Annals of Data Science (2024) 11(4):1361–1389
https://doi.org/10.1007/s40745-023-00505-0

Blockchain Adoption in Operations Management: A Systematic Literature Review of 14 Years of Research

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Received: 16 September 2022 / Revised: 22 October 2023 / Accepted: 12 November 2023 /
Published online: 16 December 2023

Abstract

Blockchain technology has ushered in significant technological disruptions within the operational management sphere, fostering value creation within operational management networks. In recent years, researchers have increasingly explored the potential applications of blockchain across diverse facets of operational management. Recognizing the pivotal role of comprehending prior research endeavors within any scientific domain for the development of a robust theoretical framework and a nuanced understanding of research progression in both the scientific realm and its practical applications, this study aims to identify areas where blockchain can be effectively employed. This objective is accomplished through an exhaustive systematic review of existing research on blockchain applications in the field of operations management. In pursuit of this goal, a comprehensive dataset comprising 9188 papers published up to the year 2020 is amassed and subjected to analysis employing life cycle analysis, bibliometrics, and textual analysis. The outcomes of this research elucidate the emergence of five distinctive clusters within the landscape of blockchain applications in operational management: Decentralized Finance, Traceability, Trust, Sustainability, and Information Sharing. These findings underscore the dynamic and evolving nature of blockchain's impact in this domain.

Keywords Blockchain · Operations management · Trust · Traceability · Transparency · Systematic literature review

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1 Introduction

The proliferation of digital technology within the framework of Industry 4.0 has significantly enhanced the adaptability and productivity of various industries in their production, consumption, and information exchange processes [1]. Consequently, this transformation has given rise to a digital business ecosystem, facilitated by information and communication technologies, which stands in contrast to conventional commercial environments. This novel digital landscape offers organizations across diverse sectors an innovative avenue to harness technological resources and services to better address customer demands. In this interconnected environment that encompasses every organization, there is an imperative for companies to embark on technological revolutions in order to spearhead the development of new forms of innovation [1]. As an illustration, big data pertains to information technology applications within the realm of business, specifically addressing the challenges posed by extensive datasets. Concurrently, the scientific facets and investigative dimensions of big data are collectively denoted as data science [2]. The discipline of data science encompasses a diverse array of subfields, one of which is data mining. Data mining [3] and the process of knowledge discovery encompass a comprehensive set of stages, including data selection, data cleansing, data transformation, data preprocessing, data mining or modeling, the interpretation of acquired knowledge, and its subsequent presentation [4]. Furthermore, the fast adoption of digital technologies leads to many competitive advantages [5]. Hence, most industries are moving toward keeping up with technologies to maximize their productivity by using them. Blockchain is one of the modern era's effective technologies, which has made a massive revolution in various industries.

Blockchain is a distributed, decentralized general ledger in which transactions consist of a chain of organized blocks. These blocks are unchangeable. Blockchain can help store and record data and encrypted transactions on a peer-to-peer network. Moreover, the commercial relationship between strangers is essentially based on trust, and trust is one of the inherent components of the consensus mechanism in blockchain; in other words, transactions are evaluated and recorded through consensus protocol [6]. Furthermore, blockchain can lead to considerable improvements in transparency, accountability, trust, security, efficiency, and cost minimization [7]. Blockchain features allow it to be used in operations management.

Operations management is managing assets dedicated to producing and supplying products and services. Most departments and organizations rely on centralized systems of information technology for storing and managing their data that most of them are not able to store and manage their data in real-time and are susceptible to being attacked in various ways [8].

Because of the complexity and congeries of processes done in various areas of operations management, blockchain is of a significant role. It can facilitate processes and decrease fraud and cheating, reduce costs and guarantee the originality of goods and services, increase the speed of processes and make their procedures more transparent, as there is no third person, and the buyer can track their good from the time of production until the time it is received and be sure of the originality of the good. Furthermore, blockchain is of great potential to improve processes and increase the

commercial models in supply chain management [9]. Furthermore, blockchain has several implications for established theories in operation management. This includes the principal-agent theory, where blockchain alters the dynamics of trust and information asymmetry between the principal and the agent [10]. Additionally, in transaction cost theory, blockchain can play a role in reducing transaction costs, curbing opportunistic behavior, and mitigating uncertainties within the business environment [10].

Many researchers are interested in blockchain applications in various operations management areas. However, because of the extension and novelty of this subject, there are lots of research gaps. Therefore, to comprehensively study the literature related to this subject, it should be made use of a method that analyzes and categorizes the studies while examining the important literature in this field. A systematic review is a bibliographic and descriptive-analytical method through which a deep analysis can be done by reviewing the subject comprehensively. In this research, by plotting the life cycle of the related research, the past status has been reviewed, and the future status has been predicted. Also, by clustering research fields in recent years, future research paths have been discussed.

The remaining part of this paper has been organized as follows. Section 2 represents theoretical literature in blockchain technology, operations management, and the application of blockchain in operations management. In Sect. 3, the methods used for conducting analyses in this paper have been briefly explained. Then, in the next section, the results of the methods used for life cycle analysis, bibliometrics, and content analysis have been fully described. In Sect. 5, the five clusters resulting from keyword analysis have been discussed. Finally, conclusions and suggestions for future research have been presented in Sect. 6.

2 Theoretical Literature

2.1 Operations Management

In a broader context, operations management (OM) can be characterized as the practice of making decisions and solving problems in order to effectively allocate the limited resources within an organization [11]. To put it differently, OM is a systematic procedure that transforms an organization's resources into value-enhancing products and services while adhering to the organization's established policies. Consequently, it represents the segment of an organization responsible for the conversion of various inputs into required goods or services, all while maintaining a specified level of quality [12]. Furthermore, the evolution towards smart manufacturing has resulted in the digitization of operations management, enabling the rapid access to process data for the purposes of monitoring, error detection, and data storage [13].

Operations management plays an essential role in making the best use of resources [14]. Generally, operations management includes a vast range of various areas. Some of the most important operations management areas examined in this paper include supply chain management, manufacturing, production, logistics, quality control, inventory control, value chain, human resource management, and information management.

2.2 Blockchain Technology

Nakamoto presented the concept of blockchain in the electronic cash system known as Bitcoin [15]. Blockchain is a distributed database which replicated and shared among members of a network. Each block in the chain enters a list of transactions and a hash into the previous block [16]. Each block usually consists of three components: a header block, a set of transactions, and metadata containing transaction validity information. The header block causes a new block to be connected to the previous block in the chain, which includes an encrypted algorithmic hash that has been created from the data in the block, a time mark, and a hash from the previous block; therefore, a related chain in chronological order is created [17]. After the block is created, all users participate in the network, looking for the next block by attempting to solve the complex mathematical function and creating a correctly encrypted block of transactions to add it to the general ledger of the blockchain. This process is called mining [18]. In other words, in a blockchain, blocks are stored on a decentralized set of nodes or computer instruments to guarantee both transparency and security. It is improbable that an institution could control a set of transactions as each block is stored in several nodes and its accuracy should be agreed on before being added to the chain. As more nodes are added, the network will be more extensive, and the system will become safer because hacking becomes more difficult [17].

