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Enhancing Transparency and Accountability in Sustainable Finance Through Blockchain Technology: A Systematic Review of the Literature

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Abstract: This systematic review seeks to synthesize the existing literature on the integration of blockchain technology into sustainable finance, with a particular focus on its role in enhancing transparency and accountability. A bibliometric analysis was conducted using the PRISMA methodology, incorporating a meta-analysis of scholarly articles published between 2018 and 2023. The analysis was based on data extracted from databases such as Springer Link, Dimensions, and Google Scholar, using the search terms "blockchain," "sustainable," "finance," "transparency," and "accountability." Open-access articles from reputable, peer-reviewed journals were selected to ensure the reliability of the data. Research questions were framed following the PICo method, addressing the specific impacts of blockchain technology on sustainable finance systems. The review highlights that blockchain has the potential to significantly enhance transparency and accountability in sustainable finance by providing robust mechanisms for transaction traceability and verification. Notably, blockchain technology has been applied to improve carbon market management, facilitate green bond issuance, and support the disclosure of Environmental, Social, and Governance (ESG) data. Despite these promising applications, several challenges remain, including regulatory uncertainties, technological limitations, and integration complexities, which could hinder its widespread adoption. To facilitate the global integration of blockchain in sustainable finance, it is recommended that financial institutions invest in technological infrastructure and training. Furthermore, policymakers should work towards harmonizing regulatory frameworks, while researchers are urged to pursue interdisciplinary, empirical studies to address the potential and limitations of blockchain technology. A shift in academic curricula to include blockchain's implications in finance and sustainability is also recommended to better prepare future professionals. In conclusion, while blockchain holds significant promise for improving transparency and accountability, its broader adoption will require addressing technological, regulatory, and socio-economic barriers.

Keywords: Accountability; Blockchain; Sustainable finance; Transparency; Technology

1 Introduction

The connection between technology and sustainability has emerged as a hub for creative solutions in the quickly changing financial landscape. The financial industry is being asked to take on a more transformative role as the world community struggles with social injustice, resource depletion, and climate change [1]. The financial world needs to overcome the problems of adopting a more efficient and transparent financial system. Blockchain technology is a potentially revolutionary instrument that can completely transform financial transactions, especially in sustainable finance [2]. Sustainable finance emphasizes integrating ESG into sustainable investment decisions and corporate operations, marking a paradigm shift in the financial sector [3]. Sustainable finance aims to reallocate funds to endeavours and projects that benefit society and the environment and produce financial rewards [4].

The technology, which is a decentralized ledger that powers cryptocurrencies but goes far beyond them, is known as blockchain technology [5]. The disruptive force that could revolutionize the financial sector is blockchain, which is based on three fundamental principles: decentralization, immutability, and transparency [6]. Blockchain solves numerous problems with conventional financial systems by offering a transparent and safe record of transactions. Its

decentralized structure gives blockchain its intrinsic transparency [7]. Stakeholders of the blockchain network have access to the same copy in the ledger, and modifications require consensus. Transactions cannot be changed and irreversible backwards after they are recorded. By doing this, fraud risk is decreased and financial data's credibility is increased [8]. Blockchain presents the idea of smart contracts, through self-executing with the terms of the promise clearly put into code [9]. In the context of sustainable finance, this automation has the potential to streamline complex procedures and guarantee that funds are distributed exactly [10]. So, it has been addressed as a transformative component in different areas, including finance.

A seminal whitepaper on Bitcoin introduced the concept of a decentralized and distributed ledger as a means of conducting secure, transparent, and tamper-resistant transactions [11]. Subsequent developments in blockchain technology have extended its applicability beyond cryptocurrencies, with an increasing focus on its potential to revolutionize traditional financial systems [12]. Numerous scholars have highlighted the key attributes of blockchain that contribute to its disruptive potential. Tapscott and Tapscott [13] emphasized decentralization, cryptography, and consensus mechanisms as foundational principles that enhance security and transparency. These features are particularly pertinent in the financial context, where trust and accountability are paramount. The relationship between blockchain technology and sustainable finance represents a natural evolution, aligning technological innovation with the ethical imperative of addressing global environmental and social challenges [14]. It is within this intersection that the potential for blockchain to enhance transparency and accountability in sustainable finance emerges. Blockchain's transparency arises from its distributed ledger, where every participant has real-time access to an immutable record of transactions [15]. In sustainable finance, this transparency can be leveraged to trace the flow of funds, ensuring that investments align with ESG criteria [16]. Burritt and Schaltegger [17] argued that blockchain's transparency can mitigate "greenwashing," where investments are portrayed as more sustainable than they are.

Smart contracts, self-executing pieces of code embedded in the blockchain, automate contractual agreements and hold the potential to revolutionize accountability in sustainable finance [18]. By encoding the terms of sustainable investments, smart contracts ensure automatic execution. This reduces the requirement for intermediaries and minimizes the risk of disputes if the predefined conditions are met [19]. Adopting blockchain technology in developing countries has several opportunities and challenges. The potential for blockchain to empower individuals in regions with inadequate access to traditional financial services [20]. In developing countries, where a significant portion of the population remains unbanked, blockchain's decentralized nature offers the promise of financial inclusion and access to capital [21, 22]. However, challenges persist in terms of infrastructure, regulatory frameworks, and public awareness [23]. The study by Marke et al. [24] on blockchain in the carbon market demonstrates how distributed ledger technology (DLT) can enhance transparency and streamline the issuance and trading of carbon credits. Similarly, Tapscott and Tapscott [13] present cases where blockchain is utilized in supply chain finance to ensure ethical sourcing and fair trade practices. Blockchain's inherent design, characterized by decentralization and DLT, has been touted as a solution to improve transparency in financial systems [25]. By creating an immutable and transparent record of transactions, blockchain minimizes the need for intermediaries and enhances trust among stakeholders. Empirical studies [26, 27] underscore the potential of blockchain in providing a transparent and auditable trail of financial flows, thereby fostering greater accountability.

ESG criteria have become integral considerations in sustainable finance. Blockchain technology offers a means to integrate ESG factors seamlessly into financial transactions and reporting [28]. Previous studies [29, 30] demonstrate how blockchain-based platforms can track and verify ESG metrics, allowing investors to make more informed decisions aligned with sustainability goals. The blockchain's capacity to encode "self-executing contracts", or "smart contracts," opens up possibilities for process automation in sustainable finance [31]. Transparent and impassable agreements are made possible by these contracts, which enable the automatic fulfillment of predetermined terms. Some scholarly research [15, 32] argue that smart contracts improve accountability by streamlining transactions, lowering administrative expenses, and guaranteeing adherence to predetermined sustainability requirements. Blockchain has drawbacks despite its hailed advantages, particularly regarding scalability and energy usage [33]. Blockchain protocols' high energy consumption due to their computational complexity raises questions about their potential effects on the environment and could contradict the sustainability narrative [34, 35].

