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DECODING THE COST FACTORS OF BLOCKCHAIN THROUGH DIGITAL TRANSITION – INSIGHTS FROM A SYSTEMATIC LITERATURE REVIEW OF THE YEARS 2020-2024

A BLOKKLÁNC KÖLTSÉGTÉNYEZŐINEK DEKÓDOLÁSA A DIGITÁLIS ÁTMENET SORÁN – SZISZTEMATIKUS IRODALMI ÁTTEKINTÉS A 2020-2024 ÉVEK ALAPJÁN

The authors' research objective was to investigate the use of blockchain technology in the financial industry, considering its associated costs. They conducted a systematic literature review in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews) guidelines, selecting 74 relevant articles. Using thematic keyword analysis with VOSviewer, they developed a Conceptual Framework for Blockchain Cost Impact in the Financial Industry and categorized the costs into three categories: Technology Development and Maintenance Costs, Testing and Quality Assurance, and Compliance and Legal Costs. This framework aims to facilitate future research and practical applications by identifying cost efficiencies and navigating regulatory challenges, ultimately supporting informed decisions on blockchain's integration in the financial sector.

Keywords: **blockchain, compliance, cost, financial industry, SLR (Systematic Literature Review)**

A szerzők kutatásának célja a blokklánc-technológia pénzügyi szektorban történő alkalmazásával összefüggő költségek feltérképezése. A PRISMA (Preferred Reporting Items for Systematic Reviews) irányelvek mentén rendszerezett irodalmi áttekintést végeztek, amely során 74 releváns tanulmányt választottak ki elemzésre. A kulcsszavak tematikus elemzéséhez a VOSviewer szoftvert használták, amely alapján kidolgozták a blokklánc pénzügyi iparágra vonatkozó költséghatási koncepcionális keretrendszerét. A feltárt költségtípusokat három fő kategóriába sorolták: (1) technológiai fejlesztési és fenntartási költségek, (2) tesztelési és minőségbiztosítási költségek, valamint (3) megfelelési és jogi költségek. A keretrendszer célja, hogy elősegítse a további kutatásokat és gyakorlati alkalmazásokat a költséghatékonyság azonosításával és a szabályozási kihívások kezelésével, támogatva a megalapozott döntéshozatalt a blokklánc pénzügyi szektorba történő integrációjában.

Kulcsszavak: **blokklánc, megfelelés, költség, pénzügyi szektor, SLR (Systematic Literature Review)**

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The global economic turbulence due to the recovery from the pandemic and the unstable of political issues has catalyzed an unprecedented shift in digital behaviors and accelerating the adoption of innovative technologies across various sectors (Gupta & Kumar, 2021). Blockchain technology has emerged as a solution in this rapidly evolving context as businesses and financial institutions seek resilient, transparent, and secure systems (I. Ahmad et al., 2020; Basori & Ariffin, 2022), which are also related to the energy sector and economic adjustment in the financial sector (Rákos et al., 2022).

To address this issue, we employ a Systematic Literature Review (SLR) methodology, refining the articles from 2020 to the present using highly reputable databases. In this research, we propose a comprehensive definition of blockchain cost that transcends traditional monetary and physical expenses. Our primary research addresses the following question: "What are the specific costs associated with implementing Blockchain technology, especially in the financial industry?" By exploring this question, our research aims to dissect the cost components of blockchain implementation, identify the key drivers of its impact, and provide a comprehensive analysis to contribute to further research direction of the post-pandemic situation, which offers a mix of challenges and opportunities for embedding blockchain technology within the core of mainstream financial industry.

Blockchain's increasing applicability in business environments is largely attributed to its distinctive technological features. As a decentralized and immutable ledger system, blockchain eliminates the need for intermediaries, thereby reducing operational costs and increasing transaction speed (Zhang & Zhang, 2022). Its transparency and auditability make it ideal for industries requiring high trust and compliance, such as finance and supply chain management (Yin & Yang, 2023). Additionally, the integration of smart contracts – self-executing contracts with predefined rules – enables automated processes and reduced administrative burdens (Shamsi et al., 2022). These features support enhanced traceability, security, and operational efficiency, which are critical for business scalability and risk mitigation. This technological foundation explains the surge of scholarly and practical interest in blockchain's economic viability and cost structure.

Our research stems from the work of Onjewu et al. (2023), which presents a groundbreaking shift in understanding blockchain technology's economic and strategic impacts, moving beyond its initial applications to address broader organizational and societal challenges, introducing that blockchain technology can revolutionize traditional assumptions about agency theory. The implication of blockchain across various sectors, further supported by Kumar et al. (2023), focuses on integrating blockchain with IoT in logistics and supply chains, emphasizing the potential cost savings and security benefits of adopting blockchain-IoT systems, addressing the need for a strategic approach to technology adoption that prioritizes sustainability and emerging technology maturity. Further studies go deeper into behavioral drivers of blockchain assimilation and the challenges of digital transformation (Patil et al., 2023; Liyanaarachchi et al., 2024), proposing the importance of collaborative networks in reducing the costs associated with adopting new technologies and the need for balancing security with privacy and regulatory compliance, for minimizing the potential costs of non-compliance and consumer distrust. In our research, we concentrate on the cost implications of blockchain technology in the financial sector, drawing inspiration from a recent study by Gan and Lau (2024) and Biro et al. (2019), which underscores the essential role of trust in diminishing the costs tied to financial transactions and bolstering the adoption of blockchain technology that fostering a trustful environment can lead to significant decreases in both operational and reputational expenses for financial institutions.

Therefore, through this SLR, we anticipate offering comprehensive insights into the financial dynamics of blockchain technology during a critical period of global economic recovery.

