


RESEARCH ARTICLE

A comprehensive and bibliometric review on the blockchain-enabled IoT technology for designing a secure supply chain management system

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(Received 17 January 2022; revised 12 August 2022; accepted 25 August 2022)

Abstract

Blockchain is a well-known prominent technology that has gotten a lot of interest beyond the financial industry, attracting researchers and practitioners from numerous businesses and fields. Specific uses of blockchain in supply chain management (SCM) are addressed in business practice. By combining two perspectives on blockchain in SCM, this study provides comprehensive knowledge in this field using a bibliometric approach. We will explore the worldwide research trend in related topic areas. By collecting data from the Web of Science, we collected 400 articles related to our research topic from 2016 until early 2021. We eliminated research in the form of technical reports, editorials, comments, and consultancy articles to maintain the quality of the data gathering. VOSviewer is used to create visualization maps based on text and bibliographic information. The examination uncovered helpful information, such as annual publishing and citation patterns, the top research topic, the top authors, and the most supporting funding organizations in this field.

Key words: Bibliometric; blockchain; internet of things; review; supply chain management

Introduction

With the advancement of modern technology and tight business processes, firms face difficulty due to fierce rivalry and the increasing complexity of international trade (Bojnc & Ferto, 2009; Lei et al., 2021). Thus, pushing the business flow through the supply chain (SC) (Abdel-Basset, Manogaran, & Mohamed, 2018; Liu et al., 2022). According to Lou, Liu (Lou et al., 2011), an SC is a network of providers, manufacturers, retailers, distribution centers, and clients via which raw materials are purchased, converted, manufactured, and supplied to the appropriate client. Moreover, SC will create market value where single firms are not self-adequate. Therefore, single firms can no longer become a generator of economic growth. Instead, these chains should coordinate with the whole network of organizations to produce and deliver products and services to end-users aiming for some goals such as sustainability (Lou et al., 2011; Pan et al., 2021).

As a complex business, supply chain management (SCM) entails having the right things in the appropriate quantity at the proper time, in the right position, for the right price, and in the right situation for the appropriate client (Wu et al., 2016). SCM's extremely functional and economical operations rely on transmitting information and material flows as a complicated network of providers, manufacturers, distributors, warehouses, and retailers (Lou et al., 2011). Nevertheless, issues like delivery, overstocking, delays, and stocks are expected in true SC due to the typical

SCM system's complexity, unpredictability, susceptibility, and expense. Unsurprisingly, the physical handling of delivered commodities results in human mistakes, leading to large economic losses.

As a result, the SC must become more competent to meet these problems. A competent SC is defined as a contemporary and integrated system that encompasses everything from isolated, single-firm, and regional applications to the full and systematic deployment of SC (Abdel-Basset, Manogaran, & Mohamed, 2018). It provides cheaper, better, and faster items that SC manager desires.

The fast advancement of information technology (IT), particularly the use and growth of the internet, has resulted in higher intelligent manufacturing and networked organization modes (Cao et al., 2022a; Chen et al., 2020; Vahdat, 2020). Moreover, the ultimate success of the SC is determined based on the success in coordination, integration, and management of the entire business process SC. Thus, the introduction of the internet aids in achieving the basic aim of creation in SCM, enabling information exchange in SCM while lowering overall cost, boosting operational effectiveness, and increasing competitive advantage. Internet of Things (IoT) is the Internet's next-generation network (Cao et al., 2022b; Lou et al., 2011), which uses wireless data transfer, radio frequency identification, radar sensors, computers, and other technology to build a proper Internet that covers the whole globe (Christopher, 2012; Yan et al., 2022). Organizations can accomplish pervasive connectivity among objects (things), automotive data collection, sensor fusion, real-time processing, and ubiquitous computing in the physical world by implementing IoT technology and virtual reality (Lou et al., 2011; Sui et al., 2020; Yang et al., n.d.).

While facilitating the fast creation of IoT apps, the present IoT-centric design has resulted in many isolated data silos that limit the IoT's full potential for holistic data-driven business applications. In addition, remote IoT technology platforms have privacy and security issues (Wu et al., 2022; Yang et al., 2021; Zheng et al., 2021). Blockchain is widely known as a decentralized option for data organization, enabling the peer-to-peer transfer of digital assets without intermediaries (Aste, Tasca, & Di Matteo, 2017). Besides that, it can resolve financial transactions without the assistance of banks and other reliable agencies. Al-Rakhami and Al-Mashari (2021) as blockchain has features such as non-tempering, consensus mechanism, and a smart contract (Yan et al., 2021). In addition, the security of exchanging distributed data is ensured by blockchain technology which can provide a significant impact on organizational governance. Additionally, it may modify how those involved in the SC organize their interactions and how they communicate and share goods and data (Min, 2019). Therefore, blockchain technology has provided a viable alternative for the security of IoT-based information systems. IoT devices may submit data to a shared transaction repository with tamper-resistant records using a blockchain. It allows business partners to access and deliver IoT data without the need for centralized control and administration (Pal & Yasar, 2020).

