Blockchain in supply chain management: A review, Bibliometric and network analysis

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Abstract

Blockchain is a distributed ledger technology that has attracted both practitioners and academics attention in recent years. Several conceptual and few empirical studies have been published focusing on addressing current issues and recommending the future research directions of supply chain management. To identify how blockchain can contribute to supply chain management, this paper conducts a systematic review through bibliometric and network analysis. We determined the key authors, significant studies, and the collaboration patterns that were not considered by the previous publications on this angel of supply chain management. Using citation and co-citation analysis, key supply chain areas that blockchain could contribute are pinpointed as supply chain management, finance, logistics, and security. Furthermore, it revealed that IoT and smart contracts are the leading emerging technologies in this field. The results of highly cited and co-cited articles demonstrate that blockchain could enhance transparency, traceability, efficiency, and information security in supply chain management. The analysis also revealed that empirical research is scarce in this field. Therefore, implementing blockchain in the real-world supply chain is a considerable future research opportunity.

Keywords; Blockchain; Supply Chain Management; Literature review; Bibliometric; Network Analysis

1. Introduction

Blockchain is a distributed database of transactions, ledgers, and digital occurrences (Crosby, 2016) that provides a decentralized platform that serves as an immutable platform for participating parties (Zeng et al., 2018). Blockchain was introduced in 2008 by Nakamoto for a peer-to-peer financial transaction procedure named Bitcoin (Nakamoto, 2019). Before Bitcoin, most people trusted a centralized middle man, such as banks and governments, to make financial transactions (Hutt, 2018). Bitcoin revolutionized that by providing a transparent and immutable procedure without a central authority. Bitcoin came as a digital currency, but the blockchain technology could have many more implications (Swan, 2015). However, we need to briefly narrate how blockchain works to interpret its impact in other fields. Blockchain is a chain of blocks. Each block contains the data, hash, and the hash of the previous block. Hash is a unique encrypted code of letters and numbers, which is the identification of the block. The hash of the last block refers to the previous block that makes the chains of blocks. The hashing function is taking input and generating unpredictable output through a hashing algorithm (Vujicic et al., 2018). Hashing is a significant aspect of blockchain technology immutability (Kumar B, 2020), which empowers this technology to contribute to other fields rather than only finance. There are numerous implications and applications for blockchain, ranging from financial transactions (Tapscott & Tapscott, 2017), manufacturing (Abeyratne & Monfared, 2016), logistics (Pournader et al., 2020), and supply chain management (Saberi et al., 2019).

Recent studies indicate an inclination of implementing blockchain in supply chain management by scholars and industry managers (Linda Pawczuk, 2017; Pournader et al., 2020). Although blockchain in supply chain is in its early stages, it is predicted to transform supply chain significantly in the future (Kamble et al., 2019; Winkelhaus & Grosse, 2020). Surveys show that supply chain managers and scholars are reasonably optimistic about blockchain in supply chain management (Hackius & Petersen, 2017).

Although academic papers on blockchain in supply chain management are scarce, we witness the increasing quantity of blockchain studies in specific supply chain knowledge areas (Pournader et al., 2020). For example, Min (2019) studied risk, and Hughes et al. (2019) studied information management in supply chain. Moreover, many articles such as (Nowiński & Kozma, 2017), (Ying et al., 2018), (Tapscott & Tapscott, 2017) and (Sikorski et al., 2017) focused on the finance side of blockchain contribution to supply chain.

Besides, there are still limited papers on blockchain in a specific angle of supply chain management. Namely, Francisco and Swanson (2018) explored the transparency and traceability that blockchain brings into supply chain management. Furthermore, Saberi et al. (2019) studied the adoption barriers of blockchain and (Kshetri, 2018) considered supply chain management objectives.