In this context, blockchain technology has emerged as a major component of sustainable finance, offering unique features that address some of the ancient challenges faced by traditional financial systems. DLT, sometimes known as blockchain, is a decentralized, unchangeable digital ledger that makes it possible to retain safe and open records of transactions [36]. Blockchain reduces costs, minimizes the risk of fraud, and increases transparency by enabling peer-to-peer transactions without the use of middlemen through the use of cryptographic algorithms and consensus mechanisms [37]. Existing literature suggests that while blockchain holds promise for enhancing transparency and accountability in financial systems, its deployment in sustainable finance faces various technical, regulatory, and institutional barriers. The major challenge is the scalability and interoperability of blockchain networks, particularly in the context of handling large transaction volumes and integrating with existing financial infrastructure [38]. Additionally, concerns related to data privacy, security, and regulatory compliance pose significant hurdles to the

adoption of blockchain technology in financial applications [39]. Furthermore, the lack of standardized frameworks for evaluating the environmental and social impact of blockchain-based financial initiatives presents challenges in assessing their effectiveness and sustainability outcomes.

A thorough grasp of the current status of research in sustainable finance is urgently needed, given the increased interest in this area and the potential for blockchain technology. By synthesizing current information and identifying opportunities for further research and development, this comprehensive study aims to minimize this research gap. The primary objectives of this study are to identify and examine existing research on the utilization of blockchain technology in sustainable finance within the global context. The review process intends to solve the research question as: what are the key trends, challenges, and opportunities in blockchain technology for sustainable finance, considering prolific journals, authors, citations and countries, as well as its potential implications and recommendations for effective integration of blockchain technology in sustainable finance enhancing transparency and accountability? This study employs bibliometric analysis and proposes to assess the key trends, challenges, and opportunities related to the use of blockchain technology to promote transparency and accountability in sustainable finance. In addition, to explore the potential socio-economic, environmental, and governance implications of blockchain-based financial innovations in the global context and deliver insights for policymakers, practitioners, and researchers to facilitate the effective integration of blockchain technology into sustainable finance initiatives globally. However, there are several limitations inherent in this systematic literature review (SLR). First, the scope of the review is limited to studies published in academic journals, conference proceedings, and other scholarly sources. As a result, relevant insights from industry reports, whitepapers, and grey literature may not be fully captured. Second, the review focuses specifically on transparency and accountability, which may limit the generalizability of findings to other aspects of sustainability. Additionally, the rapidly evolving nature of blockchain technology and sustainable finance may result in some studies becoming outdated over time.

2 Methodology

This study employed bibliometric analysis and SLR to solve the research problem. The research question is formulated based on the PICo method which is population (P), the interest of the study (I), and context (Co) [40]. Blockchain technology in sustainable finance is considered as population, transparency, and accountability are researcher interests, and the study is contextualized from a global perspective. This study employed the SLR methodology, guided by the PRISMA procedure created by Liberati et al. [41]. The SLR aimed to enable informed conclusions about the research questions with varying degrees of certainty [42]. The review process followed the "identification," "screening," and "included" phases of PRISMA, as illustrated in Figure 1.

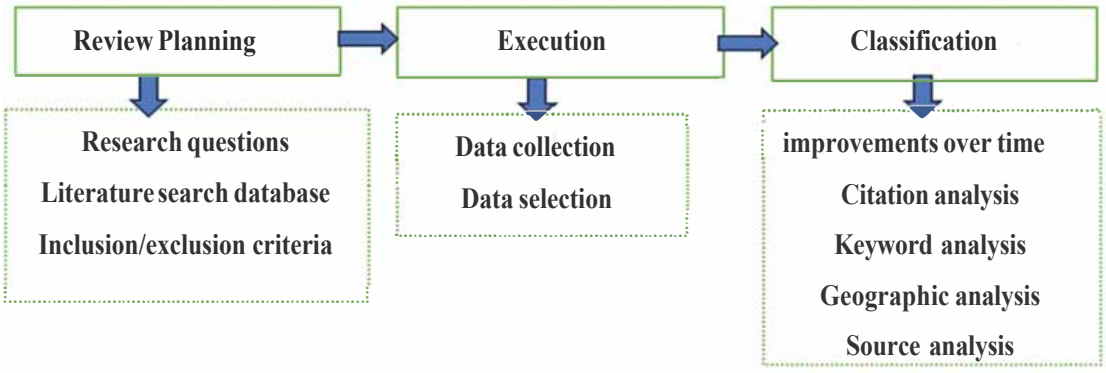

Figure 1. Methodological stages of systematic analysis for bibliometrics

Figure 1 shows the process of review planning, execution, and classification utilized in this study. The review process commenced with the formulation of research questions, followed by a systematic literature search using predefined inclusion and exclusion criteria. The execution phase involved guiding data collection and selection from reputable databases, including Google Scholar, Springer Link, and Dimensions. The classification phase employed analytical frameworks to evaluate the collected articles, encompassing temporal trends, citation analysis, keyword analysis, geographic distribution, and source analysis, thereby providing a comprehensive understanding of the literature.

2.1 Identification

In the first stage of the review protocol, the data extraction process occurred on August 5, 2024, from Springer Link, Dimensions, and Google Scholar databases, employing a precise set of search parameters meticulously defined beforehand. The study used search strings of "blockchain," "sustainable," "finance," "transparency," and

"accountability" within the comprehensive dataset. The dataset under scrutiny comprises scholarly articles released during the timeframe spanning from 2018 to 2023, with a particular emphasis on those disseminated in reputable journals such as Sustainability, IEEE Access, Journal of Cleaner Production, Technological Forecasting and Social Change, Sensors, Applied Sciences, Energies, Electronics, International Journal of Production Research, Journal of Business Research, and Frontiers in Blockchain. Solely articles were considered in this search endeavor, and it is noteworthy to mention that all the chosen publications fall under the category of Open Access. The record identified from the Springer Link (N)=266, Google Scholars database (N)=304, and Dimensions database (N)=456. In total, 1026 articles were identified initially.

2.2 Screening

The initial screening was conducted to meet the inclusion requirements that were published in "English" and "journals." Articles from "2018–2023" were included through the use of automatic article screening features by study kind, language, report type, and publication date in "dimensions" and the "Google Scholar" database. Conference papers, book chapters, research notes, editorial comments, and unpublished data, including institutional reports and dissertations, are among the non-English publications and articles published during the time period under screening. The researcher removed 36 duplicate articles. After removing the duplicate articles, 534 articles were excluded due to document types, irrelevant articles, and language reasons.