There are different kinds of literature about the characteristics of blockchain. However, all of them mention the exact nature of it. Generally, there are three main blockchain concepts: consensus, cryptography, and smart contracts. Other characteristics of blockchain explain the mechanism of the above four components in another way. A brief explanation of three main concepts has been given below.

Consensus The content of the ledger showing the historical and present statuses have been stored by blockchain. For repeating and updating the ledger, the consensus of all parties is required. In other words, several parties should reach an agreement called a consensus [19].

Cryptography Blockchain uses cryptographic techniques to ensure the integrity of distributed ledgers. Whole network data is secured by the cryptographic encryption, which permits authorized users to decrypt information [19].

Smart contracts Recording, validating, and blockchain characteristics make it possible to make smart contracts in addition to advocating digital identity. Smart contracts allow making a valid contract through a public network without the presence of a third person [20].

The present literature categorizes blockchain networks through several methods based on parameters, managed data, accessibility, and access control [19]. Blockchains can be extensively categorized into two groups of Permissionless and Permissioned based on the access mechanism.

Permissioned blockchains referred to as private or consortium blockchains, such as Hyperledger, and Ripple operate as closed networks [21]. To become part of these networks, nodes must obtain explicit permission from network administrators [21]. Conversely, permissionless blockchains, exemplified by Bitcoin and Ethereum, function as open networks that welcome participation from anyone, allowing individuals to

freely join or exit the network [21]. These networks heavily rely on cryptocurrencies as incentives for user engagement [21]. Furthermore, blockchain consensus mechanisms can be classified into two categories: permissionless consensus and permissioned consensus [22]. In permissionless consensus, anyone who adheres to predefined rules is eligible to partake in the consensus process [22]. In contrast, permissioned consensus restricts participation to a limited group of authorized participants [22].

In the contemporary landscape, blockchain technology finds widespread and diverse applications across various industries. Noteworthy examples include its utilization in financial systems, Internet of Things (IoT) [23], healthcare administration, privacy and security measures, business and industrial processes, education, data management [7], as well as supply chain and operations management, among others.

2.3 Application of Blockchain in Operations Management

Supply chain management is intricately linked with operations management and refers to the oversight of resources allocated to the production and provision of goods and services [10]. The advent of digital transformation presents an opportunity for these management functions to adapt and effectively address the complexities inherent in contemporary supply chains [10]. Companies can foster and improve cooperation with their partners, such as suppliers and customers, through the utilization of information technologies [10]. This collaborative effort encompasses the exchange of data, harmonizing decision-making processes, and aligning objectives with various stakeholders, with information technologies recognized as pivotal elements in facilitating rapid and secure cooperation [10]. Several modern information technologies have influenced the SCM and OM communities, resulting in accelerated transaction processing and heightened visibility [10].

When utilized in OM applications, blockchain technology offers five key strengths:

(1) *Visibility* This refers to the capability of supply chain participants to track items throughout the entire supply chain, enhancing transparency [24].
(2) *Aggregation* Information stored on the blockchain can originate from various sources, including companies, customers, regulatory bodies, and smart sensors, allowing for a comprehensive view of the supply chain [24].
(3) *Validation* Once information is recorded on a distributed ledger, it is authenticated and resistant to tampering [24]. Blockchain has the potential to establish decentralized identity management with robust security features. Moreover, the validation aspect of blockchain creates opportunities for generating digital claims on supply chain assets and engaging in asset trading [24].
(4) *Automation* Blockchain enables the execution of specific transactions automatically in response to predefined conditions, streamlining processes and reducing the need for manual intervention [24].
(5) *Resiliency* The blockchain database is fault-tolerant, as it is replicated on every node. This resiliency ensures that the system can continue to operate even if one or more components or nodes experience failures, enhancing the overall reliability of the supply chain management system [24].

Indeed, smart contracts play a pivotal role in automating OM transactions [24]. They can significantly boost transaction speed, making processes more efficient and reducing the time required to complete various tasks [24]. Moreover, smart contracts facilitate the execution of comprehensive and self-executing contracts, ensuring that all terms and conditions are met without the need for intermediaries, which can further streamline OM operations [24].

The implementation of blockchain has a profound impact on the accuracy, reliability, visibility, incorruptibility, and timeliness of supply-chain processes and transactions [25]. These attributes make it highly appealing for enhancing the robustness, transparency, accountability, and decision-making within risk management [25]. Consequently, the emergence of blockchain offers invaluable opportunities for organizations seeking to prepare for and effectively respond to uncertain and complex situations, ultimately bolstering their resilience in a rapidly changing business landscape [25].

Here are some of the problems in OM that blockchain can potentially address:

(1) Enhancing Data Aggregation

The study of information flows within supply chains has been a prominent research focus within OM [24].

How Can Blockchain Be Beneficial? Blockchain technology offers a platform for consolidating data from diverse sources, including firms within a supply chain, regulatory bodies, and consumers, over time [24]. What makes this valuable is that it does so without the need for a single centralized authority to oversee and control the process [24].

(2) Advancing Contract Automation

Automation via blockchain offers at least two significant advantages, with the first being improved coordination throughout the supply chain [24].

How Can Blockchain Be Beneficial? Blockchain technology, in conjunction with smart contracts, facilitates the automatic initiation of the entire supply chain process [24]. This means that decisions related to production, shipping, and inventory can be automated and synchronized across the entire system [24]. Additionally, information concerning orders and payments becomes verifiable. Automated contracts empower buyers by ensuring commitment and reliability in transactions [24].

(3) Enhancing Supply Chain Risk Management

Effective supply chain risk management is of paramount importance in practical operations, involving a multi-step process: (1) identifying risks, (2) prioritizing them, (3) formulating a treatment plan, (4) proactively reducing risk exposure beforehand, (5) mitigating risk impact afterward, and (6) continuously reviewing performance and learning [24].

How Can Blockchain Be Beneficial? Establishing a connection between the entire supply chain, spanning from raw material producers to retailers, through a blockchain platform can empower companies to significantly enhance visibility within their extended supply chains [24]. This includes the ability to pinpoint factory locations, identify potential bottlenecks, and unveil any excessive geographic concentrations of production resources, thereby bolstering their risk management capabilities [24].

(4) Blockchain's Role in Ethical, Sustainable, and Responsible (ESR) Operations

ESR operations encompass vital concerns such as labor conditions, child or forced labor, funding conflicts, famine prevention, and responsible utilization of natural resources like land, water, and energy, especially in the context of operational decisions [24].

How Can Blockchain Be Beneficial? Blockchain technology holds the potential to validate the origin of products, ensuring that they are manufactured in facilities certified for ethical and environmentally responsible practices [24]. When implemented correctly, blockchain safeguards these certificates against duplication, double-counting, or illegal sale. This technology enhances the ability to verify the integrity of ESR operations and products [24].