Blockchain is not the only technology that attracted the attention of supply chain managers and scholars. Other emerging technologies such as Internet of Things (IoT), smart contract, and artificial intelligence would transform supply chain management significantly (Winkelhaus & Grosse, 2020; Xu et al., 2018). Those emerging technologies can either contribute individually or integrate with blockchain in supply chain. Most of the papers on this topic studied specific technologies. There is a scarcity of an academic paper that reviews all the integrated technologies with blockchain in supply chain management (Venkatesh et al., 2020).

A few literature reviews were conducted on blockchain in supply chain management in the last few years. Some of these reviews have focused on the specific angel of supply chain such as sustainability (Saberi et al., 2019; Venkatesh et al., 2020), provenance (Kim & Laskowski, 2016), resilience (Min, 2019), while others have been broadly covered the topic with a comprehensive view. Still, they have been conducted relatively straightforwardly with summary statistics of published papers and topical areas (Keogh et al., 2020). Each of the studies has insights into this topic, but rigorous bibliometric, citation, and co-citation analysis of this literature can provide further insights not previously grasped.

Bibliometric analysis is a powerful method to identify emerging topical areas (Ellegaard & Wallin, 2015; Fahimnia et al., 2015; Merediz-Solà & Bariviera, 2019). Furthermore, it can facilitate identifying influential researchers, research clusters, organizations, and most contributed countries to acknowledge the significant participants (Jalali et al., 2019; Mishra et al., 2018; Muhuri et al., 2019). This study provides a comprehensive evaluation of the field by conducting bibliometric and citation analysis, starting with a pool of 769 published papers on blockchain in supply chain management. Citation and co-citation analysis are also powerful tools for identifying influential studies and trends of the topic. This paper presents the findings of the citation analysis to support the results of the bibliometric analysis. Furthermore, we conducted a co-citation analysis to identify influential studies. The algorithmically obtained co-citation results were set to conduct a further investigation for defining supply chain sections, other integrated technologies with blockchain, and blockchain's potential contributions in supply chain management.

2. Blockchain in Supply chain management

2.1 Blockchain definition and its boundaries:

Blockchain is a distributed ledger database of records, or transactions, or digital incidents that have been executed and conveyed by participants (Crosby, 2016). Numerous articles have been published to clarify how blockchain technically works in recent years (see among Francisco & Swanson, 2018; Gupta & Sadoghi, 2018; Nakamoto, 2019). Blockchain technology has been famed based on cryptocurrencies, namely Bitcoin (Underwood, 2016). Still, there are numerous implications for it, ranging from financial services (Zeng et al., 2018), manufacturing (Abeyratne & Monfared, 2016), and supply chain (Francisco & Swanson, 2018). Here, we focus on blockchain in supply chain management and blockchain's implications rather than blockchain technology's technical mechanism. Accordingly, we excluded the blockchain technological aspects such as algorithm, hash function, wallet, signature, and protocols.

2.2 Supply Chain Management definition and its boundaries:

Definitions of supply chain management differ across authors (Mentzer et al., 2001). Cooper et al. (1997) defined supply chain management as managing the total integrative flow of materials from raw material suppliers through production, warehousing, transportation to the end-users. Supply chain management consists of various thresholds, and identifying its boundaries is an essential step. Here, we consider all the supply chain echelons from supply to manufacturing, distribution, and customer side activities. Furthermore, supply chain management represents the management of the whole chain in this study. Also, we consider only the forward supply chain, so reverse logistic and closed-loop supply chain excluded.

3. Research Methodology

A literature review can provide an overview of both disparate and interdisciplinary areas (Snyder, 2019), such as blockchain and supply chain management. Moreover, it can be defined as a systematic strategy of researching, selecting, and synthesizing previous research (Baumeister & Leary, 1997; Tranfield et al., 2003). There are no specific systematic literature review methodology protocols in management science (Thomé et al., 2016). Still, studies could search for keywords to find the related literature and then implement any desired analysis (Saunders & Lewis, 2012). Fahimnia et al. (2015) instructed a methodology for data collecting and evaluating to identify influential studies, authors, and topics to define recent interests and future research.