Materials and methods

We use the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines (Hannan et al., 2023), which offer a widely recognized standard methodology, including a guideline checklist (Mengist et al., 2020). In alignment with best practices, we have based our methodology on the original PRISMA Statement (Moher et al., 2009) and the updated PRISMA 2020 guidelines (Page et al., 2021), ensuring transparency and rigor in our systematic review process. Our approach is aligned with other technology-focused systematic literature reviews that apply PRISMA standards, such as the study by Frizzo-Barker et al. (2020), which examines blockchain adoption using a similar structured review method. We developed a review protocol that detailed our criteria for article selection, search strategy, data extraction methods, and data handling.

Defining the focus and research question

The initial step of our systematic literature review (SLR) was to clearly define its focus, which is centered on exploring the costs associated with Blockchain technology from a corporate perspective. We concentrated on the financial implications of Blockchain in the business sector rather than delving into its detailed implementation or establishing a standard pricing model. The guiding research question was: "What are the specific costs associated with implementing blockchain technology in the financial industry?"

Data sources and search strategies

Our research involved systematic searches in the Scopus databases, recognized for their significance in scientific research. Scopus is one of the most comprehensive and reliable abstract and citation databases of peer-reviewed literature, known for its broad coverage across disciplines and high-quality indexing (Falagas et al., 2008). The

search was conducted by two independent researchers (P.N. and J.R.T.) using the initial keyword "blockchain" within the Scopus database. The data was extracted on January 22, 2024. To maximize the relevance and breadth of our search, we expanded our terms to include "blockchain and Expenditures," "blockchain and Company Costs," and "blockchain and Economic Impact," and applied Title Abstract Alignment (TAA) at the eligibility stage. Additionally, reference lists of eligible articles were manually reviewed to ensure comprehensive coverage of the literature.

Three researchers independently assessed the relevance of articles based on the TAA, using predefined criteria tailored to our research focus to ensure that the selected studies aligned with our research objectives. We excluded studies focusing predominantly on technical aspects without financial analysis, those unrelated to business applications, and non-English publications.

We established the final corpus for analysis by strictly adhering to the eligibility criteria and conducting a thorough review process. This research presents a carefully selected collection of literature that offers valuable insights into the costs of implementing blockchain technology in businesses. Figure 1 explains all the steps in the article filtering criteria derived from the PRISMA guidelines.

Figure 1

Documents filtering adapted from PRISMA

Identification	Keyword and syntax search "Blockchain" and "Financial"	Included : 1,801 documents Excluded : other not related documents
Screening	Document type: Articles	Included : 568 documents Excluded : other document type.
	Language: English	Included : 553 articles Excluded : other non-English articles
	Year of Publication: 2020–2024	Included : 451 articles Excluded : other non-English articles
Eligibility	Open Access or Accessible via University Network	Included : 235 articles Excluded : other articles not in open access.
	Title and Abstract Alignment (TAA)	Included : 74 articles Excluded : other articles not align to our research objectives.
Included	Total 74 articles are included in the further analysis	

Source: own compilation

Figure 1 illustrates a structured approach that ensures transparency and replicability in the selection process of our research, in line with the PRISMA guidelines for systematic reviews.

The identification phase began with a keyword and syntax search using "Blockchain" and "Financial," which yielded 1,801 documents. In the screening phase, we first refined this pool by document type, reducing the number to 568 articles. In our research, we have deliberately included only those documents classified as "articles" in our dataset. We ensure that articles undergo a rigorous double-blind peer review process to maintain objectivity and impartiality in their evaluation. After this articles filtering, we then applied language screening, further narrowing the selection to 553 articles written in English. The screening continued with a focus on the year of publication, specifically from 2020 to 2024, resulting in 451 articles. During the eligibility phase, we focused on selecting articles that were either open-access or accessible through our university's connection, narrowing our pool to 235 articles. The Title and Abstract Alignment (TAA) screening process further refined this selection to 74 articles that met our specific criteria for titles and abstracts.

Result and discussion

Descriptive analysis

In this subsection, we provide a valuable snapshot of the articles used in this research encompasses of blockchain cost analysis.

Figure 2

Overview of global blockchain research landscape (2020–2024)

Source: own compilation

Figure 2 displays the bibliometric indicators derived from a systematic literature review covering the years 2020 to 2024. The review has evidently amassed a substantial corpus of 74 articles. From these articles, a total of 647 keywords have been extracted, which will be further analyzed using clustering analysis. A notable collaboration is apparent from the involvement of 207 authors with 8 single-author articles. This collective scholarship is further emphasized by the correspondence with 22 different countries, pointing to a global interest and input into the research topic. The source materials for the review have been drawn from 56 different journals. A cross-disciplinary appeal and relevance of the research topic involvement of 33 publishers further underscores the breadth of the research community's interest in the subject matter.

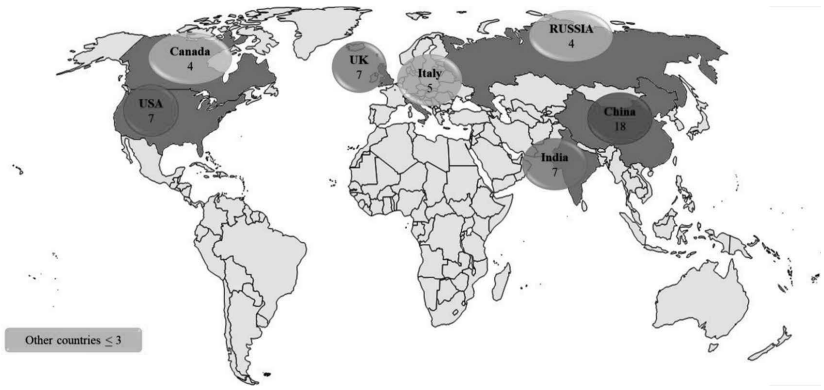
Geographic distribution of blockchain cost research

We also conducted a geographic analysis of the research output on the costs of blockchain technology, as illustrated

by the bar chart. This analysis is based on a dataset of 74 articles related to blockchain costs, sourced from the Scopus database.