(5) Collateralizing Supply Chain Assets

Contracts often present a challenge as they are typically bilateral, while supply chain resources and demands are distributed across numerous firms, consumers, and regulatory entities [24]. Furthermore, markets function most effectively with standardized, commoditized, and interchangeable items, which contrasts with the majority of corporate and supply chain resources that are highly customized [24].

How Can Blockchain Be Beneficial? The validation aspect of blockchain technology enables the generation of digital claims that can be circulated beyond traditional contract relationships [24]. Additionally, the aggregation and automation aspects of blockchain contribute to the creation of a marketplace for trading customized assets, thus addressing the challenges posed by the unique nature of supply chain resources [24].

(6) Production, Procurement, and Inventory: Mitigating the Bullwhip Effect

The bullwhip effect, a phenomenon where order fluctuations to suppliers exceed the variations in buyer sales, leading to distortion upstream, stands as a classic concern in OM [24]. The repercussions of the bullwhip effect encompass surplus inventory throughout supply chains, subpar customer service, and inefficient capacity utilization [24].

How Can Blockchain Provide Assistance? Whether it pertains to demand or supply information, visibility and validation issues persist [24]. Blockchain applications offer valuable support through their inherent features of enhancing visibility and ensuring the validation of information [24].

3 Research Background

Systematic literature review (SLR) has penetrated new areas and has been extensively used in recent years. The methodological framework of SLR is a precise method for reviewing the literature, identifying the problems that are being less covered, and discovering new techniques in the area under study. Furthermore, this approach guarantees that no related research is ignored [26]. Therefore, SLR provides a proper approach to the current blockchain technology study in OM. In this section, the papers

in which SLR is used in blockchain and various OM areas are reviewed to deeply identify the reasons behind this method.

Khanfar et al. (2012) conducted a study to explain the applications of blockchain technology in producing a sustainable production (SLR) approach. The potential contribution of blockchain technology to the economic, environmental, and social performances of producers and their supply chains has been explained. Moreover, this study explains how blockchain can affect the sustainable performance of producers by creating transparency, traceability, and sharing information in real-time. This systematic review has been done based on preferred report guidelines for the systematic review and meta-analyses (PRISMA) to conduct SLR. In this regard, 21 identified papers were examined and analyzed through content-based analysis techniques, and the applications of blockchain technology in sustainable production were identified [27]. In 2019, Queiroz et al. conducted a study to analyze and organize the literature in combining SCM and blockchain and provide a guideline for future studies. This study has followed the systematic review approach to analyze the existing literature on combining SCM and blockchain. 27 papers published in reputable journals between 2008 and 2018 were analyzed in this paper. For reviewing the literature, a systematic and interdisciplinary method was used to discover blockchain programs in the field of SCM [26]. In another paper, Paliwal et al. (2020) systematically examined the role of blockchain technology in sustainable SCM by reviewing papers published in reputable journals. The papers published in 2015 were reviewed, and this review includes 187 papers published in 2017, 2018, 2019, and early 2020. Moreover, emerging technology has been represented according to a classification framework for categorizing emerging technology literature based on the fundamental theory and the level of technological promptness for conducting literature reviews in various fields. Therefore, this study has classified an SLR and a framework for the literature on blockchain technology in sustainable SCM [28].

A study was conducted by Etemadi et al. in 2020 to visualize the scientific literature enriched by analyzing the keywords given by the authors to develop and examine blockchain capabilities to prevent cyber threats in international food supply chains. This paper has combined an SLR process with the analysis of bibliographic networks. Interdisciplinary papers published between 2016 and 2020 have been chosen to examine the revolutions in cyber threats, cybersecurity solutions, and blockchain solutions as a reference for identifying, categorizing, and identifying the requirements of a secure cyber-distributed ledger [29]. Another paper has been conducted to review and systematically analyze the existing literature focusing on SCM from the viewpoint of blockchain and smart contracts. A selected set including 106 review papers was analyzed to represent the complete view of using blockchain and smart contracts in SCM. The interval of 4 years has been selected as a time interval in this review literature [30]. A study was done by Wang et al. (2019) to conduct SLR on 24 papers that have examined the effect of blockchain technology on the methods and policies of the future supply chain [31].

Bayramova et al. conducted a study in 2021 using an SLR in which the potential effect of blockchain solutions for increasing supply chain resilience (SCR) in cybercrime has been identified. In total, 867 papers between 2016 and 2020 were

retrieved in the Scopus database and subsequently analyzed through abductive reasoning, grounded theory, and thematic meta-analysis [32]. Another paper has represented an SLR in applying blockchain in supply chains, procurement, and transportation management and has reached four categories: technology, trust, business, and traceability/ transparency. The initial bibliographic analysis presented 48 papers in the time interval from 2016 to 2018 [33]. In a paper written by Kumar et al. in 2020, the most important organizational theories used in blockchain have been determined in logistics and supply chain management (LSCM) based on the SLR. The final number of papers is 22 related papers published between 2018 and 2020 [34].

4 Research Methodology

Using SLR leads to understanding the extension and depth of existing knowledge and determination of existing research gaps, weak points, contrasts, and incompatibilities, and by analyzing existing literature, new theories are created, and specific hypotheses are examined [35]. This research has been conducted based on a four-step methodological framework.

4.1 Database

The first step of bibliographical analysis is creating a database that is used for scientometric analysis. In this paper, the most extensive list of indexed journals in Scopus and Web of Science databases are used. The Web of Science database lists all the information in each paper, including authors, bibliographic references, and addresses [36], and the database of Scopus provides comprehensive bibliographic information with high reliability and quality [37].

Searching papers in information banks was done in January 2021, and the initial results included 6252 papers from the database of Scopus and 2936 papers from the Web of Science (WOS) database, excluding books. The repeated papers extracted in both databases (Scopus & WOS) were removed, and then irrelevant papers were removed by reviewing the papers one by one and scrutinizing their titles and abstracts. 5895 were chosen for further analysis. Since OM is a broad field with direct connections to various areas such as supply chain management and financial management, efforts were made to extract articles primarily focused on pure operations management, which had relatively few articles in this field. Therefore, the final number of articles has approximately reached one-tenth; it means 567 articles have remained.