Likewise, this paper utilizes a four-step method based on the system endorsed by Coalter and Tchangalova (2020). The four steps are as follows: identify the research questions, define the boundaries, search and select the studies, bibliometric analysis, and present the results. Graph 1 demonstrates the research methodology.

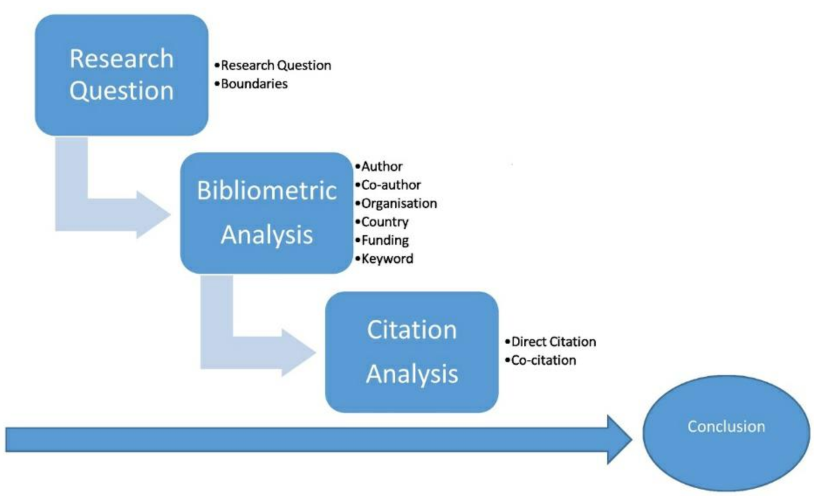

Fig 1. The research methodology.

3.1 Research questions and boundaries

Most recently published reviews attempted to identify influential authors, publications, and topics (Fahimnia et al., 2015) while considering contributed research groups, organizations, and countries are limited. Furthermore, most of them identify the trend topics and influential participants, but the network analysis and visualization of their relationship are scarce (Borgatti & Li, 2009).

Other emerging technologies can integrate with blockchain to transform supply chain management (Xu et al., 2018) but defying what technology in which threshold of supply chain management and how can bring the most value is crucial. This study attempt to answer the following questions to accomplish these objectives:

(i) what are the influential researchers, research groups, studies, affiliations, organizations, countries, and how they are related?

(ii) what are some of the main supply chain echelons that blockchain can contribute? and what are the main potential benefits?

(iii) what are some of the key emerging technologies that can integrate with blockchain in supply chain management, and what are the challenges of blockchain implementation?

3.2 Search and select

We decided to search on Scopus and then double-check the resulting records with a similar Web of Science search to ensure all the related articles are covered. The search on Scopus covered all the documents resulting from the Web of Science search, so we opted to select the Scopus database. We conducted a two-level keywords search then we realized that it excludes many related studies. Therefore, one-level keywords performed considering" Blockchain" OR" block chain" AND" supply chain" OR supplychain" keywords. Article Title, Abstract and Keywords search resulted in 769 records, while it resulted in 286 on Article Title, 685 on Abstract, 597 on Keywords search.

The majority of records were conference paper (354 records), and articles (285 records) was the second most published document type. These document types were approximately 80% of the source, while the remaining document types were only 20% of the resulting records. We opted to consider only articles and book chapters, so the remaining document types were excluded. Furthermore, we exclude non-English articles from the search result. Then, the article pool was sent to the authors to decide individually about excluding irrelevant items. Authors were agreed on most of the articles, while only eight records of the source were sent to an expert to determine whether to include or exclude them. At the end of the selection process, the source had three hundred articles which, set to conduct the following analysis.

4. Bibliometric analysis

Different methods have been used to evaluate articles in recent years. Bibliometric and citation analysis is firmly established as a research evaluation methodology, particularly in analyzing publications' content and network (Ellegaard & Wallin, 2015).