To provide comprehensive knowledge regarding integrating blockchain technology, IoT, and SCM. We, therefore, conducted a bibliometric analysis. According to (Hood & Wilson, 2001), bibliometrics is an established and reliable method that provides knowledge about a research field's evolution and conceptual structure by employing mathematical and statistical methods (Callon, Courtial, & Laville, 1991). Bibliometric analysis is used in this research to demonstrate blockchain-based IoT for developing a secure SCM system. We hope to learn more about the present scientific state of blockchain-based IoT for SCM by doing bibliometric and co-citation analyses. A comprehensive view of the current literature can help develop themes (Torraco, 2016). Hence, the present investigation uses bibliometric analysis to simplify the present literature in the SCM domain related to blockchain-based IoT, which will aid future researchers in identifying possible research themes and concerns. It will also assist beginners in understanding and gaining access to it fast.

The following is the article's structure. Section 2 demonstrates the related survey and overviews the papers about blockchain-based IoT literature in SCM. Section 3 presents the research

methodology. The analysis outcome is presented in Section 4. The study's conclusion and potential research directions are discussed in Section 5.

Related work

Zhang, Gong (Zhang et al., 2019) carried out a study that used content analysis tools to perform a full systematic literature assessment on blockchain usage in the food SC. They suggested four ideas and five possible difficulties in their study. The advantages and drawbacks of implementing blockchain in food SCM were also discussed. Nevertheless, this study was not systematic research; therefore, the article selection process has not been stated. Further, there is no comparison of articles provided in the article. Besides that, only a few articles have been investigated.

Aich, Chakraborty (Aich et al., 2019) concentrated on the distinctions between traditional and blockchain-based SCs. This report also discussed the advantages and drawbacks of deploying blockchain in various industries. Nevertheless, this review was not conducted systematically; therefore, the article selection process has not been stated. Further, the paper also does not mention future work or outstanding problems.

Moreover, Duan, Zhang (Duan et al., 2020) studied blockchain implementation in the food SC and used a content-analysis-based literature review. This review presented a fundamental and thorough grasp of blockchain and its possible consequences. They also listed five significant obstacles to using blockchain in the food SC. Nevertheless, the evaluation was not conducted systematically; therefore, the article selection process has not been stated. Besides that, it excluded the IoT concern discussed in this paper. Further, future work and unresolved concerns have not been adequately addressed at the end of the paper.

Sangeetha, Shunmugan (Sangeetha, Shunmugan, & Murugan, 2020) used a systematic review technique to research blockchain for IoT-enabled SCM. They concentrated on new SCM approaches that included blockchain and IoT connectivity. They also discussed the merits and downsides of using blockchain and IoT to control SCs. Nevertheless, this work did not conduct a systematic review and did not compare certain comparable studies in their research. Further, the paper supplied no information about future work and open issues.

Furthermore, Khan and Yu (Khan & Yu, 2021) looked at the organization theory employed in the Blockchain technology literature through the lens of operations and SCM. They discovered that six organizational methodologies, namely resource-based perspective, agency theory, network theory, institutional theory, information theory, and transaction cost analysis, were employed in Blockchain technology literature in SC-related disciplines. Nevertheless, this assessment was not systematic research; therefore, the paper selection procedure is not stated clearly. Moreover, only a few articles have been investigated, and there were no future works, and open issues described clearly in the paper.

In another survey, Berneis, Bartsch (Berneis, Bartsch, & Winkler, 2021) investigated blockchain in logistics and SCM. They concentrated on the shortcomings of case studies and real instances published. This study discussed cluster analysis about the use of blockchain technology. They also offered a tangible illustration of how blockchain technology may be used in SCM and logistics. In contrast, this research was not a scientific investigation. Further, the paper has not adequately discussed future works and unresolved concerns.

Integrating trust and blockchain technology into SCM was a priority for Batwa and Norrman (Batwa & Norrman, 2021). This paper explained how using blockchain in SCM might affect trust. They also suggested a research plan to go along with it. They uncovered a deficit in connecting trust theories to blockchain applications, particularly SCM. It was not systematic research; it was restricted to cluster-based methodologies. Therefore, the paper has some drawbacks, such as the papers are not compared ultimately, and future work and unresolved concerns have not been adequately discussed.

Finally, Shwetha and Prabodh (Shwetha & Prabodh, 2021) described the present work and study on food SCM utilizing blockchain technology. This report also included future research

trends and new studies in food traceability systems. Nevertheless, this evaluation was not conducted systematically, and certain articles in the field of blockchain-based IoT in food SCM were not included.

To summarize, systematic reviews are crucial in selecting papers. However, none of the mentioned surveys provide a comprehensive SLR of present blockchain-based IoT in SCM systems, including future challenges, classification, and the strong impact of blockchain-based IoT in SCM systems. Eventually, the outcomes from the analysis articles above found that most survey papers lack classification and comparison of relevant topics. Moreover, the selection procedures are not well stated. Further, the most important for other researchers as a guide, such as future work and unresolved topics, have not been thoroughly explored in these papers (Table 1).