Figure 3

Documents analysis by countries



Source: own compilation

Figure 3 illustrates that our analysis of the cost aspects in blockchain-related articles encompasses a total of 74 across 22 different countries, with certain countries contributing a larger number of articles than the rest. Notably, other countries (not listed in the provided data) cumulatively account for publications equivalent to 3 articles or fewer each. China leads with 18 articles, reflecting strong government-backed initiatives and strategic investments in digital finance and central bank digital currency (CBDC) research (Yin & Yang, 2023). The UK, US, and India each contribute 7 articles, indicating a balanced academic and industrial interest in blockchain's financial potential, often tied to their respective fintech ecosystems. Italy, Russia, and Canada follow with moderate but meaningful contributions. While the overarching motivation across these countries is the financial applicability of blockchain, the intensity and focus of research may be shaped by national policies, regulatory frameworks, or innovation funding (Artemenko & Zenchenko, 2021; Rico-Peña et al., 2023). A summary of these patterns offers a more concise view of global interest while acknowledging key contextual distinctions.

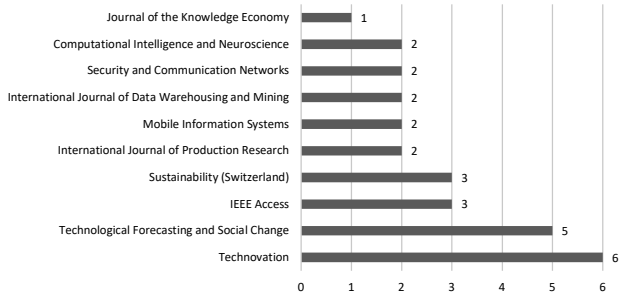
The disparity in article counts among countries may reflect several factors, including the extent of blockchain adoption in financial practices (Souissi et al., 2023; Yin & Yang, 2023), government support for technology innovation (Artemenko & Zenchenko, 2021), research funding availability, and the academic community's interest (Rico-Peña et al., 2023; Zhan et al., 2023). The predominance of certain countries suggests a more robust ecosystem supporting blockchain research, which could influence the direction of future studies and technological implementations in the financial sector.

Publication journal for blockchain research articles

Figure 4 shows the of article distribution by journal source on blockchain technology. Technovation emerges as the leading journal with 6 articles. This prominence could reflect the journal's focus on cutting-edge technological advancements and their impact on economic development and business practices. Technological Forecasting and Social Change follows closely with 5 articles, while IEEE Access and Sustainability (Switzerland) each contribute 3 articles. These journals' engagement highlights the multifaceted nature of blockchain cost research, encompassing both the technological underpinnings and the sustainability aspects of its implementation in the financial sector. International Journal of Production Research, Mobile Information Systems, International Journal of Data Warehousing and Mining, Security and Communication Networks, and Computational Intelligence and Neuroscience have published 2 articles.

Figure 4

Documents analysis by source of journal



Source: own compilation

To provide further insight into the scholarly impact of the key journals featured in our dataset, we include select metrics such as Impact Factor (IF) and Scimago Journal Rank (SJR) Quartiles. Technovation (IF: 12.0, Q1) and Technological Forecasting and Social Change (IF: 12.0, Q1) are leading journals known for their rigorous interdisciplinary focus on innovation and economic policy. IEEE Access (IF: 3.9, Q2) and Sustainability (Switzerland) (IF: 3.9, Q2) also show significant publication frequency and broad topical coverage, reflecting the interdisciplinary nature of blockchain research. These rankings indicate that the articles analyzed in this study are largely drawn from reputable, peer-reviewed sources with high visibility in their respective fields.

Nevertheless, it is essential to note that other journals not mentioned in the provided data cumulatively account for publications equivalent to 1 article or fewer each. The concentration of articles in certain journals may indicate areas of focused research interest or particular editorial policies supportive of blockchain technology studies. The involvement of a wide range of journals highlights the technology's potential impact across various sectors and disciplines, suggesting a broad academic engagement with blockchain technology. The Table 1 summarizes our finding in Figure 4.

Table 1

Impact factor and ranking of selected journals

Journal Title	No. of Articles	Impact Factor (IF)	SJR Quartile
Technovation	6	12.0	Q1
Technological Forecasting and Social Change	5	12.0	Q1
IEEE Access	3	3.9	Q2
Sustainability (Switzerland)	3	3.9	Q2
International Journal of Production Research	2	7.0	Q1
Mobile Information Systems	2	2.5	Q3
International Journal of Data Warehousing & Mining	2	1.9	Q3
Security and Communication Networks	2	2.2	Q3
Computational Intelligence and Neuroscience	1	2.3	Q3
Journal of the Knowledge Economy	1	1.8	Q3

Note: Metrics are based on Scopus and Journal Citation Reports (2023/2024)