Bibliometric analysis is a quantitative method to evaluate the scientific publication. This method facilitates authorship and keyword analysis with a focus on different aspects such as authorship, keywords (Chang et al., 2015), affiliation (Ellegaard & Wallin, 2015), geographical (Zhuang et al., 2013), and topics (Zibareva & Parmon, 2013). Moreover, citation and co-citation analysis are commonly used to evaluate publications and scholars (White, 2019). Here, we conducted authorship, keyword, citation and co-citation analysis.

Research organizations, funding agencies, and academic publishers have recently become interested in bibliometric analysis visualization (Van Eck & Waltman, 2014). Accordingly, researchers have used software such as VOSviewer, CiteNetExplorer and BibExcle to visualize bibliometric analysis. CiteNetExplore only accepts Web-of-Science output files while our data is from Scopus. Also, BibExcel provides easy interaction with other software (Persson et al., 2009), but it is used as a mediator for using other software (Fahimnia et al., 2015). Thus, we opted to use VOSviewer because it is practical software for bibliometric analysis and provides apparent visualization (Van Eck & Waltman, 2014)

VOSviewer creates maps based on three types of data, namely "network", "bibliographic" and "text" data. Bibliographic provides authorship, keyword, citation and co-citation analysis based on bibliographic data. We select "create a map based on bibliographic data". After choosing the Scopus as the source and uploading the obtained CSV file, the software provides all five types of analysis that we aimed to conduct.

4.1 Authors

Our article pool included 838 authors, 535 of them have at least one article and one citation. The top ten authors have at least three articles and ten citations. Table 1 demonstrates the top ten authors. Kouhizadeh, Sarkis and Choi dominate the table with five documents, followed by Guneshkaran and Kshetri. The top author's background is mostly management science (supply chain management), and only two out of the top ten author's background in computer science. In the following part, we conducted a co-author analysis to support this part's findings and identify collaboration patterns.

Table 1

The top 10 authors, number of articles and citations.

Author	No, of articles	No, of Citation
Kouhizadeh, M.	5	5
Sarkis, J.	5	5
Choi, T.Y.	5	5
Gunasekaran, N.	4	4
Kshetri, N.	3	3
Li, Z.	3	3
O'Leary, D.E	3	3
Jayaraman, R.	3	3
Zhu, Q.	3	3
Van hoek r.	3	3

4.2 Co-authors

Co-authorship asserts two or more authors' involvement in a publication (Reyes-Gonzalez et al., 2016). Co-authorship analysis is a powerful tool for identifying research groups (Perianes-Rodríguez et al., 2010) and leading scholars (Fonseca et al., 2016). To conduct a co-authorship analysis, we opted to identify the top 30 co-authors and associated research groups. The software shows that the top 30 authors have at least two articles and ten citations. Accordingly, setting two minimum articles and ten citation limits resulted in 31 co-authors. Ten out of thirty-one authors have not any link. Therefore, we exclude them from identifying the research groups (linked authors). Notably, Kshetri, N with two articles and more than two hundred citations dismissed in this exclusion because he has no co-author. The software clustered the co-authors in seven groups. Each cluster includes four to two co-authors who arranged the research groups. However, the clusters have not connected, which means the authors of a specific group have no co-authorship relationship with the other research groups.

Table 2 illustrates the research groups and Graph 1 demonstrates the contribution of the research groups. VOSviewer provides three types of visualization, namely "network visualization", "overly visualization" and "density visualization". We opted to use network visualization because it provides a broad view of all the group's contribution proportion and the associated network. The size of a circle determines the weight of the items and the link between the nodes represents the link between the authors (Van Eck & Waltman, 2020).

Table 2

The top research groups contributing to blockchain in supply chain.