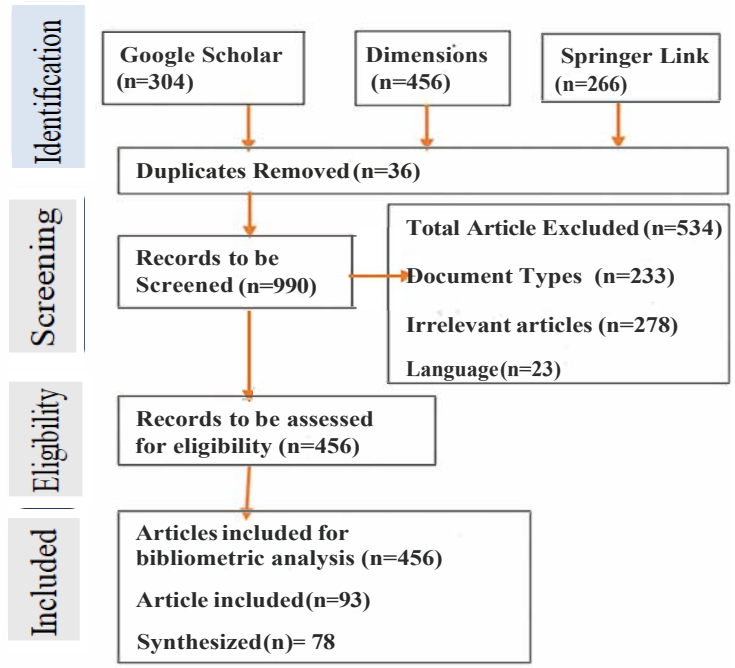

Figure 2. Review process in PRISMA chart

Figure 2 shows the overall review process in the PRISMA chart. The review began with a comprehensive search of three databases: Google Scholar (n=304), Dimensions (n=456), and Springer Link (n=266), resulting in an initial pool of 1,026 articles. Duplicate entries (n=36) were subsequently removed, leaving 990 records for further evaluation. The records were screened based on predefined inclusion and exclusion criteria. Articles were excluded for reasons such as inappropriate document types other than research articles (n=233), irrelevance to the research topic (n=278), and language restrictions other than English language (n=23). This screening process narrowed the records to 456 for detailed assessment. The remaining 456 records considered an in-depth evaluation to ensure alignment with the study objectives and bibliometric analysis requirements. Among the eligible articles, 93 based on research questions and objectives were selected for synthesis. Finally, 78 articles were comprehensively analyzed and synthesized to the research findings.

2.3 Eligibility and Inclusion for Data Extraction

After screening the relevant articles as per the research questions, 456 articles were included as eligible articles for bibliometric analysis. Among them, only 93 articles are included in the review process based on citation, objectives, and research questions. After a detailed study of the articles, 78 articles were used for the synthesizing process. Table 1 shows the inclusion and exclusion criteria of reviewed articles.

Table 1. Inclusion and exclusion criteria

Inclusion Criteria of the Works	Exclusion Criteria
As part of the literature, Blockchain technology in sustainable finance enhances transparency and accountability.	Blockchain technology in sustainable finance in different models
English language journal articles	Non-English and non-journal sources
Published from 2018 to 2023	Out from the chosen time frame
Peer-reviewed articles	Reports, master's or doctoral theses, book chapters, notes
Published in the Google Scholar, Dimensions and Springer Link databases	Duplicates

3 Results

In this study, annual scientific production, most relevant sources, most relevant authors, country scientific production, most globally cited documents, and keyword analysis are considered as the major parts of this section.

Table 2. Annual scientific production

Year	Articles
2018	4
2019	25
2020	64
2021	88
2022	111
2023	165

Table 2 depicts the annual scientific output on blockchain technology in sustainable finance from 2018 to 2023. A marked rising trend is evident, with publications increasing from 4 in 2018 to 165 in 2023. This exponential growth, particularly post-2019, indicates increasing academic interest in blockchain's potential for enhancing transparency and accountability in sustainable finance.

Table 3. Most relevant sources

Sources	Articles
Sustainability	194
IEEE Access	93
Electronics	27
Energies	27
Applied Sciences	22
Frontiers in Blockchain	20
Technological Forecasting and Social Change	20
Journal of Business Research	16
Sensors	14
International Journal of Production Research	13
Journal of Cleaner Production	10

Table 3 presents the most prolific sources ($\geq$10 articles) on blockchain technology in sustainable finance. "Sustainability" leads with 194 articles, followed by "IEEE Access" 93. "Electronics" and "Energies" contribute 27 articles each, while "Applied Sciences" has 22. The varied range of journals highlights the topic's multidisciplinary nature, technology, business, and environmental research.

Table 4 presents authors with $\geq$4 publications on blockchain technology in sustainable finance, exhibiting total articles and fractionalized counts. Leading contributors include Jayaraman R. and Salah K. with 8 articles, 1.39 fractionalized; Tanwar S. with 7 articles, 0.97 fractionalized; Kumar A. with 6 articles, 1.03 fractionalized; Kim S. with 5 articles, 2.2 fractionalized; and Yigitcanlar T. with 5 articles, 1.43 fractionalized. The fractionalized counts indicate varying levels of authorship contribution.

Table 5 and Figure 3 illustrate countries with $>$40 publications on blockchain technology in sustainable finance. China has 128 publications and India has 127 leads, followed by the USA with 86 articles. Significant contributions

also come from South Korea with 58, Australia with 54, Italy with 50, the United Arab Emirates with 43, and the UK with 42 articles. This distribution demonstrates global interest in blockchain's role in sustainable finance, focusing on developed and developing regions across Asia, Oceania, Europe, and the Middle East.

Table 4. Most relevant authors

Authors	Articles	Articles Fractionalized
Jayaraman R	8	1.39
Salah K	8	1.39
Tanwar S	7	0.97
Kumar A	6	1.03
Kim S	5	2.2
Omar M	5	0.83
Yaqoob I	5	0.86
Yigitcanlar T	5	1.43
Hu Y	4	1.37
Myeong S	4	2
Schletz M	4	1.08
Sharma G	4	0.56
Sharma R	4	0.55
Wang W	4	0.77
Wang Y	4	1.28

Table 5. Country scientific production

Region	Frequency
China	128
India	127
USA	86
South Korea	58
Australia	54
Italy	50
UAE	43
UK	42
Spain	41
Malaysia	38
Saudi Arabia	35
Pakistan	33
Netherlands	30