Research methodology

This work used bibliometric analytic techniques to investigate the architecture and substance of blockchain technology that enabled IoT and SCM to address the questions. A quantitative examination of books, journals, or other publications is known as bibliometrics. In the last few years, systematic bibliometric analysis has been used in multiple professional domains to display knowledge status, characteristics, evolution, and developing trends (Doewes *et al.*, 2022; Guo *et al.*, 2021). The analysis included word frequency, citation analysis, and counting publications by the unit of analysis (e.g., authorship, country, affiliations, and so on) (Ayoko, Caputo, & Mendy, 2022; Vahdat & Shahidi, 2020). Therefore, a significant quantity of academic research may be presented using bibliometric techniques, which can be seen from a micro to macro viewpoint (van Raan *et al.*, 2005).

Hence, the investigation concentrates on comprehending how research into the application of blockchain-enabled IoT in SCM and similar topics have grown due to the technology's inception. To cover the most up-to-date utilization of these technologies in SCM, we chose the last five years, 2016–2020 (extending to early 2021), as the time frame for the literature review. We also utilize Web of Science (WoS) to look for and evaluate relevant blockchain-enabled IoT and SCM studies using the search string in Figure 1. The following stages were engaged in this article's literature search and screening: (Figure 1).

Research questions formulation

This study, in particular, builds on previous work and utilizes bibliometric methodologies to address the following study questions:

- RQ1: How has blockchain-based IoT in SCM evolved because of its inception?
- RQ2: What nations, organizations, and writers contribute the most to SCM's scientific blockchain-based IoT research?
- RQ3: Which publications in the blockchain-based IoT research in SCM are the most effective?
- RQ4: What are the most prominent and most helpful funding agencies for publishing blockchain-based IoT in SCM research?
- RQ5: What are some of the most hotly debated research issues and developing trends in blockchain-based IoT in SCM research?

Defining the search terms used

Before analysis, search term criteria were utilized to retrieve related literature by creating exclusion and inclusion criteria. To begin, we created a list of terms for the search criteria. To find appropriate literature, we concentrated on terms linked to the burgeoning blockchain technology-powered IoT in the SCM domain. More generic synonyms or terminology, like 'shared ledger,'

Table 1. Overview of existing literature on blockchain in SCM

Year	Paper	Journal	Methodology	Limitation
2019	Zhang et al. (2019)	Conference Paper	A comprehensive literature review	<ul style="list-style-type: none"> - The articles are not compared completely - Future works and open issues are not described clearly - A few articles have been investigated - Article selection procedure is not obvious
2019	Aich et al. (2019)	International Conference on Advanced Communications Technology	Review	<ul style="list-style-type: none"> - The procedure of selecting papers is not obvious. - The papers are not classified. - No information about future work or open issues has been supplied. - The papers are not compared completely
2020	Duan et al. (2020)	International Journal of Environmental Research and Public Health	A literature review	<ul style="list-style-type: none"> - The articles are not classified - The papers are not compared completely - No information about future work or open issues has been supplied
2020	Sangeetha, Shunmugan, and Murugan (2020)	International Conference on I-SMAC (IoT in Social, Mobile, Analytics, and Cloud) (I-SMAC)	A systematic review	<ul style="list-style-type: none"> - The procedure of selecting papers is not obvious. - The papers are not classified. - No information about future work or open issues has been supplied. - The papers are not compared completely
2021	Khan and Yu (2021)	Journal of Physics: Conference Series	A systematic literature review	<ul style="list-style-type: none"> - The procedure of selecting papers is not obvious. - The papers are not fully compared - Topic of the IoT is not really addressed - No information about future work or open issues has been supplied - A few papers are checked out
2021	Berneis, Bartsch, and Winkler (2021)	Logistics	A systematic literature review	<ul style="list-style-type: none"> - The papers are not classified - The papers are not compared completely - No information about future work or open issues has been supplied

(Continued)

Table 1. (Continued.)

Year	Paper	Journal	Methodology	Limitation
2021	Batwa and Norrman (2021)	Operations and Supply Chain Management	A literature review	<ul style="list-style-type: none"> - The papers are not compared completely - No information about future work or open issues has been supplied
2021	Shwetha and Prabodh (2021)	International Conference on Computing Methodologies and Communication	A comprehensive review	<ul style="list-style-type: none"> - The procedure of selecting papers is not obvious. - No information about future work or open issues has been supplied. - The papers are not compared completely