Figure 1 shows the steps for analyzing the bank of papers based on the PRISMA diagram (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) presented by Mohr et al. in 2009 [38]. As this study aims to conduct a bibliographic analysis of scientific papers, various keywords have been used to search for relevant papers to be selected. In this research, two groups of keywords have been selected, which were collected using the list of books, glossary, titles of journal papers, and Scopus & WOS databases, and included 31 words in the field of OM and five words

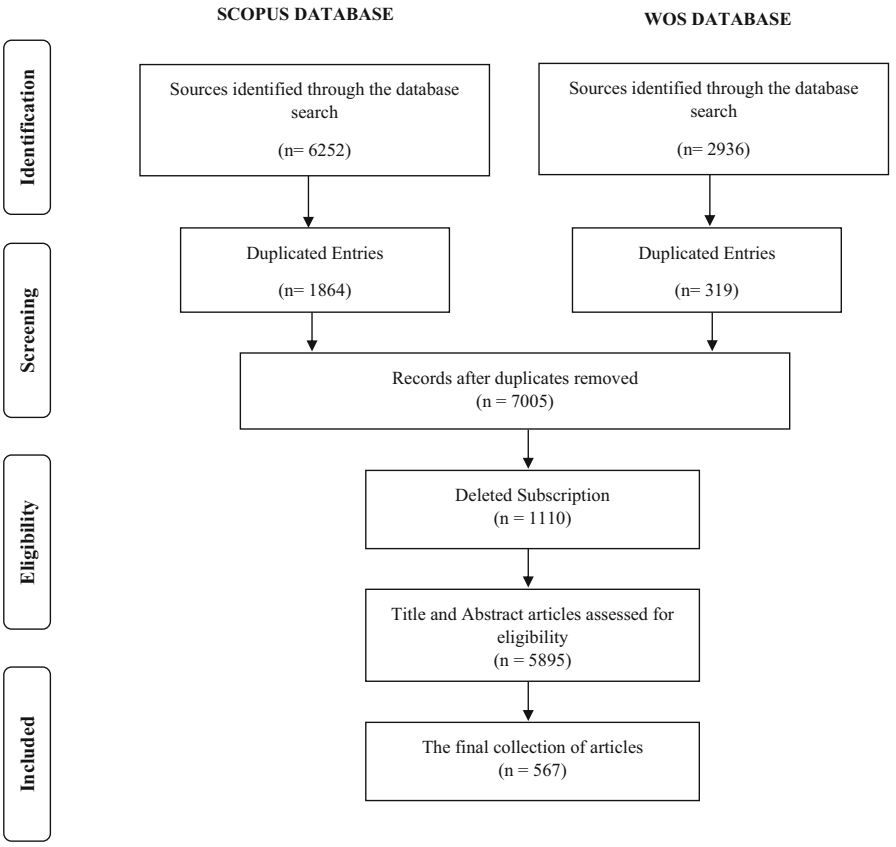

Fig. 1 Flow of information through the different phases

in the field of blockchain. Finally, after final refinement, 14 keywords related to OM and four keywords related to BC were selected, which have been given below:

The keywords of the first group have been defined for selecting key documents in the field of blockchain:

"Blockchain," "Blockchains," "Distributed Ledger," "Block chain".

The keywords of the second group have been defined for selecting key documents in the field of operations management:

"Agile OR Agility ", " Just-in-time OR Just in time ", " Lean ", "Logistic", " Manufacture OR Manufacturing ", " Operations ", " Production ", " Productivity", " Quality ", " Supply-chain ", " Value-chain".

4.2 Life Cycle Analysis

Life cycle analysis is one of the most applicable techniques that are used for analyzing data, estimating future perspectives or trends, and describing the history of technology [39]. Little introduced the concept of the life cycle of technology [40]. The life cycle

analysis includes four steps as introduction, growth, maturity, and saturation, considering integrity and competitive effect. By recognizing the present level of technology, its future procedure and saturation level can be predicted, and the capabilities of that technology can be estimated for more progress. Moreover, by determining the revolution path of technology, the impeding or growth factors can be identified. Discovering technology's maturity and future capabilities help researchers continue to research the field under study [37].

In this research, Loglet Lab4 software and Least Squares analysis have been used to predict the future and the growth trend of the subject under study. The method of least squares is a method in which the sum of the residuals is minimized. Predicting the future of technologies is based on curve fitting techniques using technology performance indicators which show their evolution over time [41]. Analyzing the growth and propagation of logistic components is in the form of an S-curve, which is somehow similar to wavelet analysis which refers to compression and signal processing (Meyer). Equation (1) is used to calculate logistic growth.

$$\mathrm{N}\ (\mathrm{t}) = \frac{K}{1 + \exp[-\frac{\ln(81)}{\Delta t}\left(t - t_{m)}\right]} \tag{1}$$

where K is the asymptotic limit to which the growth curve approaches and it shows the level of growth saturation, Δt is the period needed for a path to grow from 10 to 90% of the K limit, and tm is the midpoint [42]. Also, the Fisher-Perry conversion curve is used to convert the logistics curve to a linear curve. Through doing this, Δt, tm, and K can be determined [39].

4.3 Bibliographic Analysis

Prichard introduced bibliographic analyses [43]. Bibliometrics is a field of research that includes various methods and techniques for quantitative analysis of research fields. Bibliographic analysis facilitates a deep understanding of a research area, determining its borders, discovering top authors, and new directions for future studies [44]. Generally, bibliographic information is used for processing and analyzing quantitative and qualitative data [45]. The high popularity of this method in recent years can be because of the following reasons:

- To Evolute and access to bibliographic software such as VOSviewer and large databases such as Scopus and WOS [46];
- To Manage large volumes of unstructured scientific data from a micro and macro viewpoint [46, 47];
- To identify the overall view of research gaps and recognition of the amount of participation of researchers in the field under study [46];
- To Measure and evaluate the relative quality and the knowledge being developed by researchers [48];
- To Eliminate the judgments and biases of experts [37].

Despite the advantages of bibliometric analysis, there are some limitations: this method can measure the actual value of the data qualitatively, it makes an interruption

between the start and finishing times of the research, and all the scientific revolutions are not accessible as all the scientific studies are not published in the form of journals [37]. In this paper, the method of bibliometric analysis has been used along with other qualitative methods like expert judgment and content analysis. Moreover, the VOSviewer text extraction technique and other content analysis techniques have been used to visualize and randomly create networks of extracted terms from the scientific literature to cover some limitations of this method.

4.4 Content Analysis

Content analysis is a measurement method that has become a popular research study in management. Content analysis is used for identifying and summarizing literature procedures and measuring hidden structures in quantitative research studies. Especially, when obtaining valid data from traditional resources are difficult [49]. In a structural and systematic approach, content analysis can be used to evaluate a large amount of data [50]. The analysis of the title, abstract, and keywords of the papers based on the text mining technique is used to identify the patterns, relationships, and trends used in the papers. The process of identifying valuable information is called text mining. Text mining identifies top countries and popular methods and categorizes papers based on their methodology's most important research subjects [37].

5 Results

In this section, the procedure for publishing papers in the field of blockchain technology in OM has been evaluated, and interesting findings have been represented regarding countries, institutes, journals, authors, and papers. Figure 2 shows the number of papers published on blockchain in OM (2016–2020) by year. No important paper has been found in this field before 2016.

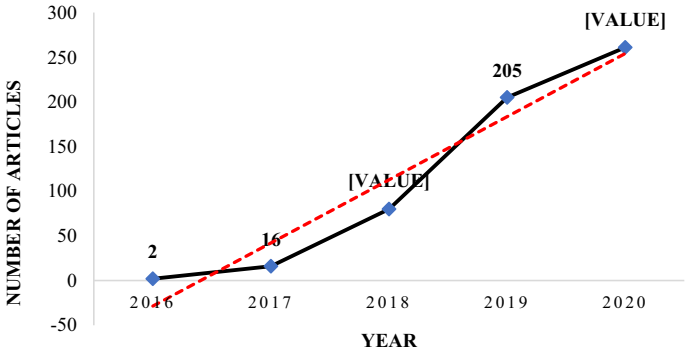

Fig. 2 Frequency of published articles in the field of blockchain in operations management by year

Based on Fig. 1, the first paper was published in 2016 entitled "Food-agricultural Supply Chain Tracking System for China Based on RFID and Blockchain Technology." In this paper, the status of the development and use of blockchain technology and RFID (Radio Frequency Identification) has been first studied; then, they analyzed the advantages and disadvantages of using RFID and blockchain technology in constructing the food-agricultural supply chain tracking system. Furthermore, they concluded that food safety is effectively ensured by tracking valid data of agricultural products in the supply chain process [51].