Cluster 1	No, of doc	No, of cits	Cluster 2	No, of doc	No, of cits	Cluster3	No, of doc	No, of cits
Kouhizadeh,M.	5	149	Dolgui,A.	2	92	Gunasekaran, A.	4	41
Saberi,S.	2	103	Ivanov, D.	2	92	Kambel, s.s.	2	10
Sarkis,J.	5	141	Sokolov, B.	2	92	Sharma, R.	2	10
Zhu,Q.	3	12						
Cluster 4	No, of doc	No, of cit	Cluster 5	No, of doc	No, of cits	Cluster 6	No, of doc	No, of cits
ChenL.	2	18	Fosso wamba, S.	2	59	Choi t,m.	5	60
Shi, W.	2	22	Queiroz, M.	2	54	Iuo, S.	2	13
Cluster 7	No, of doc	No, of cit						
Jayaraman, R.	3	19						
Salah, K.	2	15						

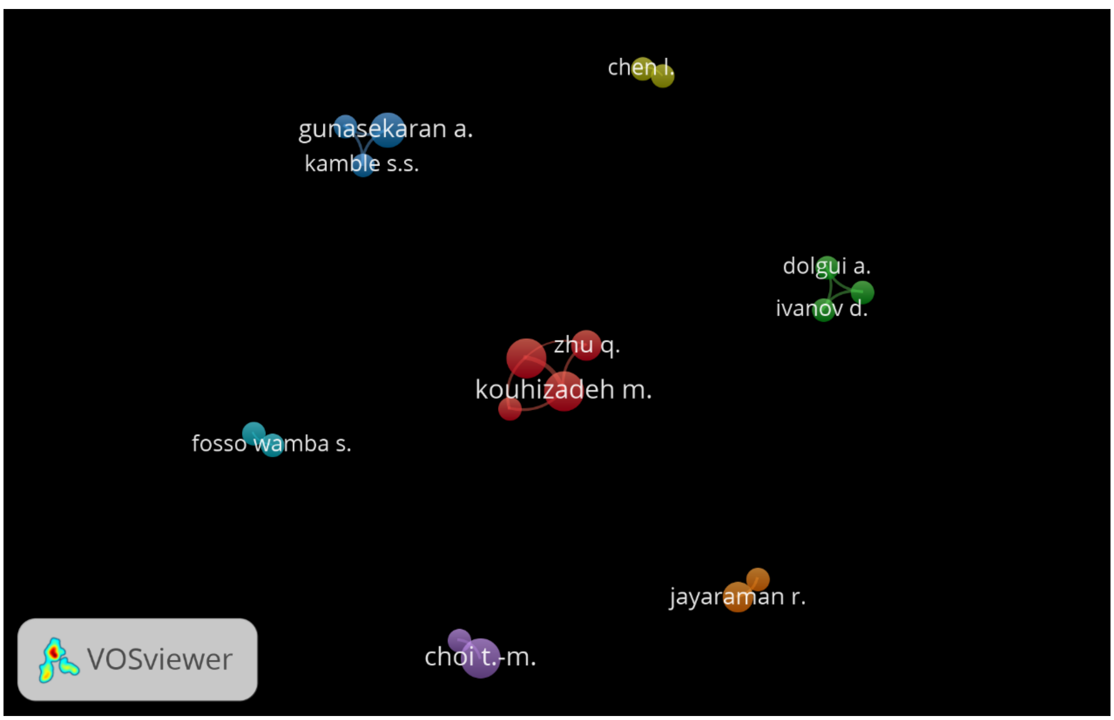

Fig. 2. The top research groups network map contributing to blockchain in supply chain.

Cluster 1, including Kouhizadeh, Saberi, Sarkis, and Zhu is the most prominent research group with the highest proportion. Most of the co-author's background is management science. However, Chen and Shi

(Cluster 5) background is computer science, specifically distributed ledger systems. The only cluster that benefits from management and computer science is cluster 8, including Salah, K (blockchain/IoT) and Jayaraman, R (supply chain).

To summarise, the co-author analysis defined seven outstanding research groups, ranging from four to two scholars, mainly from a management science background. All the scholars of a specific cluster have a similar background, and only one research group consists of scholars with both computer and management science backgrounds.