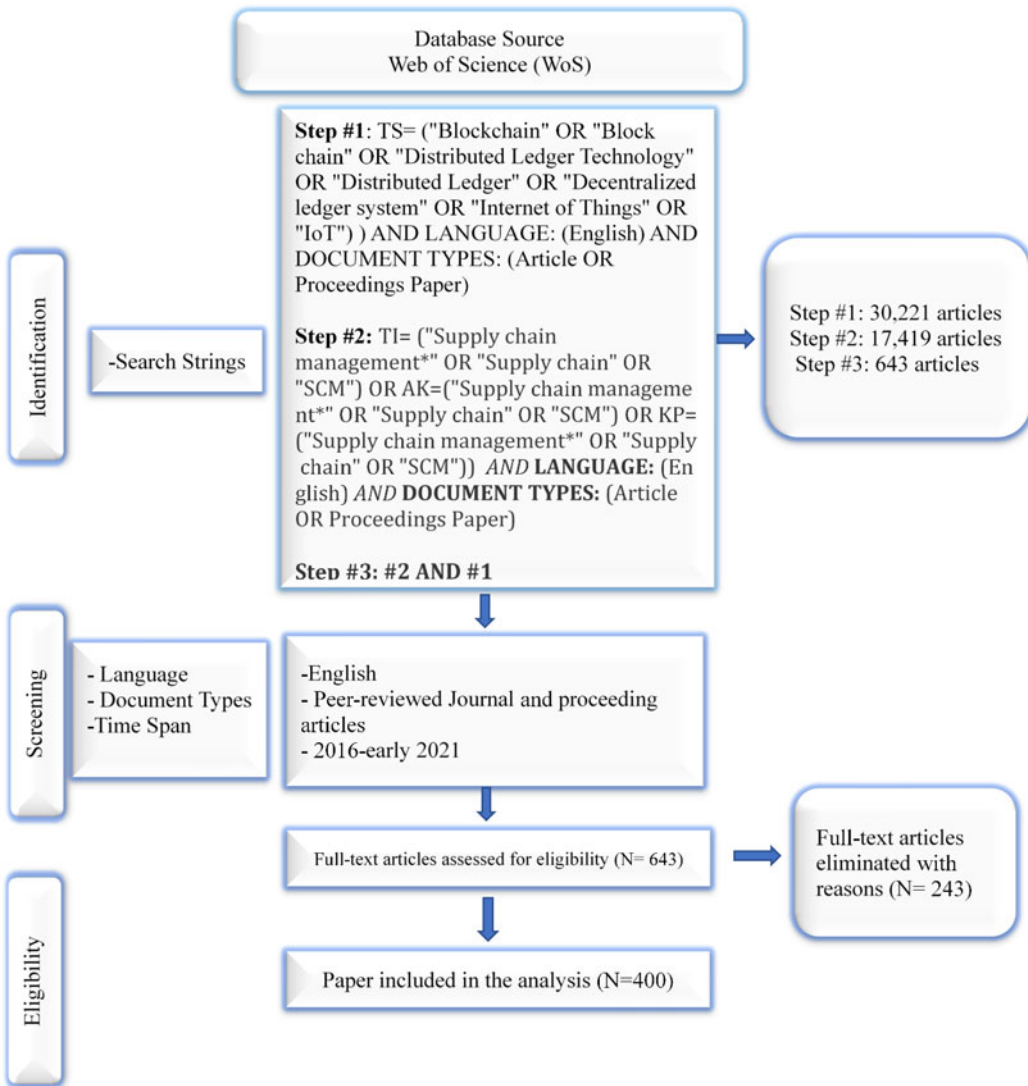


Figure 1. Procedural of the selection criteria.

'distributed ledger,' and 'decentralized ledger system,' were added because of the nature of blockchain. Simultaneously, exclusion criteria were established to eliminate papers unrelated to the core issue or written in a language other than English. We also included conference papers, proceedings, and books in this study to broaden the coverage of the literature. Preliminary research in technical reports, editorials, comments, and consulting papers was omitted to guarantee quality, uniformity, and academic rigor.

Defining the database used

We utilize the WoS to gather a large amount of professional and academic literature for this investigation. There are several benefits to gathering books from WoS, including (i) WoS is the world's leading scientific citation index; (ii) it has a stringent selection procedure that results in high-quality and effective published research; (iii) WoS has earned the respect of scholars

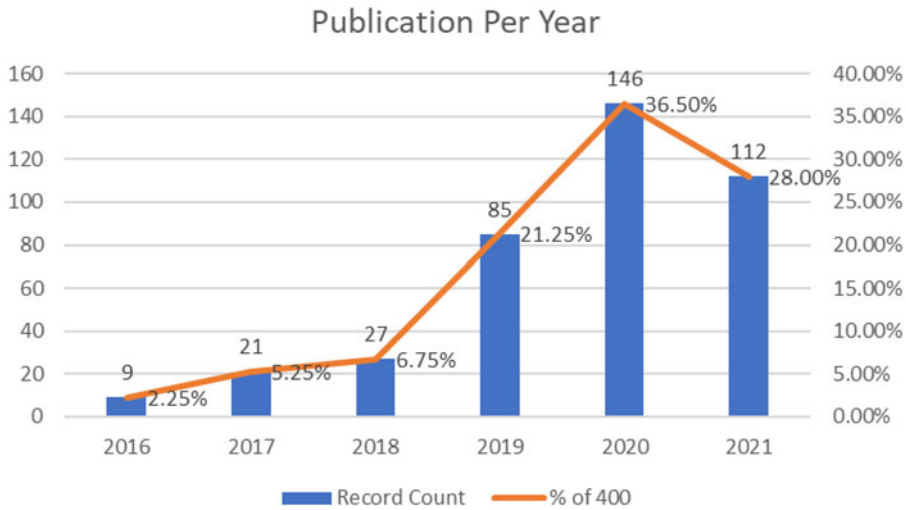


Figure 2. The annual publication indexed by WoS from 2016 to 2021.

over the years by managing more than 20,300 conference proceedings, prestigious journals, and books; (iv) and it supplies investigators with some beneficial analytical attributes (Dabbagh, Sookhak, & Safa, 2019).