5.1 Life Cycle Analysis

An S-shaped curve was used to recognize the life cycle of blockchain in OM. This curve shows productivity growth as a function of research activities conducted in a particular field. The blockchain life cycle in research studies done in OM has been presented in Fig. 3.

Figure 3 shows the growth in 10 years and predicts the growth until 2033. After the first paper was published in 2016, the growth phase has increased exponentially in 2018, and it is estimated that this growth will continue for another eight years. This exponential rate can be explained by the increasing use of "supply chain" and "blockchain technology" in papers. The use of these concepts has tremendously increased after 2018. It is predicted that the number of papers published in this field will be 2000 in 2027. Therefore, this extraversion shows a clear potential for further improvements in this field. This level does not indicate the final saturation, but it shows it will reach a new level. In other words, if innovations are made in this field, the growth period is still extendable.

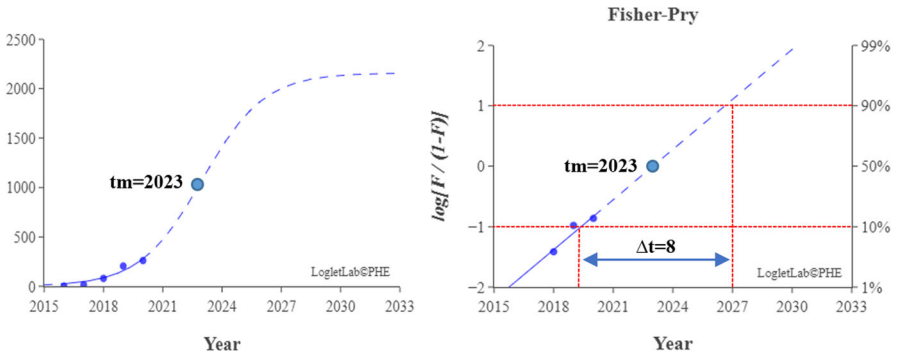

Fig. 3 Life cycle of research in the field of blockchain in operations management

5.2 Bibliography

5.2.1 Countries

In the present study, a part of the bibliometric analysis was dedicated to countries studying OM. Therefore, 20 top countries were introduced considering publishing papers in OM, and countries that have obtained a high citation mean compared to other countries have been identified. According to the results of the bibliographic analysis, it was found out that China, with the publication of 104 papers from 2016 until December 2020, is the most productive, and the United States with 3273 citations is the most influential and collaborative country. Table 1 lists the top 20 countries with the highest rate of paper publication and utmost citations.

In the above table, the amount of countries' cooperation has been shown, and it has been represented visually in Fig. 4.

Based on Fig. 4, the density of countries in the red areas indicates that the highest level of international cooperation in publishing research papers has been made by countries like the United States, India, China, Germany, and the United Kingdom.

5.2.2 Universities and Research Centers

The activity level of universities and research centers in various scientific fields has led to the extension and development of science, and it has become a proper ground for making progress in the scientific area. Hence, the most influential universities and research centers in blockchain in OM have been identified. Table 2 includes information about active universities and research centers in the area of research and introduces 10 top universities and research centers by considering the highest citation mean.

Based on Table 2, Vienna University of Economics and Business with 732 citations, Hong Kong Polytechnic University with 154 citations, and Southeast University with 112 citations have been identified as including the most citations among the influential universities and research centers in the field of blockchain in OM.

5.2.3 Top Journals, Papers, and Authors

The number of published papers in each journal has been identified using bibliometric analysis in the present study. Among active journals in the field of blockchain in OM, the International Journal of Production Research has been identified as the most influential journal with 1431 citations, and IEEE Access, with a total of 23 papers, has included the most number of papers in the field of OM. According to the number of published papers and the number of citations in OM, ten top journals have been introduced in Table 3.

One of the numerical indicators that can lead to competition in research and the growth of scientific productions is the scientometrics index of citations which is estimated based on the number of citations attributed to papers. As the mentioned indicators are higher for a research paper, the more the efficiency of the paper is in the

Table 1 The most productive and influential countries

Rank	Most productive countries		Most influential countries		Most collaborative countries	
	Country	Publication no	Country	Citation no	Country	International network
1	China	104	United States	3273	United States	422
2	United States	91	China	1587	China	303
3	India	79	United Kingdom	1261	United Kingdom	200
4	United Kingdom	43	India	1069	India	163
5	Germany	37	Austria	951	Germany	125
6	Australia	23	Germany	896	France	114
7	France	22	France	861	Austria	88
8	Italy	20	Italy	625	Malaysia	85
9	Russian Federation	17	Australia	474	Australia	83
10	South Korea	16	Japan	463	Canada	75
11	Canada	15	Switzerland	460	Italy	74
12	Hong Kong	15	Canada	451	United Arab Emirates	72
13	Indonesia	15	Russian Federation	442	Japan	70
14	Malaysia	13	Brazil	354	Hong Kong	60
15	Turkey	11	Hong Kong	336	Russian Federation	49
16	United Arab Emirates	11	Spain	311	Brazil	48
17	Switzerland	10	Malaysia	295	New Zealand	47
18	Brazil	9	South Korea	270	Greece	42
19	Austria	8	Taiwan	235	Taiwan	35
20	New Zealand	8	Netherlands	215	Switzerland	31

field under study. Considering this issue, the most efficient papers in the blockchain field in OM have been introduced in Table 4.

5.2.4 Co Citation-Cited References

In Fig. 5, the network plan of co citation- cited references has been represented. The node's size corresponds to the number of citations, the lines related to the citations in each direction, and the distance between nodes correspond to the tendency of references to be referenced by other references.

