blockchain systems, proposing novel architectural solutions. [53] analyze blockchain's integration in smart cities, emphasizing its role in resource optimization. [54] focus on blockchain's potential to improve supply chain transparency, highlight the use of blockchain in digital identity management, addressing issues of privacy and security.

The literature review is based on the most used words in this article and on other articles that were investigated; the figures presented above were beneficial, as they helped us better relate the incident words with the word "Blockchain" to analyze this better. The impact that Blockchain technology has had since its implementation as software reinforces the aspects of security, transparency, privacy, and performance, so currently, this technology is more required than other technologies; this was analyzed thanks to the articles on the Scopus platform, where we rely on to create a table where there is a brief description of what the article is, The strengths and weaknesses of each software with this type of technology.

4. Discussion

Blockchain technology has become a versatile tool that transcends the boundaries of financial transactions. In the commercial realm, Blockchain is used to improve supply chain management, ensure product authenticity, streamline audit processes, and provide traceability in the production chain. Additionally, in non-commercial sectors, such as healthcare and education, Blockchain has been deployed to protect medical records, verify academic credentials, and ensure the integrity of health data.

Although Blockchain has great potential, it also presents significant challenges. One critical hurdle is scalability, as the amount of data stored on a blockchain can be limited compared to traditional databases. In addition, security and privacy must be approached with care, as the immutability of records can pose problems if sensitive data is stored incorrectly. Widespread technology adoption may also require significant changes in infrastructure and government regulations.

As Blockchain technology continues to evolve, its advantages are expected to expand and intensify. Decentralization and resistance to manipulation will continue to be valuable in an increasingly digital world oriented towards efficiency and transparency. Blockchain technology is also driving the emergence of new applications, such as cryptocurrencies and smart contracts, which promise to change further how we interact with information and digital assets.

Literature review is essential to assess the impact and relevance of Blockchain technology. By analyzing keywords and reviewing related articles, you can gain deeper insight into how this technology is being used and how it is evolving. In addition, the figures and tables presented in previous research can help to visualize better and understand concepts related to Blockchain, making it easier to analyze and apply them in different contexts.

In conclusion, this article has highlighted the profound impact of Blockchain technology on various spheres of society over the years. Its usefulness has been underscored by offering an overview of its benefits, strengths, and weaknesses, providing a complete understanding of its potential and limitations.

In addition, this technology's crucial relevance during the COVID-19 pandemic and in the years after has been underlined. At a time when the world was forced to adapt to drastic changes and unprecedented challenges, Blockchain technology emerged as a fundamental tool that drove digitization and automation globally, benefiting both individuals and organizations.

Since its conception, blockchain technology has been a critical driver for digitization, innovation, and automation worldwide. Its ability to strengthen the security and reliability of digital transactions and safeguard users' information and assets has significantly contributed to the evolving technological landscape.

Table 2 shows a reference list across different fields in blockchain apiication. This comprehensive reference list aims to provide a structured overview of the current state of blockchain research, highlighting its diverse applications, unresolved challenges, and future opportunities. By synthesizing findings from multiple studies across different fields, the list serves

Table 2. Comprehensive reference list on blockchain applications, challenges, and opportunities across diverse fields.

Number	Reference	Objective	Higligths	To improve
Engineering				
1	[20]	Introduce the concept of blockchain for decentralized transactions.	He founded the concept of blockchain; basis for future studies.	Focused solely on cryptocurrencies.
2	[21]	Explore the challenges and opportunities in blockchain technology.	It provides a broad framework of blockchain applications.	It does not include detailed empirical analysis.
3	[22]	Conduct a systematic review of blockchain applications.	Clearly classify application areas and challenges.	Limited in practical implementation analysis.
4	[23]	Explore non-financial applications of blockchain.	It introduces multiple use cases outside of cryptocurrencies.	It lacks recent data on its adoption.
5	[24]	Evaluate how smart contracts can manage energy networks.	Useful for decentralized energy systems.	It is limited to the energy sector, it does not cover other applications.
6	[25]	Explore how to integrate blockchain and IoT to improve traceability.	It combines relevant technologies for practical applications.	It requires more in-depth analysis of use cases.
7	[26]	Provide design principles for blockchain-based systems.	It offers practical guidelines for designing blockchain-based solutions.	Limited focus on financial applications.
8	[27]	Analyze the impact of blockchain on traceability and security in supply chains.	Focused on security and transparency.	Limited to the logistics sector.
9	[28]	Explore how blockchain transforms digital supply chains.	It examines a growing sector.	No practical examples.
10	[29]	Review blockchain adoption in manufacturing.	Explore efficiency and transparency in manufacturing.	Little emphasis on implementation costs.
11	[30]	Assess the relevance of blockchain in industrial automation.	Innovative for Industry 4.0 applications.	Limited to theoretical cases.
12	[31]	Explore how blockchain improves energy management.	Useful for renewable integration.	It requires more empirical data.
13	[32]	Investigate the relationship between artificial intelligence and blockchain.	Relevant for joint technical developments.	Theoretical, with few real cases.
14	[33]	Identify use cases in logistics.	It addresses relevant sectors of the supply chain.	It does not include longitudinal studies.
15	[34]	Analyze the impact on traceability in construction.	Innovative in a little-studied sector.	Limited to initial concepts.
Health				
16	[35]	Explore the use of blockchain in health data management.	It offers security and traceability solutions.	No testing on complex systems.
17	[36]	Assess the potential of blockchain in healthcare.	Innovative for electronic health records.	No recent data.
18	[37]	Review current applications in health.	Comprehensive and well-structured review.	Empirical analysis is lacking.
19	[38]	Provide secure systems for sharing medical data.	Combination with IoT.	No large-scale applications.
20	[39]	Design a system for personal medical records.	Innovative and privacy-focused.	Requires testing in multiple regions.
21	[40]	Improve integrity and traceability in investigations.	Relevant to clinical trials.	No cost analysis.
22	[41]	Examine how blockchain optimizes data management.	Promotes security in e-health systems.	Limited to theoretical analysis.
23	[42]	Design a blockchain-based clinical data sharing system.	Promotes interoperability in health.	No practical implementation.
24	[43]	Explore general applications in health.	Innovator in clinical trials.	Review limited to one sector.
25	[44]	Identify emerging areas of use in health.	It covers various applications.	Limited in depth.