Moreover, WoS records saved to text files had complete and detailed data on author, publication year, institution, and source journal (van Nunen *et al.*, 2018). The search methods mostly concentrated on titles, keywords, and abstracts to investigate this subject’s correlation ideas and research information. WoS yielded a total of 400 papers that were found to be genuine.

Bibliometric analysis

The bibliometric study of blockchain in SCM is presented in this section. The analysis is carried out to respond to the research questions.

Analysis of publication output

Because of the novelty and newness of blockchain in SCM, the number of publications each year ranges from 2016 to early 2021. We noticed that the academic community is starting to be interested in integrating blockchain and SCM. As presented in Figure 2, the total number of publications each year has been steadily growing since 2016, and it reached its peak in 2019 and 2020. All

Table 2. Top five subject areas according to publications

Subject category	Year (2016–2021)	Subgroups in different period	
		2016–2018	2019–2021
Engineering Industrial	111	23	88
Management	88	12	76
Operations Research Management Science	82	12	70
Computer Science Information Science	77	7	70
Telecommunications	76	7	69

to integrate with the SC, with the first literature appearing in 2016 (Christidis & Devetsikiotis, 2016; Feng, 2016).

Since the emergence of the blockchain, introduced by Satoshi Nakamoto in 2008 (Nakamoto, 2009), blockchain technology has created hype in the financial area band. In WoS, there were around 100 subject groups for blockchain and SCM literature. Table 2 shows the top five topic areas, which include management (88 articles), engineering industrial (111 articles), computer science (77 articles), operation research management science (82 articles), and telecommunications (76 articles). The number of papers in each group mirrored the various fields' development patterns in blockchain research in SCM. In other words, as time passed, blockchain study became more multidisciplinary.

Analysis of countries, institutions, and authors

Exploring papers' geographical and geographic distribution might be aided by examining nations and organizations. Figure 3a depicts the blockchain and SCM nation collaboration network. The node size showed how many papers were published in each nation. As the nodes expanded, more papers were released. It has been noted that blockchain has attracted worldwide attention, with experts from all over the globe contributing to it by delving further into the blockchain literature in SCM. Figures 3a and 3b illustrate the graphic representation of the nations and institutions involved in blockchain and SCM studies. As presented in Figure 3a, the largest density of contributing countries regarding the paper publication of blockchain in SCM is found in China, the USA, and England. Table 3 shows that China is the leading country with 112 published articles on the related topic. USA and England have published 87 and 56 articles, respectively.

Numerous scientific institutions were highly concentrated, as seen in Figure 3b, resulting in some important clusters of institutions that collaborate in the authoring of papers. Table 4 shows the top ten most prolific publishing institutions. The following organizations contributed significantly to the research: Khalifa University of Science and Technology (10 articles), Worcester Polytechnic Institute (11 articles), National Institute of Industrial Engineering Nitie (8 articles), California State University System (8 articles), and California State University Bakersfield (7 articles).

Table 3. Top ten nations according to the publications

Rank	Country	Publications	% of papers	TC
1	China	112	28%	1142
2	USA	87	21.750%	1711
3	England	56	14%	998
4	India	48	12%	597
5	Italy	24	6%	310
6	Germany	23	5.750%	719
7	Australia	20	5%	236
8	South Korea	20	5%	178
9	France	18	4.5%	594
10	Taiwan	17	4.250%	222

Note: TC, the total citations of a country.

Table 4. Top ten institutions according to the publications

Rank	Institutions	Publications	Country
1	Worcester Polytechnic Institute	11	USA
2	Khalifa University of Science and Technology	10	UAE
3	California State University System	8	USA
4	National Institute of Industrial Engineering Nitie	8	India
5	California State University Bakersfield	7	USA
6	Hong Kong Polytechnic University	7	Hong Kong
7	National Institute of Technology NIT System	7	India
8	University of Hong Kong	7	Hong Kong
9	Chinese Academy of Science	6	China
10	Chongqing University	6	China

Moreover, [Table 5](#) presents the top 10 most productive authors in blockchain and SCM indexed by WoS. 10 most effective authors are from USA and UEA, and the rest is from China and England.

Analysis of the most cited journal

[Table 6](#) presents WoS indexed top 10 most cited blockchain in SCM papers. The paper titled 'Blockchain technology and its relationship to sustainable supply chain management' written by Saberi, Kouhizadeh (Sangeetha, Shunmugan, & Murugan, 2020) was the most cited paper, with 373 citations from the WoS database. As shown in [Figure 4](#), the nodes of an author named Saberi are bigger than others based on the citation parameter, which is the same as [Table 6](#).