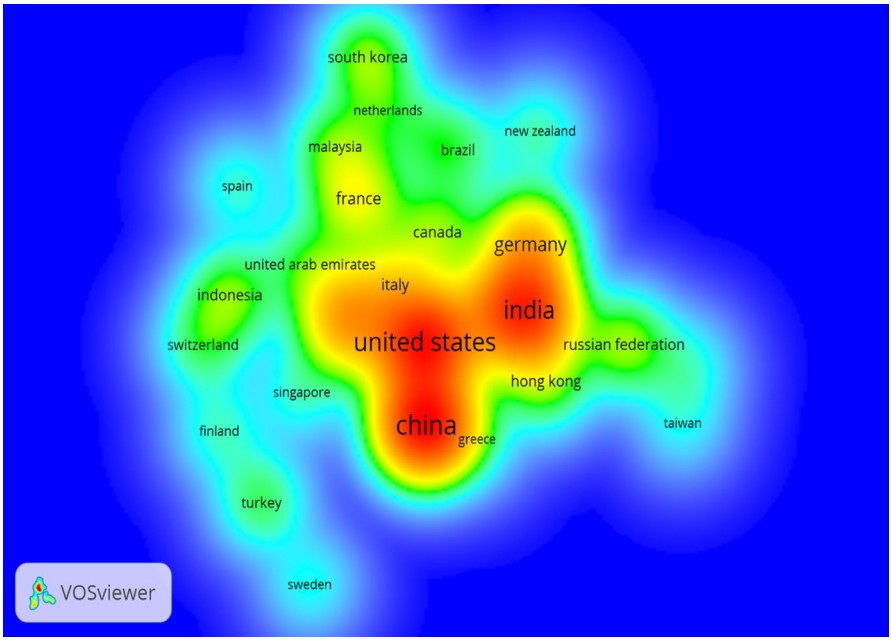

Fig. 4 International cooperation of countries

Table 2 The most influential universities and research centers

Rank	Organization	Country	Citation no
1	Vienna university of economics and business	Austria	732
2	The Hong Kong polytechnic university	Hong Kong	154
3	Southeast university	China	112
4	Shenzhen university	China	97
5	University of southern California	United States	89
6	Aston university	United Kingdom	67
7	California state university	United States	62
8	University of Liverpool	United Kingdom	62
9	Auckland university of technology	New Zealand	53
10	Excelsia college and Indiana Wesleyan university	Australia	53

The top authors have been represented based on the number of publications and the mean of citations in Fig. 6. In the figure, the size of each circle shows the total citations for each author, while the color of the circles shows the mean of a citation for each paper. In this regard, blue, green, and red indicate low, medium, and high, respectively. Moreover, the distance between two authors shows the amount of relationship between

Table 3 The most influential and productive sources

Rank	Most influential sources			Most productive sources		
	Source	IF	Citation no	Source	IF	Publication no
1	International journal of production research	8.568	1431	IEEE access	3.367	23
2	International journal of information management	14.098	1071	International journal of production research	8.568	21
3	IEEE access	3.367	742	ACM international conference proceeding series	0.61	14
4	Supply chain management	8.647	555	Sustainability (Switzerland)	3.251	13
5	International journal of production economics	7.885	364	International journal of information management	14.098	10
6	Sustainability (Switzerland)	3.251	323	Proceedings of the international conference on industrial engineering and operations management	0.19	9
7	Transportation research part E: logistics and transportation review	6.875	223	Supply chain management	8.647	8
8	Computers and industrial engineering	5.431	196	International journal of production economics	7.885	7
9	Robotics and computer-integrated manufacturing	5.666	122	IOP conference series: earth and environmental science	0.41	7
10	Frontiers Of engineering management	1.520	90	Transportation research part E: logistics and transportation review	6.875	5

Table 4 the most effective articles existing in the blockchain in the operation management field

Rank	Title	Publication year	Source	Citation
1	An agri-food supply chain traceability system for China based on RFID and blockchain technology	2016	13th International conference on service systems and service management	468
2	1 Blockchain's roles in meeting key supply chain management objectives	2018	International journal of information management	434
3	Blockchain technology and its relationships to sustainable supply chain management	2019	International journal of production research	432
4	The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics	2019	International journal of production research	294
5	A supply chain traceability system for food safety based on HACCP, blockchain and internet of things	2017	14th International conference on services systems and services management	264
6	Developing global qualification-competencies ledger on blockchain platform	2018	Proceedings of 17th Russian scientific and practical conference on planning and teaching engineering staff for the industrial and economic complex of the region	212
7	A novel blockchain-based product ownership management system (POMS) for anti-counterfeits in the post supply chain	2017	IEEE access	194
8	Blockchains everywhere-a use-case of blockchains in the pharma supply-chain	2017	Proceedings of the IM IFIP/IEEE international symposium on integrated network and service management	189
9	Supply-chain management system for plastic pipes market based on open blockchain framework	2019	Proceedings-21st IEEE international symposium on a world of wireless, mobile and multimedia networks	188
10	Blockchain-based traceability in agri-Food supply chain management: a practical implementation	2018	IoT vertical and topical summit on agriculture	175

Fig. 5 Co citation- cited references

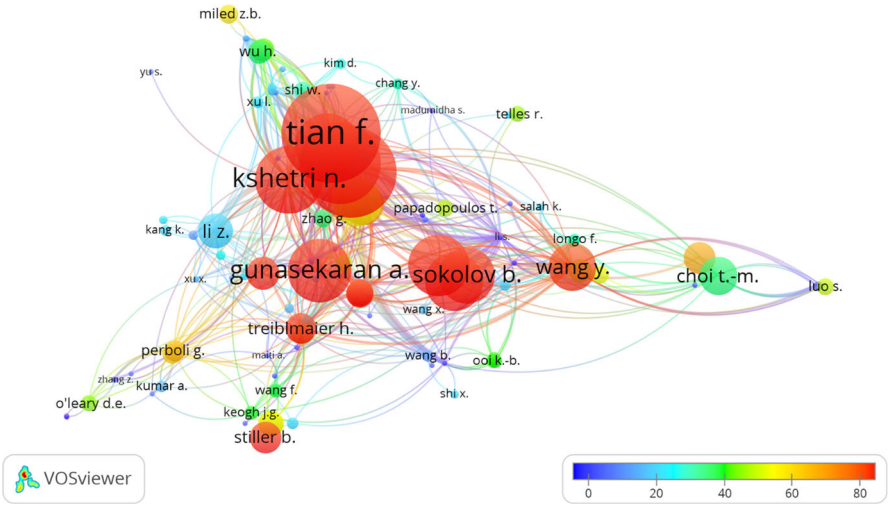

Fig. 6 The top authors

authors and their mutual citations. Hence, the less the distance between two authors, the closer their relationship.

Among the authors; Feng Tian, Department of Information Systems and Operations, Vienna University of Economics and Business with two papers and 732 citations, Joseph Sarkis, Worcester Polytechnic Institute, Foisie School of Business with six papers and 660 citations, Mahtab Kouhizadeh, Foisie Business School, Worcester Polytechnic Institute with four papers and 583 citations have been recognized as the most influential authors in the field of BC in OM.

6 Research Subjects

The text mining function of the VOSviewer has also been used to identify subjects (among keywords in the titles, abstracts, and paper keywords). Figure 7 shows the network visualization of subjects and sub-fields of the research. Considering the frequency of keywords and their compatibility with other keywords, the authors identified and analyzed prevalent topics and different clusters.

6.1 Clustering

In this section, the clustering of keywords has been done by the VOSviewer software with occurrences, and after examining represented clusters given by the software and scrutinizing the existing papers in each cluster, the modified clusters were proposed in the following order, including Decentralized Finance, Traceability, Trust, Sustainability and Information Sharing.