Figure 3. Keyword analysis

Table 6. Most global cited document

Paper	Total Citations	TC per Year	Normalized TC
Monrat AA, 2019, IEEE Access	730	121.67	3.76
Wang W, 2019, IEEE Access	694	115.67	3.58
Pournader M, 2019, International Journal of Production Research	579	96.5	2.98
Bodkhe U, 2020, IEEE Access	500	100	5.77
Chang Y, 2019, International Journal of Production Research	446	74.33	2.30
Perboli G, 2018, IEEE Access	396	56.57	2.33
Dubey R, 2020, International Journal of Production Research	388	77.6	4.48
Alladi T, 2019, IEEE Access	294	49	1.52
Abad-Segura E, 2020, Sustainability	292	58.4	3.37
Yigitcanlar T, 2020, Energies	287	57.4	3.31
Chang Se, 2020, IEEE Access	286	57.2	3.30
Wong L, 2020, International Journal of Production Research	255	51	2.94
Fraga-Lamas P, 2019, IEEE Access	251	41.83	1.29
Jaoude Ja, 2019, IEEE Access	249	41.5	1.28
Shahid A, 2020, IEEE Access	247	49.4	2.85
Alnuaimi Bk, 2022, Journal of Business Research	242	80.67	7.62
Lobschat L, 2021, Journal of Business Research	220	55	5.13
Syed Ta, 2019, IEEE Access	213	35.5	1.10
Mourtzis D, 2022, Energies	206	68.67	6.48
Park A, 2021, Sustainability	201	50.25	4.68

Table 6 presents the most cited papers (>200 citations) on blockchain technology in sustainable finance enhancing transparency and accountability. Monrat AA (2019, IEEE Access) leads with 730 citations (121.67 annually, normalized TC 3.76), followed by Wang W (2019, IEEE Access) with 694 citations. Pournader M (2019) and Bodkhe U (2020) are also significant, with the latter showing rapid impact (500 citations, normalized TC 5.77). Other significant contributions include Chang Y (2019) and Perboli G (2018). The normalized TC scores adjust for publication year, providing insight into each paper's relative influence over time.

This keyword analysis highlights the focus on "blockchain", and "technology" emphasizing them as crucial tools for enhancing "transparency" and "accountability" in sustainable finance. Key themes include data-driven research, supply chain management, and governance, reflecting blockchain's potential to transform these areas through improved transparency and accountability. Table 7 reflects the article types and their numbers.

Table 7. Paper classification

Article Type	Number of Articles
Qualitative research	26
Quantitative research	24
Mixed research	23
Review articles	5
Total	78

4 Discussion

This section includes a discussion on the impact of blockchain technology on transparency, accountability, sustainable finance, sustainable performance, key challenges, and opportunities, and implications of blockchain-based financial innovations.

4.1 Blockchain Technology for Transparency and Accountability

Blockchain technology is an emerging technology that can reform transparency and accountability [43]. The major feature of blockchain technology is that it is segregated and constant, making it more reliable for data safety and accessibility [44]. This feature makes this technology within the control of limited parties, minimizing third-party efforts and redundant alterations of data [16]. Blockchain's features also intensify other important issues like credibility and innovation in multiple sectors [45]. In supply chains, blockchain can ensure reliable and safe delivery of products between the transacting parties to prevent illegal activities [37]. In the medical sector, blockchain can provide data safety about patient and staff information, records, and many more [46]. In finance, blockchain can regulate financial transactions and reduce the prevalent risks [47]. Though numerous benefits surround blockchain technology, it possesses some challenges, such as scalability, privacy, interoperability, and energy consumption, which should be considered timely [48]. Moreover, the concerns about privacy and complexity require careful consideration [29]. Despite these challenges, blockchain technology provides sustainability, ensuring long-term progressive efforts for transparency and accountability across numerous domains [49]. A progressive increase in the use of blockchain technology is anticipated in the near future due to increased innovation and ongoing growth, which will transform the world of information exchange and business transactions [50].

Blockchain enhances transparency and accountability by creating immutable, time-stamped, and tamper-proof records of transactions. Each transaction is recorded on a decentralized ledger accessible to all stakeholders, ensuring real-time visibility and traceability. This eliminates the risk of data manipulation, promotes trust, and provides a clear audit trail. Such as blockchain can enable transparent supply chain tracking, ensuring that ethical practices are followed from production to consumption. By decentralizing trust and enabling independent verification, blockchain addresses systemic inefficiencies in transparency and accountability mechanisms.

4.2 Blockchain Technology and Sustainable Finance

Blockchain technology can reform sustainable finance by enhancing transparency and efficiency [43]. Its segregated and constant feature ensures the safety of financial transactions, reducing the prevalent financial risks [51]. Blockchain can also develop reliable financial instruments that support sustainability and impact investments [52]. For instance, blockchain can be used to find out the environmental and social impacts of projects, increasing investors' trust in their investments [48]. Likewise, blockchain can facilitate the creation of tokenized assets that represent sustainable projects, positively impacting the investments made by individuals and institutions [29]. Despite the apparent benefits of this technology, issues with scalability, interoperability, and complexity must be resolved to promote its ongoing use and innovation [48]. Similarly, concerns about confidentiality and data security need more considerations [53]. But such few challenges cannot deny the fact that blockchain technology holds a greater future in transforming the financial sector and enhancing long-term benefits [54]. With continuous research and progress, we can expect to see a gradual increase in applications of blockchain that will lead to a sustainable impact in the financial sector, particularly in investments [55].

Blockchain addresses inefficiencies in sustainable finance by rearranging processes such as carbon credit trading, green bond issuance, and impact investing. By tokenizing assets, blockchain ensures transparency in fund allocation and utilization, preventing issues like greenwashing. Decentralized ledgers enable investors to verify the environmental and social impact of their investments, fostering trust and confidence. Additionally, blockchain reduces transaction costs and speeds up cross-border payments by eliminating intermediaries. Through real-time reporting and verifiable data, blockchain supports sustainable financial instruments and ensures alignment with global sustainability goals, making sustainable finance more accessible, efficient, and accountable.

4.3 Blockchain Technology and Sustainable Performance

Blockchain technology may enhance sustainable performance by contributing to improving transparency, traceability, and efficiency [56]. Its unbreachable and decentralized nature ensures that the data are safe and can be accessed by all authorized parties [44]. This technology removes the role of intermediaries and reduces the risk of data manipulation or corruption [16]. Blockchain's transparency boosts the trustworthiness, accountability, and sustainability in supply chains, energy, finance, and other sectors [32]. For instance, in supply chains, blockchain technology can track the products from their beginning to the final consumer, enhancing transparency and ensuring that there have not been practices of any unethical activities [45]. In the energy sector, blockchain technology may help in the trading of renewable energy certificates by promoting clean energy adoption [37]. In the finance sector, blockchain technology can ensure secured transactions and reduce the risk of fraud, promoting a sustainable financial system [46]. However, blockchain technology for sustainable performance also has challenges for implementation. For it to be accepted and used globally, scalability, interoperability, and energy consumption issues must be addressed [47]. Furthermore, privacy and data security concerns should be addressed carefully [29]. Despite these challenges, blockchain technology contains huge potential for improving sustainability and enhancing organizational performance [57]. As research and development continue, there is always a possibility of more innovation and

implication of blockchain technology that will bring positive change in human life through the way we produce, consume, and conduct business [50].