Table 5. Top 10 most productive authors

Rank	Publications	Author	Institutions	Country
1	11	Sarkis, Joseph	Worcester Polytechnic Institute	USA
2	10	Jayaraman, Raja	Khalifah University of Science and Technology	U ARAB EMIRATES
3	10	Salah, Khaled	Khalifah University of Science and Technology	U ARAB EMIRATES
4	7	Gunasekaran, Angappa	California State University	USA
5	7	Omar, Ilhaam A.	Khalifah University of Science and Technology	U ARAB EMIRATES
6	5	Choi, Tsan-Ming	Hong Kong Polytechnic	Hong Kong
7	5	Kouhizadeh, Mahtab	Worcester Polytechnic Institute	USA
8	5	Li,Zhi	Guandong University of Technology	China
9	5	Lim, Ming K.	Conventry University	England
10	5	Yan, Bo	Fudan University	China

Table 6. The top ten most referenced writers and their most cited papers

Author	Citations	Source	Country	Year	Title
Saberi, Kouchizadeh, Saberi et al. (2019)	373	International Journal of Production Research	USA	2019	The link between blockchain and long-term supply chain management
Ivanov, Dolgui, Ivanov et al. (2019)	247	International Journal of Production Research	Germany	2019	The ripple influence and supply chain risk analytics as a result of digital technologies and Industry 4.0
Zhong, Xu, Zhong et al. (2017)	138	International Journal of Production Research	China	2017	Big Data Analytics for Physical Internet-based intelligent manufacturing shop floors
Dolgui, Ivanov, Dolgui et al. (2020)	132	International Journal of Production Research	France		Smart contract design and implementation in the supply chain using blockchain-based dynamic modeling
Treiblmaier, Treiblmaier (2018)	128	Supply Chain Management-An International Journal	Austria	2018	The impact of the blockchain on the supply chain: a theory-based research framework and a call for action
Büyükoğkan and Göçer, Büyükoğkan and Göçer (2018)	127	Computers in Industry	Turkey	2018	Digital Supply chain: Literature Review and a proposed framework for future research
Toyoda, Mathiopoulos, Toyoda et al. (2017)	127	IEEE Access	Japan	2017	A Novel Blockchain-based Product Ownership Management System (POMS) for Anti-Counterfeits in the Post Supply Chain
Fatorachian and Kazemi, Fatorachian and Kazemi (2018)	119	Production Planning & Control	England	2018	A critical investigation of industry 4.0 in manufacturing: theoretical operationalization framework
Kamble, Gunasekaran, Kamble, Gunasekaran, and Arha (2019)	116	International Journal of Production Research	India	2019	Understanding the Blockchain technology adoption in supply chains-Indian context
Wang, Singgih, Wang et al. (2019)	113	International Journal of Production Research	England	2019	Making sense of blockchain technology: How will it transform supply chains?

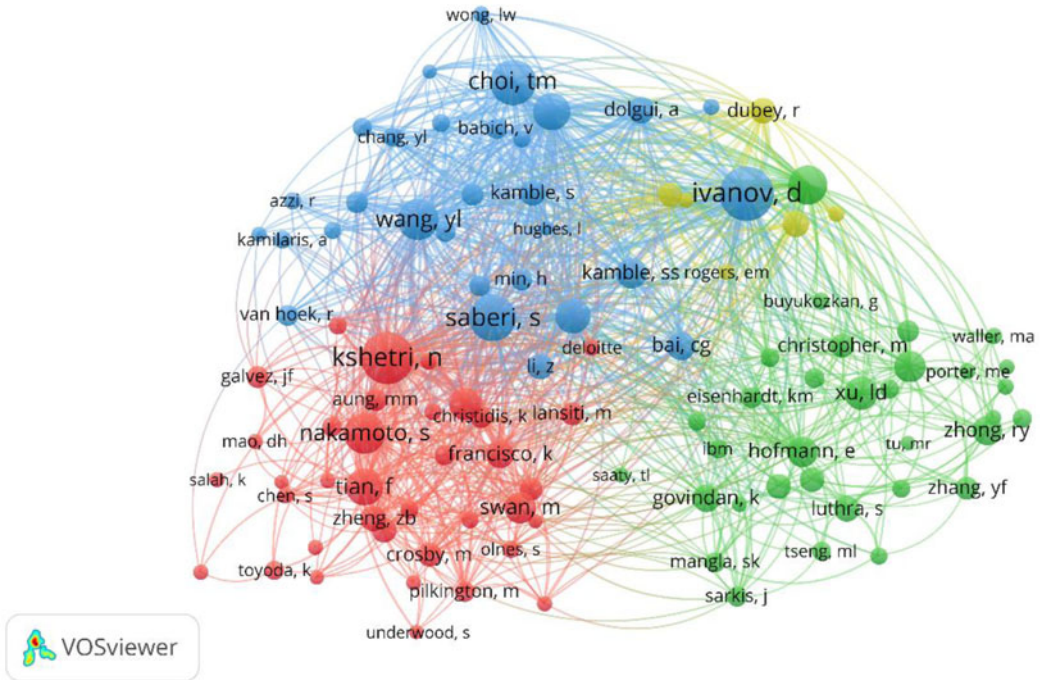


Figure 4. The graphical map of writers who have been co-cited in blockchain and SCM studies.