Source: own compilation

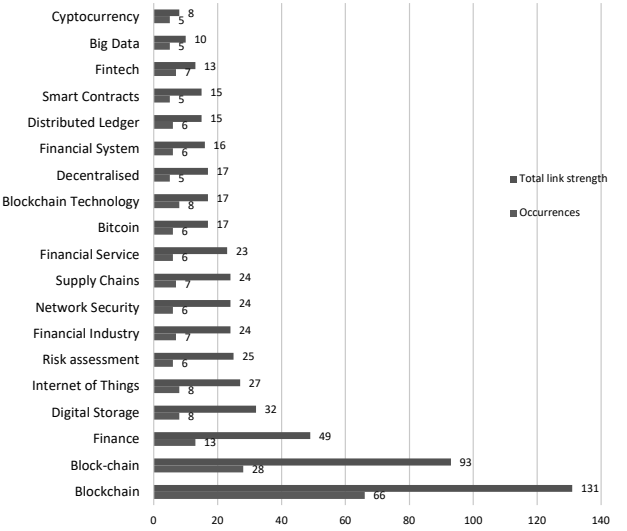
Co-occurrence network analysis of blockchain research keywords

We conducted a co-occurrence network analysis of keywords to delve into the thematic focus and interconnectedness within blockchain cost research. We utilized the VOSviewer for mapping, akin to multidimensional scaling with a rich statistical background, alongside a clustering algorithm similar to modular network division (Vysochan et al., 2021; Waltman et al., 2010). We set the threshold for the keyword co-occurrence analysis at a minimum of 5 occurrences. Out of the 647 keywords, only 19 meet this threshold. For each of these 19 keywords, using the VOSviewer, we calculate the total strength of the co-occurrence links with other keywords. The bar chart in the following figure illustrates these calculations.

Figure 5 shows the Keyword Frequency and Link Strength Analysis. In this dataset, the keyword "Blockchain" emerges as the most prevalent and interconnected term, appearing 66 times and having a total link strength of 131. Following closely behind is "Block-chain" with 28 occurrences and a total link strength of 93. Additionally, the keyword "Finance" stands out with 13 occurrences and a total link strength of 49, indicating its significance in blockchain discussions. Other notable terms include "Digital Storage" and "Internet of Things" with 8 occurrences each. Furthermore, keywords such as "Risk assessment" and "Financial Industry" demonstrate moderate occurrences (6 and 7 times) yet possess considerable total link strengths with 25 and 24. The following Figure 6 displays the clustering analysis of keyword co-occurrence.

Figure 5

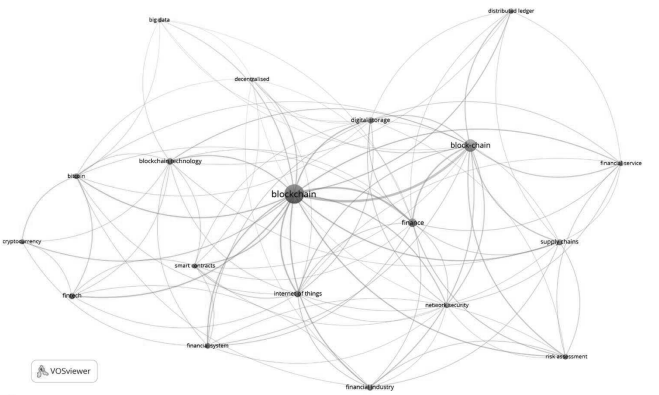
Keyword frequency and link strength analysis



Source: own compilation

Figure 6

Article analysis by keyword co-occurrence



Source: own compilation

Figure 6 shows cluster analysis, which categorizes related keywords into four distinct clusters–red, green, blue, and yellow. We stem with the red cluster features 'Blockchain' as its most prominent term, registering 66 occurrences and a total link strength of 131, reflecting its centrality to the discourse on innovation within the financial system, especially in the COVID time (Gupta & Kumar, 2021). Terms like 'Blockchain Technology' and 'Smart Contract' are also notable, albeit with lower link strengths of 17 each. Prior research points to this term as an increasing yet more focused interest in specific blockchain functionalities in connection to the Ethereum (Massaro, 2023; Rico-Peña et al., 2023; Zheng et al., 2023). 'Cryptocurrency' and 'Fintech' follow, with occurrences and link strengths of 5 and 8, and 7 and 13. Barradas et al. (2022), Manahov & Li (2024), and Shamsi et al. (2022) indicate a growing interest in the financial technologies supporting cryptocurrency as digital currencies and the financial applications of blockchain concerning token-based systems.

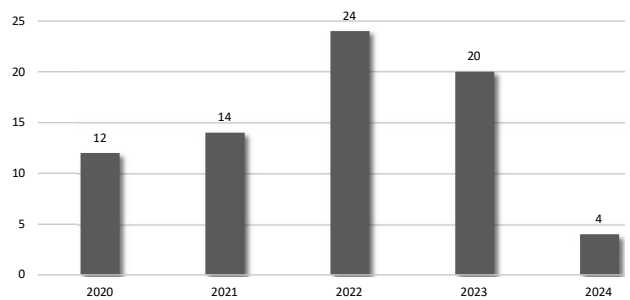
The green cluster focuses on the infrastructural aspects of blockchain, with 'Block-chain' having 28 occurrences and a link strength of 93, indicating a strong yet distinct research focus from the primary 'Blockchain' term. 'Network Security' and 'Distributed Ledger', with equal link strengths of 15, reflect concentrated scholarly attention on the security and architectural facets of blockchain that are essential for its implementation in financial services (Cerchione et al., 2023; Hu, 2022; Khan et al., 2020).

In the blue cluster, 'Finance' stands out with 13 occurrences and a link strength of 49, denoting an established research interest that is foundational to the financial sector's study but less directly related to the cutting-edge technologies seen in the red cluster. 'Supply Chains' and 'Financial Industry' each have a link strength of 24. According to prior research, this term has a balanced but moderate focus on applying blockchain to enhance supply chain operations and financial industry practices (Kumar et al., 2022; Lahkani et al., 2020; Wang & Wang, 2022). This keyword theme is also related to 'Risk Assessment' in supply chain finance, which is based on blockchain technology (Meng, 2022).