Blockchain drives sustainable performance by offering strong tools for tracking and verifying ESG metrics. Organizations can use blockchain to record energy usage, emissions, and waste data in real-time, ensuring transparency in sustainability reporting. This data can be securely shared with stakeholders, including regulators and investors, to validate performance claims. Blockchain also facilitates circular economy models by enabling the tracking of resources throughout their lifecycle. By ensuring reliable and transparent performance data, blockchain helps organizations align with long-term sustainability objectives and improve accountability.

4.4 Key trends, Challenges, and Opportunities in Blockchain Adoption for Sustainable Finance

The promise of blockchain technology to transform sustainable finance by encouraging accountability and transparency is becoming more widely acknowledged. This trend is highlighted by studies such as those by Hui and Loang [43], who highlight the pivotal role of blockchain and AI in boosting green finance, particularly in the renewable energy sector. However, challenges persist, including regulatory hurdles, technological limitations, and issues of digital access, which must be addressed to ensure scalable and practical implementation. Similarly, Kazachenok et al. [29] discuss the enhancement of green bond issuance through blockchain, which offers benefits like traceability and auditability but also faces significant regulatory and infrastructure challenges.

The adoption of blockchain in sustainable finance is also marked by efforts to improve ESG practices. Oncioiu et al. [16] note that ESG disclosure, facilitated by blockchain, significantly boosts financial transparency and governance, ultimately enhancing Return on Assets (ROA) and promoting sustainable practices. Nevertheless, the need for legislative harmonization remains a critical barrier to effective reporting and adoption across different jurisdictions. In developing regions such as Asia and Africa, the progress in sustainable finance initiatives is promising, as highlighted by Muhammad et al. [51]. These regions present opportunities for global collaboration and knowledge exchange, which could further drive the adoption of blockchain in promoting sustainability. However, the implementation of blockchain in these regions also highlights the importance of addressing local challenges, such as infrastructure and regulatory readiness, to fully harness the technology's potential.

4.5 Socio-Economic, Environmental, and Governance Implications of Blockchain-Based Financial Innovations

Blockchain technology holds significant potential for socio-economic, environmental, and governance improvements, particularly in enhancing transparency and reducing inefficiencies. Jimoh et al. [45] demonstrate how blockchain can improve transparency and efficiency in Nigerian industries, suggesting that its careful application in government sectors could resolve longstanding trust issues through smart contracts. This aligns with findings from Rathore [37], who discusses blockchain's role in enhancing marketing transparency and efficiency, albeit with a call for ongoing research to maximize its potential in various sectors. Environmental implications are also a key area of interest. For instance, Chen [44] highlights blockchain's role in enhancing accountability in carbon markets, which is crucial for rapid decarbonization efforts. Similarly, previous studies [15, 52] discuss the potential of blockchain in democratizing green finance and improving cybersecurity, respectively, although they also acknowledge the challenges related to regulatory frameworks and the complexity of blockchain integration. Governance implications are another critical aspect. Lafarre and Van der Elst [47] examine how blockchain can enhance the efficiency of Annual General Meetings (AGMs) by lowering costs and speeding up decision-making processes. However, this raises legal questions about the coexistence of physical and blockchain-based AGMs, highlighting the need for further exploration of governance frameworks that can accommodate both models.

To facilitate the effective integration of blockchain technology into sustainable finance initiatives, several recommendations can be drawn from the literature. Policymakers should prioritize the development of regulatory frameworks that support blockchain adoption while addressing issues of privacy, security, and interoperability, as emphasized by Sedlmeir et al. [7] and Salah et al. [56]. Furthermore, cross-field collaboration, as suggested by Chen [44], is essential for leveraging blockchain's potential in addressing climate challenges and achieving rapid decarbonization. Practitioners, particularly in the finance and energy sectors, should focus on building scalable and practical blockchain applications that enhance transparency and efficiency. This requires overcoming technological hurdles and fostering partnerships, as noted by Hui and Loang [43] and Jimoh et al. [45]. Additionally, it is essential for continuous investigation to address the ongoing challenges related to smart contracts and data integrity, as highlighted by Rathore [37] and Javaid et al. [53]. Researchers are encouraged to explore the socio-economic, environmental, and governance implications of blockchain further, particularly in developing regions where the technology's impact can be transformative. Muhammad et al. [51] and Kazachenok et al. [29] suggest that future research should focus on the scalability of blockchain solutions and the creation of practical use cases that can be empirically tested. Moreover, interdisciplinary research that bridges technology, finance, and environmental studies could provide valuable insights into the holistic impact of blockchain in sustainable finance.

5 Conclusions

Blockchain technology has emerged as a transformative tool in sustainable finance, offering significant potential to enhance transparency and accountability. The findings from various studies indicate that blockchain's decentralized and immutable nature improves the traceability and verification of financial transactions, which is crucial for sustainable finance initiatives. Blockchain enables efficient carbon market management, green bond issuance, and ESG disclosures, all of which are vital components of sustainable finance. Furthermore, blockchain's influence is increased by integrating it with other technologies like AI and IoT, which improve data security, integrity, and operational effectiveness.

Despite its potential, the adoption of blockchain in sustainable finance faces several challenges. Regulatory hurdles, technological complexities, and the need for cross-sector collaboration are recurring themes across the literature. The success of blockchain in this domain hinges on addressing these challenges, particularly through the harmonization of legislative frameworks and the development of practical use cases that can demonstrate its value in real-world applications. The socio-economic, environmental, and governance implications of blockchain-based financial innovations are profound. Blockchain can democratize access to finance, support climate governance, and improve corporate governance by fostering greater transparency and accountability. However, these benefits must be balanced against the risks of reinforcing existing power dynamics or exacerbating inequalities if the technology is not implemented thoughtfully.

6 Implications

The study explores blockchain technology's potential in sustainable finance, emphasizing its ability to enhance transparency and accountability in operations like carbon credit trading and ESG reporting (Appendix Table A). It highlights the need for financial institutions to invest in infrastructure, training, and cross-sector collaboration to address scalability and interoperability challenges. Policymakers must develop harmonized regulations and standards to facilitate blockchain integration while mitigating risks like data privacy concerns. Academic research is vital for assessing blockchain's real-world impact and addressing ethical implications. Interdisciplinary studies and updated curricula are crucial for preparing professionals to leverage blockchain for achieving SDGs.