Table 7. Top 5 productive journals

Source	Record count of publications	% of 400
IEEE Access	43	10.750%
Sustainability	36	9%
International Journal of Production Research	30	7.5%
Industrial Management Data System	21	5.250%
Journal of Cleaner Production	21	5.250%
Computers Industrial Engineering	15	3.750%
Production Planning Control	15	3.750%
International Journal of Production Economics	12	3%
Supply Chain Management An International Journal	11	2.750%
Computers in Industry	10	2.5%

Analysis of the most popular venues

Table 7 illustrates the top ten most popular venues that have released journals in the blockchain and SCM domain. The result showed that IEEE Access is the most popular venue, with 43 published articles from 2016 to early 2021. Furthermore, the second place is for Sustainability, reaching 36 papers from 2016 to early 2021. In contrast, Table 8 presents the top 10 funding agencies in blockchain and SCM research indexed by WoS.

Table 8. Top 10 funding agencies

Funding agencies	Record count of publications	% of 400
National Natural Science Foundation of China NSFC	52	13%
Fundamental Research Funds for The Central Universities	13	3.250%
European Commissions	9	2.250%
National Science Foundation NSF	9	2.250%
Engineering Physical Science Research Council EPSRC	7	1.750%
National Natural Science Foundation of Guandong Province	7	1.750%
UK Research Innovation UKRI	7	1.750%
China Postrdoctoral Science Foundation	6	1.5%
Khalifa University of Science and Technology	6	1.5%
National Key Research and Development Program of China	5	1.250%

With 52 papers, the National Natural Science Foundation of China (NSFC) has financed most of the 400 publications examined in this study. Furthermore, 13 articles are supported by Fundamental Research Funds for The Central Universities, while European Commission has supported nine papers. China is in the lining of competition for the total number of publications and providing funds to support the research in the blockchain and SCM domain.

Analysis of hot research topics and emerging trends

This investigation created various keyword co-occurrence networks to catch the trendy investigation and rising trend in blockchain in SCM. The VoSviewer program was used to create a knowledge area map for the term co-occurrence network, as illustrated in [Figure 5a](#). It presented that the largest node belongs to the blockchain where the highest occurrence number is 181, with a total link strength of 850. It shows that these topics have been the hottest topic recently.

Furthermore, [Figure 5b](#) shows the overlay visualization map chosen as a more valid tool for verification of the recent trend in the academic field. The items are colored differently based on the publication year. In this study, those terms that appeared recently (the average year of publication is 2020) are more yellow. From [Figure 5b](#), we may see that ‘supply chain transparency’, ‘agriculture’, ‘food security’, ‘covid-19’, ‘artificial intelligence’, and ‘circular economy’ are the emerging topic trends that mostly occurred in research in 2020.

[Figure 5c](#) also depicts a density visualization map demonstrating the host research themes according to paper-weights. The greater the topic’s weight, the stronger the hue. Theoretical knowledge and popular research topics are primarily clustered around ‘blockchain’, ‘challenge’, ‘supply chain management’, and ‘traceability’, according to keyword research.

Conclusion and future research directions

This article provided a structured bibliometric analysis of the existing literature of Blockchain-based IoT technology for SCM security. Even though some previous studies have been discussed and reviewed this related topic, this study has not completed a bibliometric and network analysis to provide a comprehensive picture of the recent literature in the field. This initial effort maps the relationships between the most important works concerning the initial research objectives to visualize significant contributions to the field.

The study answered the first research question by examining 400 papers on the Blockchain-enabled IoT in SCM, released from 2016 to early 2021. The result presented that