Decentralized Finance Nowadays, one of the most important topics studied in papers is Decentralized Finance. The most important keywords of this cluster based on the frequency of articles are Finance, Ethereum, Operations Management, Cryptocurrency, Supply Chain Performance, and Supply Chain Finance.

Traceability One of the other important and distinctive topics related to blockchain technology is traceability. Based on their frequency, the most important keywords in papers include Supply Chain, Manufacturing, Logistics, Traceability, Internet of Things, Transparency, and Production.

Trust Trust is one of the characteristics of blockchain technology. In other words, blockchain provides a ground in which there is no need for trust between network

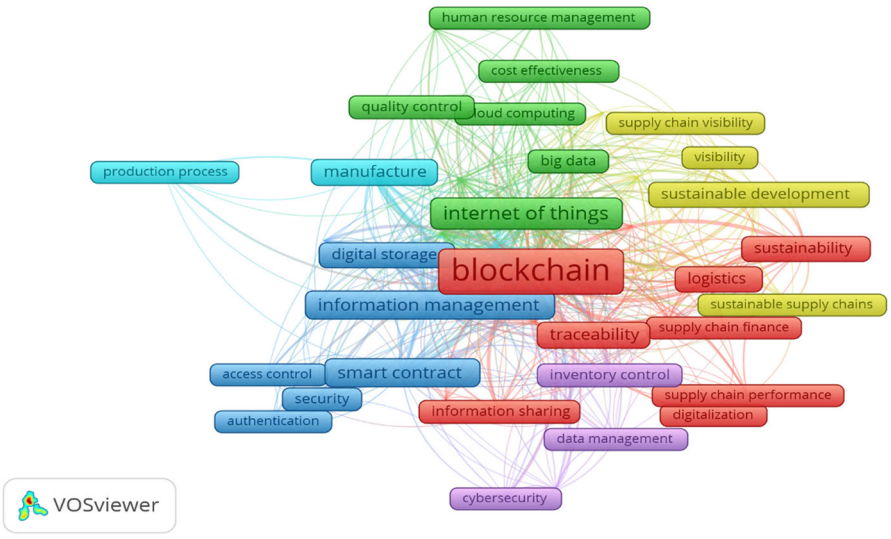

Fig. 7 the four main research topics in blockchain in operation management

members as the necessary arrangements to conduct transactions in a secure context with blockchain technology are already provided. Security, Smart contracts, Trust, and Automation, are among the most critical keywords in the Trust cluster based on their frequency in the papers.

Sustainability Considering the advent of Industry 5.0 and its emphasis on environmental issues and sustainability, this cluster is significant. In this cluster, the keywords of the highest frequency in the papers are Integration, Sustainability, and Efficiency.

Information Sharing the last cluster is the cluster of information sharing, which is highly important in transferring information and data. The keywords in this cluster that are of the most frequency are Information Management, Information Sharing, and Risk Management. The clustering of each of these five clusters is shown in Table 5.

7 Discussion

In recent years, blockchain technology has had various applications in OM, including decentralized, high security, and immutability. Moreover, the procedures of the 4.0 industry and digital revolutions have made it easy to use blockchain in OM. However, industrial applications and scientific cooperation in this field are still in the phase of being proven. So, the extracted clusters from the keywords in Sect. 4.3 have been explained in detail to describe blockchain applications in OM.

7.1 Decentralized Finance

Considering the accumulation of keywords in the cluster of Decentralized Finance which is also known as DeFi, as stated by Caldarelli and Ellul, a financial infrastructure is based on general blockchain, and it changes the traditional financial products to transparent protocols which are done without intermediaries [52]. In other words, Defi aims to activate all the financial instruments of traditional financial ecosystems, such as contacts, all financial services, and their derivatives, in a decentralized world [53]. In their study, Chen & Bellavitis; and Schär stated that DeFi causes the extension of financial range, the decrease in the costs of transactions, the encouragement of unlicensed innovations, the improvement of free accessibility, and the creation of new commercial opportunities [54, 55]. Moreover, Lemieux et al. stated that DeFi, affecting national sovereignty and financial transfer channels, leads to the point that technology companies and national governments do not use traditional methods by making new digital infrastructures for conducting bank issues, financial issues, and payments [56].

Meanwhile, Supply Chain Operation, Asset Management, and Auditability topics were of the least frequency among the bank of papers in this cluster.

7.2 Traceability

Traceability is one of the principal characteristics of blockchain. By focusing on the accumulation of keywords in this cluster, as stated by Mirabelli and Solina, traceability can be defined as accessing all information being examined in the life cycle

Table 5 Final clustering of keywords in blockchain in operation management

Clustering	Keywords	F	Clustering	Keywords	F
Decentralized finance (DeFi)	Cryptocurrency	57	Trust	Access control	36
	Auditability	6			
	Ethereum	101			
	Asset management	5			
	Digitalization	38		Authentication	81
	Finance	165		Automation	140
	Profitability	10		Cloud computing	81
	Supply chain finance	53		Complex networks	11
				Cybersecurity	51
	Supply chain operation	4		Security	520
	Supply chain performance	56		Smart contract	462
	Operations management	69		Trust	457
	Human resource management	16	Sustainability	Efficiency	173
Traceability	Logistics	601		Efficiency	2
	Manufacturing	606		Integration	269
	Production	376		Integration	4
	Supply chain	1000		Supply chain visibility	52
	Big data	221		Sustainable development	62
	Industry 4.0	241		Sustainability	250
	Visibility	132		Sustainable supply chains	31
	Internet of things	491		Supply chain network	72
	Quality assurance	22		Supply chain process	46
	Quality control	24			11
	Data provenance	28	Information sharing	Information sharing	154
	Transparency	378		Data management	51
	Traceability	495		Information management	203
	Value chains	28		Inventory control	14
				Risk management	86
				Digital storage	26

of a product or service using registered identifiers [57]. Moreover, Kamble et al. declared that blockchain could trace trusted information through collecting, sharing, and transferring valid data in resources, process, storehouse, distribution, and sales. Any information can be searched in every blockchain-based on-time order. The inherent characteristics of blockchain, such as providing a common safe and decentralized database, increase trust through transparency and traceability for commodity transactions, data, and financial resources [58]. Furthermore, in their research, Behnke and Janssen stated that the main assurance of blockchain for SCM is its potential to increase transparency and product traceability by allowing the exchange of trading data between two or more supply chain partners, the immutability of stored transaction data, and maintaining only one copy of the transaction database without the intervention of an intermediary and third party [59]. Also, Lohmer and Lasch declared that the transparency of blockchain and the performances of smart contracts lead to flexible and short time relations between small and medium companies. Furthermore, they concluded that immediate processing causes the improvement of transparency among stakeholders, and simultaneous and independent access of all partners also increases agility [8].

In this cluster, keywords with the least frequency are Quality Assurance, Quality Control, Data Provenance, and Value Chain.