Lastly, the yellow cluster, though smaller, captures the intersection of blockchain with broader data and organizational concepts, with 'Big Data' at 5 occurrences and a link strength of 10 and 'Decentralised' at 5 occurrences and a link strength of 17. Based on the yellow clustering analysis, we found nascent research themes that are poised to gain momentum as the implications of decentralization and the utilization of large datasets in blockchain are explored more fully (Barradas et al., 2022; Zhan et al., 2023).

Figure 7

Documents analysis by year



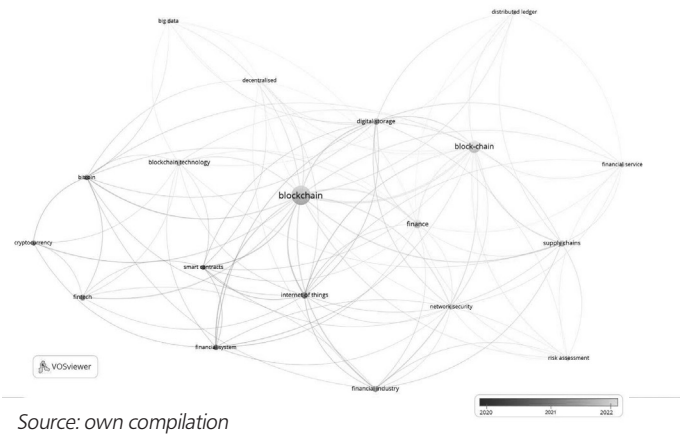
Source: own compilation

To complete our clustering analysis, we emphasize how the dataset underscores the importance of economic factors in driving the adoption and evolution of blockchain technology. Understanding the cost dynamics associated with blockchain is crucial for its broader acceptance and smooth integration into existing financial and organizational structures. We believe this analysis will contribute to future studies and provide insights into economic factors, focusing on thorough cost-benefit assessments, the impacts of evolving regulatory landscapes, and identifying new areas of application where blockchain technology can deliver substantial economic advantages. Figure 7 illustrates the frequency of articles included in our research.

Figure 7 shows the longitudinal analysis, which reveals a clear trend of increasing and then slightly decreasing scholarly interest in the cost implications of blockchain technology over five years from 2020 through 2024. The figure starts with 12 articles published in 2020 as a baseline for our filtering criteria. An increase to 14 articles in 2021 indicates a continued and slightly intensified interest in the economic analysis of blockchain. The peak in 2022 might reflect a culmination of interest driven by technological advancements. in 2023, the frequency decreased to 20 articles. This reduction might indicate that some initial questions regarding the cost of blockchain technology have been addressed, and slight normalization in research output after the previous year's spike. Subsequently, an obvious sharp decline to 4 articles is observed in the most current year. It is also important to consider that data for 2024 might be incomplete, given the year is still ongoing or recently concluded, and more publications could emerge retrospectively.

Figure 8

Overlay visualisation of the articles time frame



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To support the analysis of the time frame analysis for a compelling graphical representation of the temporal spread and interconnection of keywords within the body of research on blockchain, we utilize the overlay visualization from 2020 to 2022 and beyond. Figure 8 shows the color gradient from purple-blue to green to yellowish hues signifies the transition of keyword prominence over time, with the purple-blue end of the spectrum representing earlier periods (2020-2021) and the yellowish tones indicating more recent occurrences (post-2022).

In the visualization, 'Blockchain' is the most prominent term and is centrally located, suggesting it is a foundational topic within the research corpus. Its position and size indicate a high frequency of occurrence and strong link strength across the entire timeframe, although the color suggests its peak prominence was around the 2020-2021 period.

Adjacent to 'Blockchain', terms such as 'Smart Contracts', 'Blockchain Technology', 'Financial System', and 'Bitcoin' share a similar coloration, implying they

were more frequently discussed in earlier research during the same period as 'Blockchain'. Their proximity to 'Blockchain' suggests a strong association and relevance to the foundational technology.

The shift towards the yellowish hues for terms like 'Network Security', 'Digital Storage', 'Distributed Ledger', 'Financial Service', and 'Supply Chains' indicates these topics have gained traction in the more recent phase of research, post-2022. This shift could imply a growing scholarly focus on the practical aspects of blockchain implementation and integration into various financial services and systems.

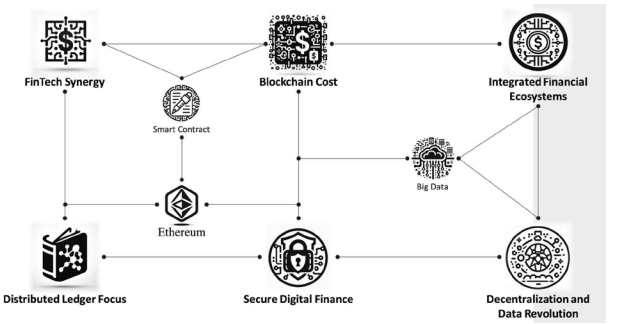
Moreover, 'Decentralised' and 'Big Data' are observed in a distinct yellow cluster. This suggests that these concepts have become particularly relevant in the latest research, potentially reflecting recent developments or shifts in focus within the blockchain discourse, possibly due to the growing appreciation of blockchain's role in decentralization and the handling of big datasets in financial technology.

The clustering and color overlay in this visualization offer a temporal dimension to the co-occurrence analysis, allowing us to discern not only the thematic concentrations but also their evolution over time. The prominence of foundational blockchain terms in earlier periods could reflect the initial exploratory phase of blockchain research. In contrast, the emergence of terms associated with application and integration in later periods may indicate a maturation of the field, with increased attention to the challenges and opportunities of applying blockchain in various financial contexts.