Author Contributions

Conceptualization, Bhandari.; methodology, Tiwari; software, Bhandari and Tiwari.; formal analysis, Bhandari and Tiwari.; investigation, Tiwari and Dhakal.; resources, Dhakal.; data curation, Bhandari and Dhakal; writing - original draft preparation, Bhandari.; writing—review and editing, Bhandari and Tiwari.; supervision, Bhandari and Tiwari. All authors have read and agreed to the published version of the manuscript.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

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Conflicts of Interest

The authors declare no conflict of interest.

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Appendix

Appendix Table A. Meta-analysis

Source	Study Focused	Results and Conclusion
[43]	Analyze FinTech's impact on green finance for sustainable energy, focusing on blockchain and AI integration.	FinTech boosts green finance using blockchain and AI for renewable energy. Challenges include regulations, tech hurdles, and digital access. Collaboration is vital for scalable, practical implementation, enhancing transparency, efficiency, and investment decisions.
[45]	Surveying the current landscape, identifying challenges, and proposing future directions for integrating blockchain technology with AI applications.	The paper notes that while blockchain and AI integration is emerging, it holds promise for enhancing AI through decentralized storage and security, though challenges like privacy, consensus, and interoperability remain.
[44]	To DLTs enhance data consensus, transparency, and accountability in carbon and energy market operations.	Blockchain enhances accountability in carbon markets, requiring cross-field collaboration for rapid decarbonization and climate crisis solutions.
[16]	Analyze ESG disclosure's impact on financial transparency with AHP to identify the sector ensuring sustainable and financial reporting transparency.	ESG disclosure boosts financial transparency, governance, and stakeholder perceptions, enhancing ROA and sustainable practices, with legislative harmonization needed for effective reporting.
[51]	Compare sustainable finance initiatives in Asia and Africa, analyzing impact, efficacy, impediments, and prospects for global sustainability.	Asia and Africa show progress in sustainable finance initiatives. Collaboration and knowledge exchange opportunities exist for global sustainability.
[50]	To identify blockchain adoption in developing economies, address challenges, and propose the ICT regulatory agency's role in sustainable implementation.	Blockchain improves transparency and efficiency across Nigerian industries, necessitating careful planning for its application in government sectors, potentially resolving trust issues with smart contracts.
[37]	To improve transparency, security, and efficiency while combating ad fraud and ensuring data integrity in advertising supply chains.	Blockchain boosts marketing transparency, security, and efficiency, employing smart contracts for automated agreements, requiring ongoing research to maximize blockchain's marketing potential.
[52]	To identify the threats faced by Security Token Offerings (STOs) and emphasize the need for STOs to prove their utility.	Security Token Offerings (STOs) offer potential benefits in democratizing green finance but confront infrastructure and regulatory hurdles, requiring practical use cases to unlock their true potential amidst limited empirical data.
[46]	To examine expert views on FinTech RE benefits and challenges in Hong Kong, assessing impacts on energy transition and decarbonization, and job creation.	FinTech RE might democratize energy in Hong Kong, creating new jobs and citizen participation opportunities, and necessitating new governance amidst regulatory challenges.
[47]	To discuss blockchain's role in modernizing Annual General Meetings.	Blockchain tech enhances AGM efficiency, lowers costs, and speeds decision-making. Legal questions arise regarding the coexistence of physical and blockchain AGMs.
[48]	The study aims to improve bond issuance by reducing costs and enhancing security.	The blockchain architecture improves green bond issuance with traceability, auditability, and efficiency through smart contracts.
[29]	To explore FinTech humanization in the AI economy via blockchain, identify causal relationships, and propose economic and legal approaches.	The study enhances green bond issuance using blockchain for traceability and efficiency, identifies FinTech humanization causalities, and proposes economic and legal approaches to improve institutional support in ESG finance.
[49]	Examine blockchain in climate governance for transformative potential and dominant storyline elements.	Blockchain in climate governance may reinforce technocratic approaches, leading to post-political environmental governance, favouring light-touch, voluntary governance.

Source	Study Focused	Results and Conclusion
[57]	Analyze blockchain technology applications in energy.	Blockchain enables secure, intermediary-free energy transfers. Future research should address country-specific implementation challenges with case studies.
[50]	Examine competition law challenges with blockchain, explore its advantages, and propose cooperation strategies for stakeholders.	Blockchain improves cyberspace and aids law enforcement, policymakers should adopt it, and stakeholders should collaborate for mutual goals and harmony.
[53]	To identify the blockchain's importance in finance; and its role and necessity in financial services.	Blockchain improves data integrity, payments, and smart contracts, enabling instant settlements and cross-border transactions in finance.
[54]	To examine business's role in advancing UN SDGs via technology, focusing on IoT and blockchain's impact on innovation and SDGs.	Business drives SDG innovation with IoT and blockchain, transforming models and sustainability reporting. Challenges include blockchain integration into business practices.
[55]	Investigate blockchain's role in responsible banking, assessing PRB's impact on transparency and accountability in the banking sector.	Banks face green economy pressure and require trust and transparency. Blockchain attracts SMEs and aids responsible banking. Overcoming adoption barriers is vital.
[58]	To investigate FinTech firms' sustainability during COVID-19, analyze environmental disclosures' effect on their market performance.	FinTech firms excel environmentally and financially, with disclosures affecting market performance and shareholders valuing sustainability amidst COVID-19.
[2]	Improve financial security and transparency with blockchain and AI, streamline KYC and AML, and enhance fraud detection, risk management, and auditing.	Blockchain and AI integration revolutionize finance by enhancing smart contracts' security, transparency, fraud detection, regulatory compliance, and financial efficiency.
[59]	Assess how blockchain enhances financial security during digital transformation and evaluate regulatory considerations.	Blockchain enhances transaction security, transparency, and efficiency, needing collaboration for technical, legislative, and adoption challenges, with policy emphasizing research, regulations, and responsible use.
[60]	Identify barriers and enablers for Blockchain in development aid and understand donors' and key actors' perspectives.	Blockchain enhances transparency and reduces costs in development aid, requiring collaboration for standards, technical solutions, and integrating target populations' voices.
[23]	Analyze Blockchain Readiness Challenges (BRCs) in manufacturing industries.	Identified 20 BRCs for PRS through literature review and expert recommendations. Lack of awareness and security challenges are the most influential BRCs.
[61]	Identify factors hindering blockchain adoption in supply chain networks and resistance to integrating blockchain technology in organizations.	Blockchain adoption is hindered by complexity, cost, scalability, resistance from technological, organizational, and environmental factors, and lack of regulatory frameworks.
[62]	Examine blockchain's impact on cash waqf accountability in Indonesia and strategies to enhance waqf management.	Blockchain can enhance data security, speed, and transparency in cash management, which is already acceptable in accountability.
[63]	Analyze FinTech, InsurTech, and blockchain at the intersection of sustainability.	Blockchain enhances global supply chain transparency, while digital IDs improve financial services access and cash transfers.
[64]	Examine FinTech's impact on corporate ESG performance in China and analyze regional FinTech development effects on ESG.	Regional FinTech boosts ESG performance, particularly in the East, by easing financing constraints, increasing subsidies, and promoting sustainable development.