4.3 Organisation

To conduct the organization analysis in VOSviewer, we selected "Organisations" as the co-authorship analysis units. Table 2 demonstrates the top 10 affiliations. Hong Kong Polytechnic Institute and the University of Hong Kong are first and third-ranked affiliations. Furthermore, Worcester Polytechnic Institute is the second-ranked affiliations. Noticeably, nine out of ten top organizations are located in either the US or China. Notably, Hong Kong is a prominent city with twelve publications published by only two universities. The following section analyzes the countries by conducting the network analysis.

Table 2. The affiliations contributing to blockchain in supply chain.

Affiliation	No, of Articles
Hong Kong Polytechnic University	7
Worcester Polytechnic Institute	6
The University of Hong Kong	5
IBM Research	4
California State University, Bakersfield	4
Sam M. Walton College of Business (University of Arkansas)	4
Shenzhen University	3
Universiti Utara Malaysia	3
Dalian University of Technology	3
University of Houston	3

4.4 Country

Co-authorship network analysis assists in defining scientific collaborations (Liu et al. 2005). Accordingly, we implemented the network analysis of the co-authors' countries. We created a similar co-authorship analysis by VOSviewer, but this time, we selected "country" as the unit of analysis to evaluate the co-author's countries' network. The circles' size indicates the countries' proportion, and the connecting lines' size indicates the measure of connectivity. VOSviewer provides a distance-based demonstration. The distance between nodes indicates the relatedness of the nodes, which means the more related countries are located closer in the network analysis (Van Eck et al. 2010). Seventy-four countries of different co-authors exist in our article pool. Figure 3 visualizes the network analysis of all the contributed countries. The most contributed countries' consideration signifies that the co-authors from the United States (US), China, United Kingdom (UK), Australia, Hong Kong, France and Germany are not only among the most contributed co-author countries but also highly connected.

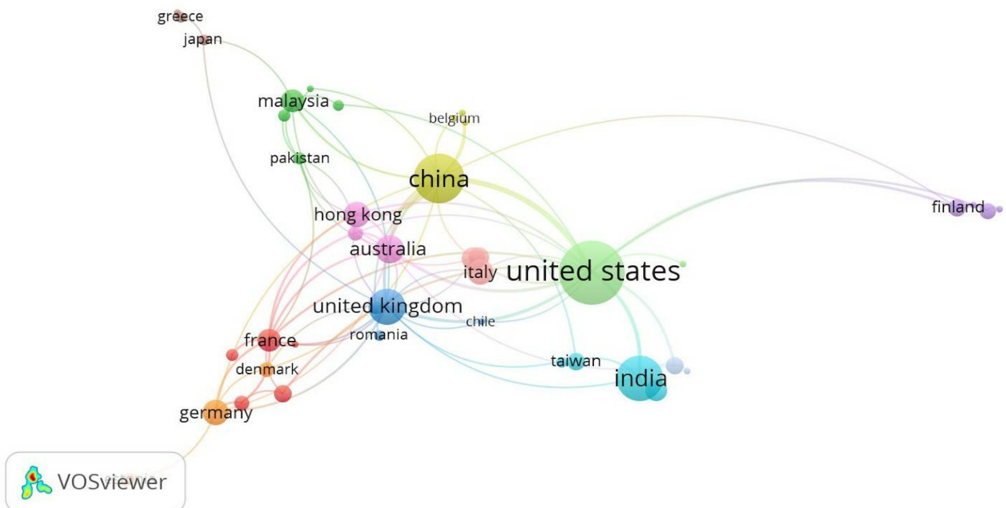

Fig3. All the contributed countries network map

In outline, eight hundred and thirty-eight authors are defined in the article pool. Top ten authors have at least three publications with forty-one citations. Co-author analysis clustered the co-authors in eight research groups ranging from four to two scholars. Most of the previously obtained top authors also appeared in the co-author analysis, which confirms the results. The US and China dominate the top ten affiliations. Moreover, the co-author's countries' analysis indicates that the co-authors from most contributed countries are also highly related.