7.3 Trust

This cluster is vital because the originality of data is necessary for many industries, inventory trust, and tracking the data received from suppliers, manufacturers, or governments. Blockchain can provide mechanisms that lead to accountability and, subsequently, reliability [60]. Based on Lohmer & Lasch, trust is essential in network management, and it can be facilitated by blockchain technology because of its transparency. Obviously, cooperation is essential for the efficiency of services, and it leads to the future success of production networks and supply chains. In modern business, creating trust is a transactional cost by itself; therefore, blockchain decreases the general costs of the transaction through transparency and a distributed nature [8]. In their paper, Centobelli et al. declared that direct affirmation and reliability of processes prevent uncertainties related to system malfunctions due to manipulation or attacks done with fraudulent objectives. Storing and recording data, information, and the history of transactions in a decentralized and distributed general ledger without a centralized reference leads to improved trust among supply chain partners [61].

In the trust cluster, the keywords with the least frequency are Complex Networks, Access Control, and Cybersecurity.

7.4 Sustainability

By focusing on the existing keywords in the cluster of sustainability, Leng et al. define sustainability as "an attractive strategy to decrease risk/ uncertainty of a system, meeting the individual needs of consumers, saving energy, carrying out social responsibility, and increasing the efficiency of resources in the production section"

[62]. Saberi et al. have defined sustainability using a triangular concept that includes a balance between environmental, social, and commercial dimensions during SCM. An important strategic and competitive issue for sustainability in supply chains is admitting and confirming that processes, productions, and activities within a supply chain should have specific licenses and criteria of sustainability [63]. As stated by Esmaeilian et al., the sustainability of a supply chain is a very complex process, and the required characteristics and needs of sustainable systems have often been vaguely defined. An effective industrial revolution that can help businesses balance their decisions on economic sustainability and environmental and social consequences needs efficient plans for sustainability [64].

Based on previous clusters, in this cluster, the keywords that have the least frequency are Sustainable Supply Chains, Supply Chain Process, and Supply Chain Visibility.

7.5 Information Sharing

Finally, emphasizing the accumulation of the existing keywords in the information sharing cluster is significant in the decentralized management model. Xue et al. stated that by creating a ground for sharing information, the scheduling of the distributed information could be realized, and high-quality, low-cost services can be provided on a peer-to-peer basis. According to them, information sharing is the main element of dynamic capabilities of the supply chain that can affect business performance. As transferring information in the supply chain should assure the accuracy and timeliness of demanded and transactional information and the customers' sufficient accessibility to the information should be guaranteed, blockchain technology has an essential role in sharing customer-based information and realizing supply chain information sharing [65]. Wan et al. declared that information sharing leads to the point that the members of an information supply chain, for example, characteristics of a product, the status of a product, ownership, data locus, and even environmental effects, are shared [66]. Moreover, as Hunt et al., blockchain leads to sharing efficient and safe information in OM [67].

The keywords having the least frequency in papers are Inventory Control, Digital Storage, and Data Management.

Regarding the accumulation of the keywords in the five clusters, which is the result of analyzing the keywords of the bank of papers, it can be concluded that in this paper, blockchain technology has applications in the following areas of operations management:

Asset Management, Finance, Human Resource Management, Logistics, Manufacturing, Production, Supply Chain, Quality Control, Value Chains, Sustainable Supply Chains, Data Management, Information Management, Inventory Control, Risk Management.

Considering the extensive and essential role that financial processes play in the realm of operations management (OM), it becomes crucial to conduct these processes on a decentralized platform, thereby obviating the need for trust between involved parties. Additionally, the incorporation of traceability and transparent information sharing ensures that all OM processes are meticulously monitored and made accessible to all

participants and stakeholders, effectively preventing instances of fraud and counterfeit products. In the present era, sustainability takes center stage as a pressing concern. Given the heightened focus on environmental conservation, blockchain technology offers the potential to mitigate challenges such as waste generation and energy consumption within OM. Lastly, as previously mentioned, blockchain technology is still in its developmental stages and faces certain challenges. To harness its full potential, widespread adoption is necessary, and it is essential to enhance its strengths while addressing its limitations.

8 Conclusion and Further Studies

In recent years, blockchain technology has experienced significant growth across various domains, particularly in the context of operations management (OM). While some research papers have delved into the application of blockchain technology, there remains a dearth of studies in bibliographic and network analysis. Given the expansive nature of OM, the existing literature in this field is extensive. Therefore, employing the systematic literature review method serves as a valuable approach to comprehensively assess and categorize the available literature, offering audiences a structured and transparent perspective and preventing them from becoming overwhelmed by the sheer volume of information. This paper has conducted a systematic review of scholarly articles from the Scopus and Web of Science (WOS) databases, encompassing life cycle, bibliometric, and content analyses, to thoroughly examine and analyze the utilization of blockchain technology in OM.

Life cycle analysis has been employed to forecast forthcoming procedures and scrutinize the research's developmental trajectory. The findings indicate a projected increase in the number of papers in this field by 2033. Bibliometric analysis sheds light on prevalent research themes in the field, especially in recent years. Based on this analysis and the results from VOSviewer software, China has emerged as the country with the highest publication count, totaling 104 papers, while the United States leads in terms of citations, with 3273 citations. Examining the authors' shared citation network, it becomes evident that Feng Tian, Joseph Sarkis, and Mahtab Kouhizadeh hold the most substantial influence in the research field, demonstrated by their overall linking power and citation impact. When considering influential journals based on their overall linking power and citation impact, the International Journal of Production Research and the University of Economics and Business take precedence with a total of 1431 citations and an impressive impact factor of 8.568. In the domain of blockchain in operations management, IEEE Access emerges as the most prolific journal, boasting 23 papers and an impact factor of 3.367. Lastly, the application of VOSviewer software has led to the identification of 5 distinct clusters, bolstering the keyword analysis. These clusters encompass keywords closely related to blockchain technology in operations management and include DeFi, Traceability, Trust, Sustainability, and Information Sharing.

Future research endeavors could consider augmenting their bibliographic data by incorporating information from additional databases and subsequently comparing it with the dataset used in this current study. Furthermore, it is advisable that, given the

industrial evolution and the rapid pace of technological advancement, researchers may increasingly gravitate towards conducting studies centered on Foresight and Future Studies within the context of blockchain technology in the fifth industrial revolution. Given the heightened emphasis on human interaction in the fifth industrial revolution, it becomes feasible to discern emerging trends, drivers of change, and their potential implications on the industry's medium and long-term future through the fusion of foresight methodologies and blockchain technology research. Consequently, through meticulous planning and forecasting, the formulation of effective strategies for the utilization of blockchain technology can be accomplished.

Author Contribution The author confirms also responsibility for following: study conception design, data coding, analysis and interpretation of results, and manuscript preparation.

Funding No funding was received for conducting this study.

Data availability The dataset used in this study are available to the public under a Creative Commons license at http://doi.org/10.14281/18241.20.

Code Availability The coding used in this study are provided in the supplementary section.

Declarations

Ethical statement I hereby declare that this manuscript is the result of my independent creation under the reviewer's comments. Except for the quotes contents, this manuscript does not contain any research achievement that have been published or written by other individuals or groups. I am the only author of this manuscript. The legal responsibility of this statement shall be borne by me.

Conflict of interest Not applicable.

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