The 74 articles in this study present various thematic keywords and have been synthesized into a conceptual diagram. Figure 9 simplified the interconnectedness of the four clusters with time frame discussed in this section.

Figure 9

Conceptual framework of blockchain cost impact in the financial industry



Source: own compilation

Figure 9 presents the Conceptual Framework of Blockchain Cost Impact in the Financial Industry, synthesizing the thematic clusters identified through VOSviewer with the three aggregate cost dimensions derived from our systematic analysis. Each node in the figure represents a second-order theme (e.g., integration, security, legal compliance), while the connections illustrate their interdependence across cost categories. For instance, 'Integration' links to both 'Technology Development and Maintenance' and 'Compliance and Legal Costs', reflecting how system compatibility affects not only technical but also regulatory expenditures. The red cluster, representing innovation and development, primarily maps onto the technology cost dimension. The green and yellow clusters–related to infrastructure and decentralization–intersect with legal and compliance themes, underscoring their relevance in standardization and security frameworks. This interconnected structure highlights how blockchain cost factors are not isolated but function as an integrated ecosystem within the financial sector.

Cost analysis of blockchain implementation

Our framework draws upon the TOE model to contextualize how technological, organizational, and environmental factors shape cost-related decisions in blockchain adoption. Furthermore, agency theory provides a lens to interpret how blockchain's promise of transparency may reduce monitoring costs and mitigate opportunistic behavior within financial ecosystems. However, we found that understanding the costs associated with blockchain technology extends beyond mere monetary and physical expenses. This condition presents a challenge in capturing its diverse aspects accurately. Nevertheless, the thematic clustering analysis helps us synthesize by extracting and interpreting the articles through specific coding techniques. We synthesize the articles into first-order categories, second-layer themes, and aggregate dimensions. The Table 2 represents the article's categories and their attributes.

Table 2 shows our systematic analysis of the articles related to blockchain costs in the financial industry. The table is divided into four key components. To ensure analytical consistency, we categorized the data across three hierarchical levels: first-order categories, second-order themes, and aggregate dimensions. Frequencies were calculated using NVivo 12 Plus based on coded document segments from the 74 articles (Tuegeh et al., 2024). Each occurrence of a conceptually similar code (e.g., "smart contracts," "DApp vulnerabilities") was aggregated under a corresponding second-order theme (e.g., "Smart Contracts"). These themes were then mapped onto broader aggregate dimensions such as "Technology Development and Maintenance" or "Compliance and Legal Costs." For example, in the case of Technology Development, high-frequency codes related to architecture and smart contract protocols were grouped into a coherent second-order theme due to their functional alignment. The bar charts in Figures 10a, 11a, and 11b represent the relative coding frequencies across document segments, providing empirical support for our category construction and its relevance within the blockchain cost landscape.

The following figures are the summarize of the relative Frequencies of Thematic Codes Across Document Segments using blindfolding method:

Table 2.

Systematic analysis of blockchain cost in the financial industry

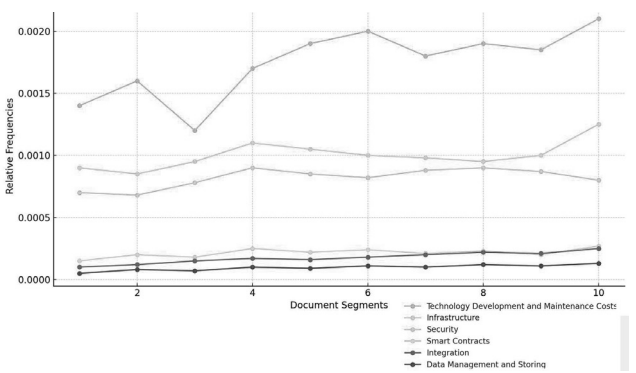
Key References	First-order categories	Second-layer themes	Aggregate dimensions
(Barradas et al., 2022; Cerchione et al., 2023; Cozzi, 2020; Dionysopoulos et al., 2024; Dodmane et al., 2023; Fei, 2023; Gupta & Kumar, 2021; Hu, 2022; Ji et al., 2020; Lian, 2022; T. Liu & Yu, 2022; Mosteanu & Faccia, 2021; Mvula et al., 2020; Yazdinejad et al., 2020; Zarrin et al., 2021; Zhao et al., 2023)	Blockchain architecture	Development	Technology Development and Maintenance Costs
	Engineering Business Model		
	Blockchain Platform		
	Protocol development		
	Decentralized applications (DApps)		
	Blockchain frameworks		
	Cryptocurrencies,		
	Distributed ledger technology		
(Alnuaimi et al., 2022; Artemenko & Zenchenko, 2021; Belchior et al., 2022; Brandl & Dieterich, 2023; Dodmane et al., 2023; Hu, 2022; Shamsi et al., 2022; Yazdinejad et al., 2020; Zarrin et al., 2021; Zhou et al., 2022)	scalability solutions	Infrastructure	
	communication		
	Network architecture		
	Digital storage,		
	Data architectures,		
	Integration		
	Middleware,		
(Cozzi, 2020; Glubokova et al., 2021; König et al., 2020; Manahov & Li, 2024; Massaro, 2023; Meng, 2022; Rrustemi & Tuchschmid, 2020; Zarrin et al., 2021; Zhang & Zhang, 2022; Zhou et al., 2022)	Cryptographic algorithms transactions	Security	
	Decentralized-related security		
	Artificial intelligence algorithms		
	Financial security and data management		
	Integrated business intelligence		
	Secured transmission method		
	Crypto asset management		
	Information security		
	International standards		
	Security of capital flows		
(Cozzi, 2020; Duran & Griffin, 2021; Hu, 2022; Roszkowska, 2021; Shi & Huang, 2022; Souissi et al., 2023; Spanò et al., 2023)	Computational complexity and resources	Smart Contracts	
	Validate smart contract code		
	Transparency and efficiency		
	Global trade regulations		
	Deep learning		
	Equity investments		
	Smart contract vulnerability analysis		
	Ethereum		
(Artemenko & Zenchenko, 2021; Lian, 2022; Mvula et al., 2020; Rodríguez-Espíndola et al., 2020; Sanober et al., 2022; Shammar et al., 2021; Xue et al., 2020)	Business systems adaptation	Integration	
	Technology alignment (IoT, PCA, AI, 3D printing)		
	Security, efficiency, and interoperability enhancement		
	Humanitarian supply chains		
	Mobile money platforms		
	FinTech and traditional institutions integration		
	Industry 4.0 business process enhancement		
	Mobile payment interoperability		
(König et al., 2020; Kumar et al., 2022; Lahkani et al., 2020; Lian, 2022; Sabour & Al-Waeli, 2023; Safiullin et al., 2020; Xue et al., 2020; Zhang & Zhang, 2022; Zhou et al., 2022; Zhu et al., 2022)	Information governance	Data Management and Storing	
	Supply chain product management		
	Product discontinuation decisions		
	Standardization in blockchain technology,		
	Financial shared service centers		
	Transparency in financial data processes		
	Blockchain for financial disclosure		
	Big data management and dissemination.		
	Blockchain in logistics and e-commerce,		
	Digital documentation efficiency.		
	Privacy and speed in data storage and transfer."		
	Industrial mortgage management		