4.5 Funding institution statistic

Shedding light on the funding institution indicated that approximately eighty percent of the funding agencies are in China, and only twenty percent are from the rest of the world. Figure 4 demonstrates the proportion of Chinese supported agencies in orange color and the other agencies from the rest of the world painted blue. Table 3 illustrates the top ten funding agencies and the number of papers. It is worth mentioning that the National Natural Science Foundation of China (NNSFC) has a significant proportion of 40%, followed far behind by the Ministry of Science and Technology, Taiwan. China's funding agencies' considerable ratio may indicate China's significant investment in Blockchain (China Mulls Blockchain Development Fund, 2020; Mark Tanner, 2018).

All in all, the geographic study of co-authorship analysis and funding institutions indicates that the US, China, and the UK are the leading countries and highly connected. Furthermore, the statistic reveals that most contributed countries located in Asia, America and Europe. Although developing countries could benefit from blockchain (Kshetri & Voas, 2018), African and Middle Eastern countries are scarce.

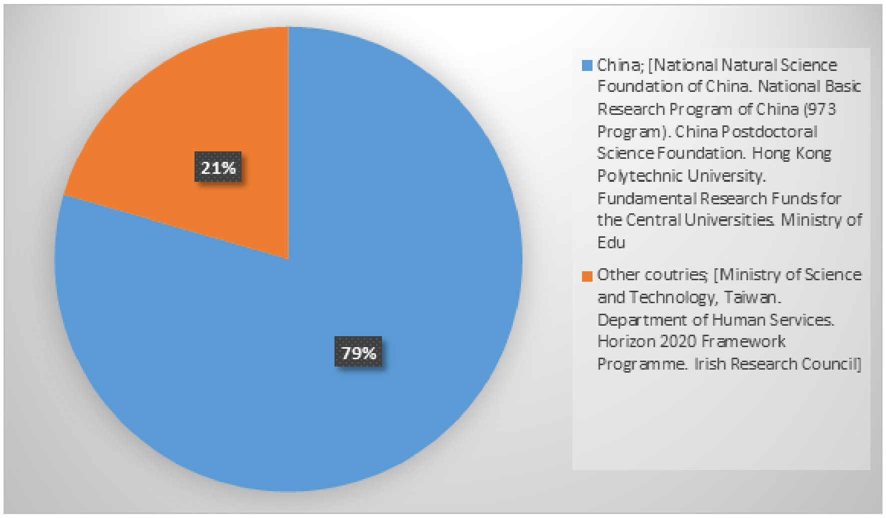

Fig. 4. The number of agencies supported by China versus the rest of the world.

Table 3. Top 10 funding agencies.

Funding institution	No, of papers
National Natural Science Foundation of China	15
Ministry of Science and Technology, Taiwan	4
National Basic Research Program of China (973Program)	4
China Postdoctoral Science Foundation	3
Hong Kong Polytechnic University	3
Department of Human Services	2
Fundamental Research Funds for the Central Universities	2
Horizon 2020 Framework Program	2
Irish Research Council	2
Ministry of Education of the People's Republic of China	2

4.6 Keywords co-occurrence analysis:

For constructing keywords co-occurrence analysis, VOSviewer extracts the keywords from Abstracts and Titles (Van Eck & Waltman, 2011) and provides a ranking list before conducting the network analysis. It also offers three units for analysis, such as "All keywords", "Author keywords" and "Index keywords". We select "All keywords" to cover all the related keywords. Blockchain and supply chains appeared as the most repeated keywords because they are the searched terms on Scopus. Table 6 illustrates the keywords and the number of occurrences.

Table 4. The most repeated keywords and its number of occurrences.