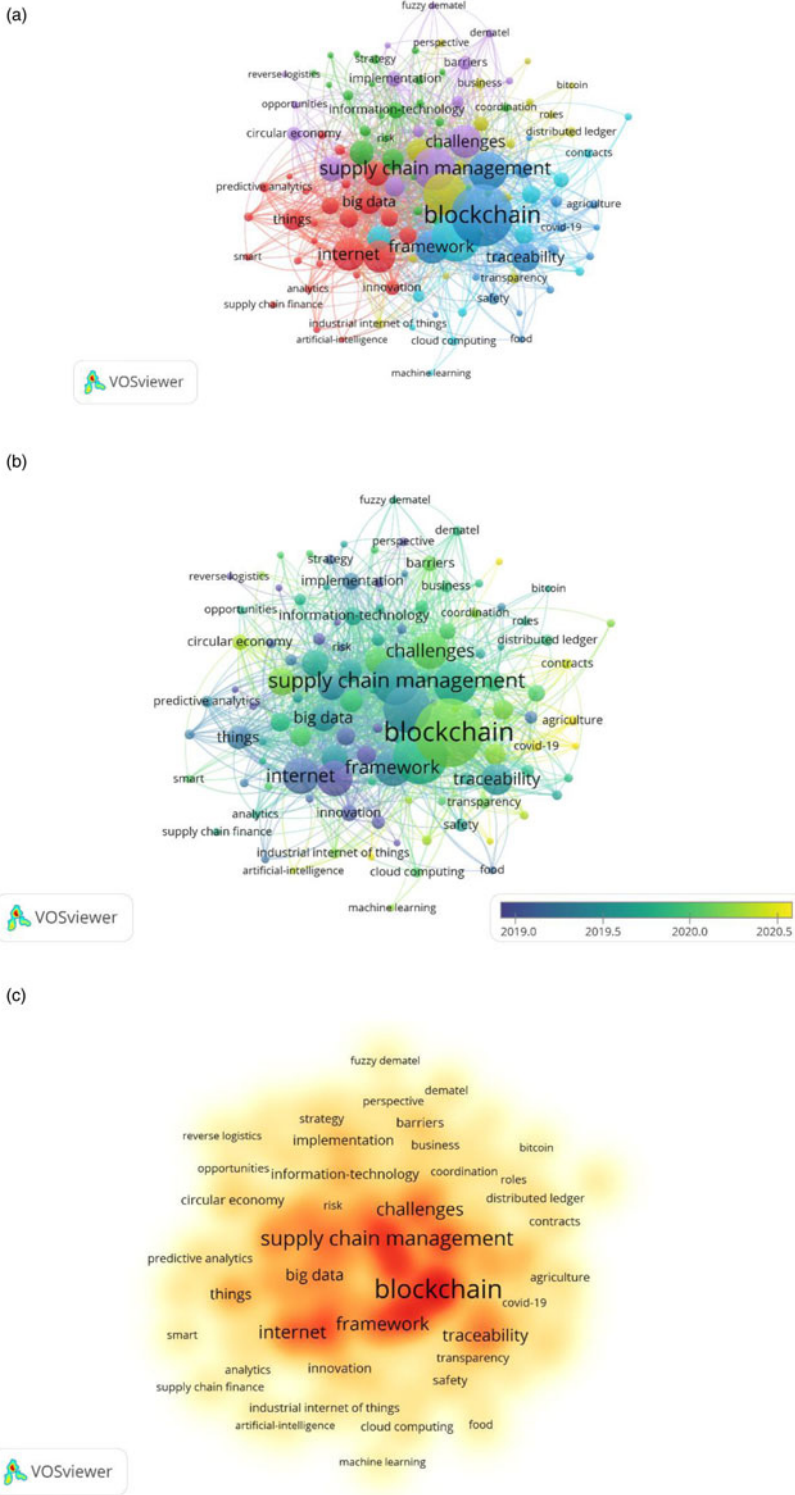


Figure 5. Knowledge domain map of a keyword co-occurrence network relevant to blockchain and SCM study: (a) network visualization map according to paper-weights; (b) overlay visualization according to paper-weights; (c) density visualization map based on article weights.

experts began to pay more attention to combining the blockchain and SCM concepts in 2016, and this trend has persisted through 2020. We also note that it took eight years for experts to integrate Blockchain into the SCM since Blockchain emerged in 2008, and with the first literature related to the integration of Blockchain and SCM appeared in 2016.

The geographic analysis showed that Asia, representative of China and the United States, provided the highest number of publications while other regions worldwide also contributed literature to the field. Even though China comes the first country to collect the highest total publication, the United States comes the first in terms of entire citations. Interesting to note that the highest total publication in terms of organizations is from the USA. Measuring the popularity of authors, Saberi, Kouhizadeh (Saberi *et al.*, 2019) is the top leading author in the analysis network, followed by Ivanov, Dolgui (Ivanov, Dolgui, & Sokolov, 2019) and Zhong, Xu (Zhong *et al.*, 2017).

IEEE Access and Sustainability have shown themselves as the most popular venues, based on the total number of publications, for publishing the latest advancements in the Blockchain field. However, Blockchain papers published in IEEE Access have impressed the expert community more than the Sustainability. In contrast, NSFC has supported the most number of researchers in investigating blockchain in SCM. VosViewer identified the emerging trend and patterns. Some possible directions are recommended for further investigation in this field: (1) Supply chain transparency; (2) agriculture; (3) food security; (4) COVID-19; (5) artificial intelligence; (6) circular economy.

Overall, the field of Blockchain-based IoT in SCM is growing significantly. We expect this development to grow and continue along with the community's interest in the field. Moreover, Blockchain-based IoT shows a promising concept and can play a significant role in preventing security breaches while strengthening SC connectivity. Furthermore, this paper has contributed to the Blockchain and SCM literature. This paper provided comprehensive knowledge related to the Blockchain domain and showed the current status associated with the topic area through bibliometric analysis. Second, we highlight some emerging processes by VOSviewer, which can be a guide for further investigation in this field of research.

This study opens up a number of directions for further investigation. The technical details of the highly cited papers mentioned in this study merit further investigation. Additionally, it would be intriguing to repeat the same bibliometric analysis on additional literature databases, such as Scopus, in order to see if the outcomes would be comparable to those of this study. Finally, some techniques such as machine learning (Wu *et al.*, 2021; Zhong *et al.*, 2021), fuzzy systems (Zhang *et al.*, 2022a), deep fusion networks (Zheng *et al.*, 2022a; Zheng & Yin, 2022), recursive neural net (RvNN) (Li *et al.*, 2017), few-shot learning (Zheng *et al.*, 2022b), and nature-inspired algorithms (Zhang *et al.*, 2022b) can help increase the efficiency of the discussed methods.

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Cite this article: Li Y, Zhu X, Darbandi M (2023). A comprehensive and bibliometric review on the blockchain-enabled IoT technology for designing a secure supply chain management system. *Journal of Management & Organization* 29, 745–762. <https://doi.org/10.1017/jmo.2022.74>