Source	Study Focused	Results and Conclusion
[7]	Explore blockchain transparency challenges, implications of information exposure, and trade-offs between data protection and process efficiency.	Blockchain transparency challenges hinder privacy, efficiency, and scalability; smart contracts trade confidentiality for functionality, while decentralized identities and zero-knowledge proofs enhance adoption.
[65]	Explore blockchain's role in accelerating SDGs post-COVID-19 across healthcare, insurance, coffee, transport, logistics, government services, employment verification, and women's empowerment.	Blockchain can accelerate SDGs, but challenges and potential remain. Stimulate discussions on blockchain's role in post-pandemic SDG achievement.
[66]	The study highlights FinTech's role in sustainability, identifies key contributors, and outlines future research directions in this field.	Three major clusters of sustainability performance, blockchain technology and digital transformation were found. There is an association between FinTech and sustainability.
[67]	Explore digital transformation's impact on accounting quality and assess corporate governance effectiveness via blockchain in banks.	Blockchain-driven digital transformation boosts accounting quality and corporate governance effectiveness, enhancing both areas simultaneously.
[68]	Explore blockchain for sustainable water management, improve efficiency with innovative tech, and secure financing for water-dependent sectors.	Blockchain improves water management through transparency, accountability, and trust; governments should invest in research to realize its benefits.
[69]	Investigate blockchain's impact on climate change and clean energy, and assess Industry 4.0 practices in sustainability.	Need to adopt a systemic approach for blockchain in addressing climate and clean energy challenges, aiding SDG 7 and SDG 13 policymaking.
[70]	Design a blockchain-based corporate governance framework to reduce credit risks, validated through interviews and focus group discussions.	Blockchain technology reduces MSME credit risk via transparency and accountability; tested frameworks in Indonesian MSMEs may not apply elsewhere.
[71]	Assess blockchain's impact on Ministry of Sports investment projects, correlating its use with financial performance and project evaluation.	Blockchain technology affects the financial outcomes of Ministry of Sports projects, revealing a minimal correlation between its usage and performance.
[72]	Explore conditions for sharing assurance info to enhance traceability, analyzing four food supply chain cases through template analysis.	Blockchain technology can improve supply chain traceability by enabling broader data sharing, necessitating organizational changes for successful adoption, and requiring standardized governance.
[73]	Assess how blockchain affects business ethics and social sustainability, examining its connection with ethics, governance, and social sustainability.	Blockchain improves business ethics, governance, and social sustainability, requiring optimal utilization for sustainable development in the Middle East.
[74]	Investigate blockchain for social sustainability in global supply chains, creating a system architecture to monitor compliance with social sustainability.	Combines blockchain, IoT, and big data for social sustainability tracing, examining implementation costs and challenges for improving social responsibility.
[75]	Examine blockchain's integration in supply chain operations, exploring opportunities, societal impacts, and challenges, across multiple industrial sectors for transformation.	Blockchain improves supply chains by providing transparency, security, and operational efficiency, benefiting industries such as healthcare, finance, and technology, while addressing challenges like data privacy.
[9]	Review blockchain-enabled smart contracts, delineating challenges, and discussing future trends in smart contract research.	Smart contracts are expected to revolutionize different traditional firms. Financial, healthcare, and energy need to adopt blockchain technology.
[76]	Explore blockchain's impact on trade finance, analyze letter of credit (LC) initiatives, and understand logistics tracking integration.	Blockchain can transform trade finance with immutability, transparency, and interoperability, but faces challenges like scalability and legal issues.

Source	Study Focused	Results and Conclusion
[77]	Compare FinTech models for ESG data evolution, addressing challenges with a sustainability framework and offering policy recommendations.	Policymakers can promote common data standards to share ESG information, using sustainability infrastructure to overcome challenges and foster growth.
[78]	Explore blockchain's influence on motivation and collaboration in education, improving understanding of its applications in higher learning.	Findings suggest that in higher education institutions, student motivation and learning outcomes are enhanced by blockchain technology, augmented by various innovative teaching methods.
[79]	Examine blockchain's impact on sustainable supply chains in developing nations, evaluating challenges in enforcing sustainability standards among stakeholders.	Blockchain offers potential for sustainability in developing nations' supply chains, facing challenges such as cost, conditions, and power disparities.
[80]	Investigate how blockchain contributes to social value in crowdfunding platforms, highlighting factors promoting or hindering its adoption.	Blockchain improves social value in crowdfunding, but legal regulations struggle to keep pace with technological advancements.
[81]	Assess blockchain's strengths, weaknesses, opportunities, and threats in Vietnam's agri-food supply chains, fostering sustainable agriculture development.	The SWOT analysis of blockchain in Vietnam's agri-food supply chains suggests policy recommendations to enable its adoption in agriculture.
[32]	Critically analyze blockchain and smart contracts in energy, exploring market impact and sustainability potential.	Smart contracts and blockchain improve energy efficiency, security, and transparency, yet face challenges like costs, technical complexities, and legal compliance. Addressing these challenges is essential.
[82]	Examine blockchain uses in agriculture, pinpointing system challenges, and proposing solutions for agricultural issues.	Blockchain improves food suppagriculture's scalability, integration, security, and privacy challengesly chain integrity and farm efficiency, facing scalability, integration, security, and privacy challenges in agriculture.
[83]	Investigate blockchain in agriculture, analyzing its challenges and benefits for implementation.	Blockchain's positive impact extends to agriculture and related sectors, fostering trust and transparency, albeit with challenges requiring further research and case studies.
[22]	Assess blockchain's effect on SME finance, analyzing challenges and opportunities in blockchain-based financing for SMEs.	Blockchain-based SME finance offers advantages but encounters regulatory and scalability obstacles, with China and India leading in research.
[84]	Explore FinTech innovations in finance, examining how regulatory frameworks uphold fairness in the ecosystem.	FinTech transforms finance with customer-centric approaches, driving growth, efficiency, and effectiveness, extensively studied across payments, financing, and regulations.
[85]	Examine blockchain's effect on smart islands in the blue economy, evaluating stakeholder perceptions in island development.	Blockchain technology in smart islands promotes a blue economy, influenced by digital literacy and driving sustainability in tourism.
[19]	Examine the competitiveness of distributed energy resources in China, assessing blockchain feasibility in energy systems.	Blockchain boosts distributed energy resources' competitiveness. The features of Blockchain technology are "decentralization, transparency, traceability and automation of contract execution".
[86]	Examine AI and blockchain in Thai tuna supply chains.	Digitalization improves food supply chains for sustainability and data monetization. AI and blockchain enhance operations, transparency, and traceability.
[87]	Study correlations between conventional and sustainable cryptocurrencies using uncertainty indices, and assess their hedging capabilities across various investment periods.	Conventional and sustainable cryptos exhibit short-term hedging potential, with sustainable ones effective against uncertain prices and policy.