Key References	First-order categories	Second-layer themes	Aggregate dimensions
(Barbereau & Bodó, 2023; Mosteanu & Faccia, 2021; Rico-Peña et al., 2023; Yazdinejad et al., 2020; Zheng et al., 2023)	Malware detection in decentralized applications	Software Requirements	Testing and Quality Assurance
	Fraudulent scheme identification		
	Machine learning in Ethereum		
	crypto-asset wallet software		
	Blockchain-SDN integration in IoT		
	Secure, energy-efficient software solutions		
	Predictive software in FinTech		
	Quantum computing and blockchain intersection		
(Barradas et al., 2022; Fei, 2023; Khan et al., 2020; Liang et al., 2022; J. Liu & Chen, 2022; Song et al., 2023; Yazdinejad et al., 2020; Zhan et al., 2023)	Ongoing maintenance	Network Maintenance	
	Real-time data processing		
	Anomaly detection in DeFi		
	VAE-Transformer for blockchain		
	Maintenance costs for network safety		
	Blockchain and edge computing		
	Network security		
	Blockchain-based neural networks		
	Real-time big data processing		
	Cryptocurrency and social media data analysis		
	K-means clustering in blockchain		
(Khan et al., 2020; Tsao & Thanh, 2021; Yazdinejad et al., 2020)	Microgrids for renewable energy	Energy-Related Expenses	
	Energy requirements		
	Energy-efficient architecture and Machine learning		
	SDN integration in IoT		
	Security energy consumption		
	Optimizing energy		
	Energy conservation in wireless networks		
(I. Ahmad et al., 2020; Akyildirim et al., 2020; Campino et al., 2022; Hu, 2022; Kutera, 2022; Paglietti & Rabitti, 2022; Safiullin et al., 2020; Zhao et al., 2023)	Regulatory compliance in digital payments	Legal and Regulatory Compliance	Compliance and Legal Costs
	Consumer protection		
	Regulatory impartiality		
	Mitigating financial fraud		
	Money laundering		
	Ponzi schemes		
	Reduction of opportunistic behaviors		
	Blockchain for transparency,		
	Regulatory sufficiency		
	Market manipulation		
(M. S. Ahmad & Shah, 2021; Belchior et al., 2022; Pimentel et al., 2021; Roszkowska, 2021)	Blockchain audit challenges	Compliance Audits	
	Costs of blockchain compliance audits		
	Technical complexities of blockchain assets,		
	Impact on financial reporting,		
	Adaptation for auditors		
	Blockchain and AI in financial reporting		
	Transforming external audits		
	Improving audit quality		

Sources: author data analysis, 2024

Figure 10

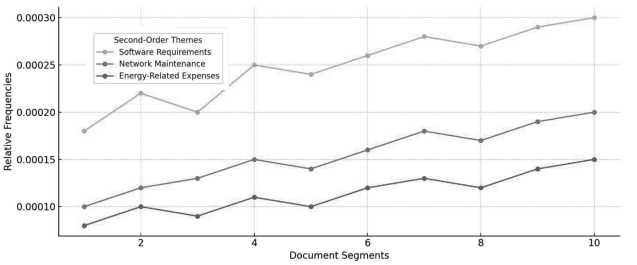
Relative frequencies for aggregate dimensions



Source: own compilation

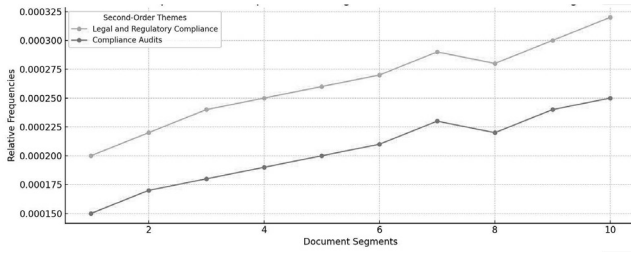
Figure 11a

Relative frequencies of testing and quality assurance



Source: own compilaton

Figure 11b
Relative frequencies of compliance and legal costs

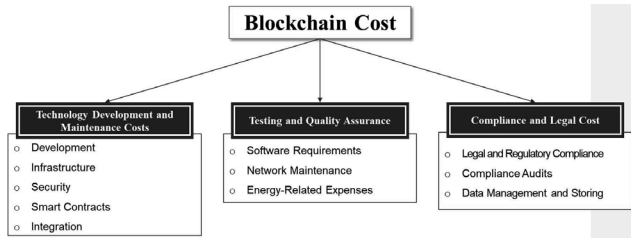


Source: own compilation

To improve clarity and alignment with our hierarchical coding structure, we present the second-order themes of blockchain cost as two separate figures based on their aggregate categories. Figure 11a illustrates the thematic frequency distribution related to Technology Development and Maintenance, while Figure 11b highlights themes associated with Compliance and Legal Costs, both offering a clearer view of the thematic emphasis across document segments.