(*continued on next page*)

Table 2. Continued.

Number	Reference	Objective	Higligths	To improve
Exact sciences				
26	[45]	Provide a framework for blockchain-based scientific research.	Useful for structuring scientific research.	Limited focus on theoretical foundations.
27	[46]	Explore the impact of blockchain on science.	It introduces key concepts for scientific applications.	It lacks specific analysis.
28	[47]	Provide mathematical foundations for blockchain security.	Analyze mathematical security in blockchain systems.	Theoretical without practical cases.
29	[48]	Review research in cryptography applied to blockchain.	Innovative for cryptographic optimization.	Little focus on applications outside of cryptography.
30	[49]	Explore fundamentals of digital currencies and blockchain.	Theoretical basis for scientific applications.	Limited to the financial context.

as a valuable resource for both researchers and practitioners. It underscores the interdisciplinary nature of blockchain, showcasing its integration with emerging technologies like artificial intelligence, the Internet of Things, and renewable energy systems.

Ultimately, this article underscores the importance of continuing to monitor and explore the ever-evolving applications of Blockchain technology. As this technology continues to mature and adapt to society's changing needs, it is essential to be aware of its developments and potential in an increasingly digitized world oriented towards efficiency and transparency. With its ability to promote reliability and security in digital transactions, blockchain technology remains a transformative force in the modern era.

5. Conclusions

Blockchain technology has proven to be a transformative tool with significant applications in key sectors such as finance, healthcare, energy, and supply chain management. This study, based on a systematic review of recent literature (2021–2023), highlights the advancements and challenges associated with its adoption. The key findings are summarized as follows:

1. Enhanced Security and Transparency: Blockchain's ability to provide immutable and decentralized data storage has demonstrated its effectiveness in improving trust and transparency in financial systems, clinical data management, and energy distribution networks.
2. Multisectoral Adoption: Initially associated with cryptocurrencies, blockchain technology has expanded its scope across diverse domains, establishing itself as an adaptable solution to address industry-specific challenges.
3. Synergy with Emerging Technologies: Integration with the Internet of Things (IoT) and artificial intelligence (AI) has enhanced blockchain's capacity to automate processes, analyze large datasets, and improve decision-making in complex environments.

Despite these advancements, significant challenges remain, including scalability limitations, high energy consumption, and the lack of clear regulatory frameworks. Addressing these barriers is imperative for broader and more sustainable adoption of blockchain technology.

The development and application of blockchain must focus on targeted solutions that overcome current challenges and maximize its potential impact in strategic sectors. The following areas are identified as priorities for research and development:

- Energy-Efficient Algorithms: Design and implementation of consensus algorithms that reduce energy consumption while maintaining network security.
- Scalability Solutions: Development of technologies such as sharding or Layer-2 protocols to handle significantly higher transaction volumes.
- Interoperability Standards: Establishment of frameworks that enable seamless communication between different blockchain platforms, fostering adoption in critical sectors such as healthcare and logistics.
- Policy and Regulation: Collaboration with policymakers to define clear guidelines that promote innovation while ensuring security, privacy, and user protection.
- Social and Global Impact: Exploration of blockchain's potential to address global challenges, such as digital inclusion, secure identity systems, and equitable access to technological resources.

The success of blockchain technology depends on the collective efforts of researchers, industry stakeholders, and governments to address current limitations and explore new applications. Its evolution will not only redefine traditional sectors but also lay the groundwork for a more secure, transparent, and efficient digital economy.

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