Source	Study Focused	Results and Conclusion
[88]	Examine blockchain's effect on intermediary roles across industries, suggesting modifications to improve operational efficiency.	Intermediary roles evolve, impacting business operations; blockchain improves transparency, traceability, and efficiency across industries.
[89]	Identify blockchain adoption factors in corporate governance, develop decentralized autonomous governance, and explore blockchain's present and future uses.	Blockchain provides efficient corporate governance solutions but faces challenges like limited transparency. It impacts shareholder confidence.
[90]	Define green FinTech through literature and empirical research, assessing its impact on the financial services industry.	The emerging literature on Green FinTech lacks comprehensive analysis; startups dominate.
[91]	Assess green supply chain economy with industrial internet of things (IIoT) and blockchain, enhancing ESG performance through risk identification and reduction.	The IIoT-Blockchain model mitigates supply chain risks with ESG recommendations, enhancing transparency, traceability, and accountability, and revolutionizing supply chain management.
[92]	To review blockchain applications in the field of finance and healthcare, and identify challenges and opportunities for blockchain technology in different domains.	Identifies blockchain use in finance, healthcare, IoT, smart grids, and more. Reviews challenges and opportunities for blockchain technology in various domains.
[93]	To summarize AI's role in Industry 4.0, blockchain technology's pros and cons, sustainability in blockchain smart cities, and implementation challenges.	Blockchain is a game-changer technology attracting attention from research and business. Blockchain enhances security, transparency, and data handling in various industries. Integration of blockchain and IoT presents challenges and research opportunities.
[94]	Review blockchain-based security mechanisms for the Internet of Medical Things (IoMT) edge networks.	Review of blockchain-based security mechanisms for IoMT edge networks. Evaluation of proposed schemes for privacy, security, and performance.
[95]	Evaluate Alibaba's supply chain efficiency post blockchain technology integration. Enhance logistics and digital documentation efficiency in B2B e-commerce.	The blockchain model enhances logistics efficiency and digital documentation efficiency. Blockchain reduces delays, duplication errors, and fraud in documentation processes. Alibaba achieves programmed trust and financial stability through blockchain technology.
[96]	Analyze the role of blockchain in sustainable supply chain management.	Traceability and transparency are key benefits of applying blockchain technology. Blockchain technology has shown potential in sustainable supply chain management. Classification framework based on grounded theory and technology readiness level.
[97]	Evaluate blockchain's impact on supply chain sustainability indicators. Assess blockchain's potential to enhance environmental, social, and governance aspects.	Blockchain enhances supply chain sustainability, improving transparency, traceability, and efficiency. The positive impact of blockchain technology on sustainability performance in supply chains. Increased studies have shown blockchain's positive effect on sustainability in recent years.
[98]	Examine blockchain integration with accounting information systems (AIS) and enterprise resource planning (ERPs) for efficiency and security.	Blockchain facilitates integration and improves efficiency, productivity, and security. E-procurement enhances ERP and AIS systems, yielding significant benefits.
[99]	Explore Blockchain-enabled applications in diverse sectors. Enhance transaction transparency and reduce risks of deformation and hacking.	Blockchain enhances transparency and security in digital content transactions. The content protection and transaction method using Blockchain Ethereum Technology minimizes the risks of deformation and hacking in transactions.

Source	Study Focused	Results and Conclusion
[100]	Explore a blockchain-based framework for collaborative resource sharing using smart contracts. Develop a demonstrator framework for stakeholder interactions in procurement and distribution.	Smart contracts enhance collaboration in supply networks through custom rules. Blockchain technology ensures data authenticity and quality in supply networks. Demonstrator framework validates smart contract applicability in real industrial scenarios.
[101]	Identify blockchain technology's current standing and major fields of application. Explore blockchain's benefits in IoT, energy, finance, healthcare, and government.	Blockchain is valuable for industrial applications and disruptive to industries. Its unique features are "privacy, security, decentralization anonymity and immutability" are significantly beneficial for sustainable finance.
[102]	Propose blockchain solution for Agri-Food supply chain with traceability and security and evaluate smart contracts for efficiency and robustness in the supply chain.	The proposed blockchain solution enhances traceability, accountability, and credibility in the supply chain. Smart contracts evaluated for efficiency and robustness in the Agri-Food supply chain. The reputation system maintains entity credibility and product quality ratings.
[103]	Evaluate the capabilities of various distributed ledger technology (DLT) platforms for developers and architects.	Lack of understanding in using DLT effectively in various domains. Comparative analysis aids in selecting suitable DLT platforms for applications.
[104]	Identify key blockchain technology (BCT) attributes for the operationalization of BCT applications. Understand the influential linkage between BCT and supply chain (SC) collaboration for success.	BCT attributes positively impact partnership growth and efficiency. Partnership growth enhances SC's financial and operational performance. Partnership efficiency negatively affects financial and operational performance.
[105]	Analyze blockchain architecture and applications in the Internet of Things (IoT), healthcare, and business and discuss challenges, solutions, and ecosystems for blockchain technology adoption.	Blockchain enhances data integrity and security in various industries. Healthcare benefits from blockchain for data sharing and disease prevention. Blockchain addresses security concerns and prevents malicious processes effectively. Hyperledger Fabric is popular but has centralization issues.
[106]	Discuss blockchain tradeoffs, applications, and consensus mechanisms and address challenges like security, privacy, scalability, and energy consumption.	There are some open issues on the adoption of blockchain like security, privacy, scalability, and energy consumption.
[107]	Explore blockchain implications for cybersecurity in intelligent manufacturing.	Blockchain integration challenges from Industry 4.0 to Society 5.0. Need for sustainable and environmentally friendly blockchain development. Focus on a decentralized governance model for effective execution of SDGs.
[108]	Enhance transparency in data sharing through visualization techniques among healthcare stakeholders.	Blockchain tech enhances data-sharing transparency for patients and partners. Patients' data sharing is facilitated by blockchain architecture for care continuity.
[109]	Using blockchain technology to address the issues with sustainable supply chain management.	Organizations can attain operational excellence in conducting life cycle assessments (LCAs) to enhance supply chain sustainability by combining blockchain technology with the Internet of Things (IoT), big data analytics, and visualization.
[5]	Investigate blockchain and cryptocurrency, emphasizing decentralization, financial application, and potential role in sustainable development.	BCT enhances security, trust, and decentralization and helps the overall financial system and stakeholders. It increases transparency, and efficiency and promotes sustainable economic development.