Based on the Figures 10 and further to 11s, we present the three major cost categories: Technology Development and Maintenance Costs, Testing and Quality Assurance, and Compliance and Legal Costs. We draw the result of Table 2 into Figure 12.

Figure 12
Comprehensive blockchain cost analysis framework (CBCAF)



Source: own compilation

Figure 12 displays a summary of our framework of blockchain cost indicators accurately constructed through a stratified analysis of coding structures. We are able to refine these costs by integrating this approach with our prior discussion on the costs associated with blockchain technology, which are deeply intertwined with various other expenses due to the blockchain system's inherent interconnectedness. We have categorized and delimited these costs based on their functionality and utility within the financial industry, informed by synthesis and coding techniques derived from earlier research. Consequently, this enables companies to consolidate potential cost categories, enhancing their ability to anticipate and prepare for possible expenses in the blockchain domain.

Theoretical implications

This study contributes to the theoretical discourse on digital transformation and blockchain adoption by introducing the Comprehensive Blockchain Cost Analysis Framework (CBCAF). The framework advances existing literature by integrating granular cost drivers–such as software development, energy efficiency, and compliance burdens–into a structured model that aligns with broader theoretical constructs. For instance, the Technology–Organization–Environment (TOE) framework emphasizes cost as a determinant of technology adoption, and our categorization directly informs that dimension. Furthermore, the framework builds on agency theory, where transparency and auditability reduce information asymmetry and monitoring costs–dimensions captured in our legal and compliance cost categories. Finally, by outlining the stages and domains of blockchain cost accumulation, our findings complement and extend innovation diffusion theory, highlighting barriers and incentives affecting blockchain integration in business settings.

Conclusion and recommendation

This study provides a comprehensive synthesis of blockchain cost dynamics in the financial sector, grounded in a systematic literature review of publications from 2020 to 2024. By classifying the costs into three key dimensions which are: Technology Development and Maintenance, Testing and Quality Assurance, and Compliance and Legal Costs. This review offers a structured framework for understanding how blockchain-related expenditures evolve during and after periods of digital acceleration.

The findings hold theoretical significance by contributing to established models such as the Innovation Diffusion Theory and the Technology–Organization–Environment (TOE) framework. Specifically, our analysis extends the Innovation Diffusion Theory by identifying cost-related barriers (e.g., high software and compliance expenses) and enablers (e.g., operational efficiency and audit transparency) that influence the rate and scope of blockchain adoption. These insights complement existing literature that emphasizes technological compatibility and perceived advantage as primary adoption drivers. Additionally, through the TOE lens, our framework categorizes blockchain cost dimensions in ways that align with environmental constraints (e.g., regulatory compliance), organizational readiness (e.g., software integration), and technological maturity (e.g., infrastructure scalability), thus enriching the predictive utility of this model for emerging financial technologies. From a practical standpoint, the cost analysis framework can inform decision-making for various stakeholders:

- Policy makers can use the findings to understand the financial burdens that hinder blockchain deployment, allowing them to craft incentives or standards that reduce legal and audit-related uncertainties.
- Financial institutions and tech developers can benchmark their blockchain expenditures against categorized cost types, enabling better budgeting and risk management during implementation.
- Auditors and compliance officers can anticipate cost drivers related to transparency and security,

preparing organizations for regulatory audits and reducing friction in system integration.

Ultimately, this study addresses the research question by offering a roadmap for navigating the economic dimensions of blockchain adoption. It not only clarifies where costs are concentrated but also explains why these costs matter, namely, because they shape the trajectory of digital transformation in the financial sector. As blockchain moves from experimentation to operationalization, understanding its cost structure becomes crucial not just for technological deployment, but for strategic positioning, trust building, and long-term value creation.

While this study provides comprehensive insights into the cost dimensions of blockchain implementation through a systematic literature review, several limitations must be acknowledged. First, the analysis is based solely on documents retrieved from the Scopus database, which, although reputable and comprehensive, may exclude relevant articles from other databases such as Web of Science or IEEE Xplore. Second, the thematic coding and classification process, despite being supported by NVivo 12 Pro and Voyant Tools, inherently involves subjective interpretation, especially in aggregating first-order codes into higher-level cost categories. Third, the evolving nature of blockchain technology means that newer cost factors or implementation dynamics may emerge beyond the scope of the 2020–2024 literature window analyzed in this study. Lastly, while the study introduces the CBCAF framework, further empirical validation in real-world business settings would strengthen its generalizability and practical utility.

Future studies may benefit from expanding the data sources, incorporating expert interviews or case studies, and applying the CBCAF framework across various industries beyond finance to test its adaptability and robustness. Thus, we recommend future research to quantify blockchain implementation costs across various industries further and develop standardized metrics for financial implications assessment. We also suggest that further research should investigate blockchain's comparative effectiveness against traditional systems, and conducting sector-specific cost analyses will enhance understanding of blockchain's unique cost structures. Furthermore, exploring regulatory changes' impact on blockchain costs and studying the broader economic impact and return on investment of blockchain implementations are crucial.

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