Keywords	No, of Occurrences	Keywords	No, of Occurrences
Blockchain	207	IoT	14
Supply chains	100	Digital storage	14
Supply chain management	83	Sustainability	14
Supply chain	65	Ethereum	12
Blockchain technology	45	Commerce	12
Internet of things	32	Sustainable	11
Smart contracts	27	development	11
Transparency	20	Distributed ledger	11
Smart contract	18	Bitcoin	11
Traceability	17	Logistic	10
Decision making	16	Distributed ledger	16
Information management	16	technology	
	16	Food supply	

As Table 4 shows, some keywords are synonymous, similar, or plural terms of a singular keyword. If we merged "Blockchain Technology" with "Blockchain", “Smart Contracts” with “Smart Contract”, and “Supply Chains” with “Supply Chain Management”, The main keywords on this topic are blockchain, supply chain management, IoT, smart contract, transparency, traceability, information management, and sustainability.

After selecting the “All keywords”, the software suggests setting the occurrence minimum number at five, which results in seventy-eight keywords. Figure 5 demonstrates the keyword’s network analysis. The blockchain and supply chain is the biggest nodes and closely connected because of the selected search terms on Scopus. Moreover, traceability, transparency and smart contract are categorized in the same cluster with supply chain and blockchain. Furthermore, supply chain management and blockchain technology neighboring indicate the blockchain technology’s close correlation with supply chain management (Kshetri, 2018). In cluster 3, Smart contract and information management are in an intimate connection that could verify the smart contract's considerable role in information management (Liu et al., 2019). Traceability is connected to blockchain and information management, reflecting blockchain's ability to develop traceability in supply chain information management (Feng Tian, 2016).

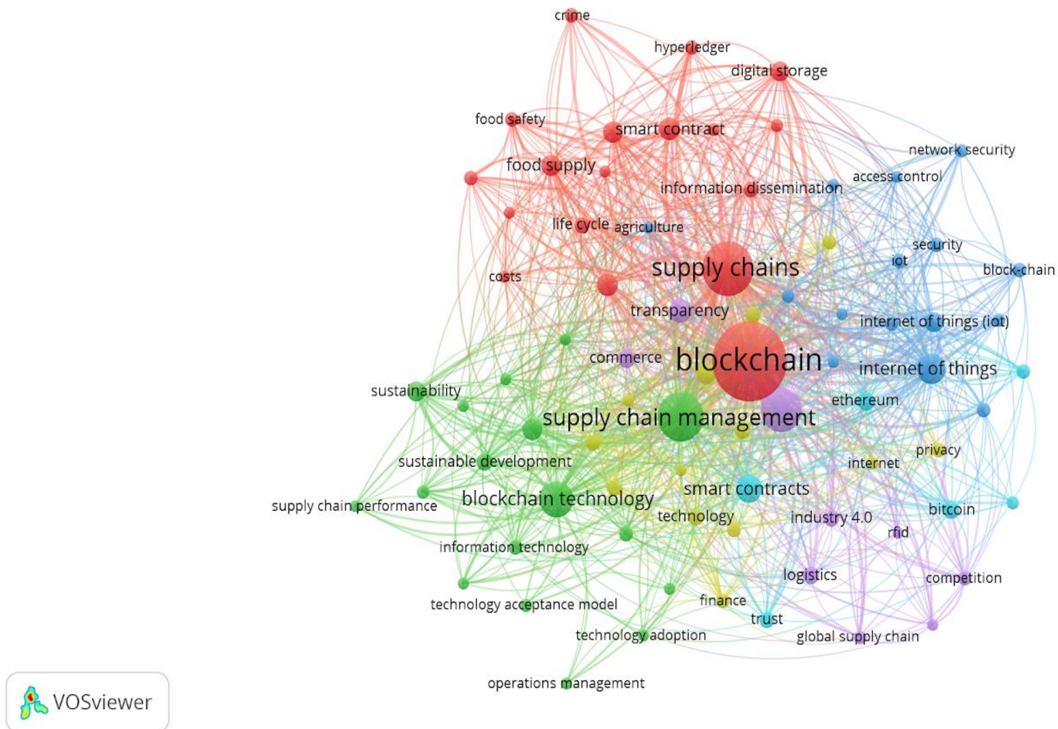

Fig 5. The keywords and their connection network map.

5. Citation Analysis

Citation analysis is a visualized network analysis to examine the relationship between publications based on direct citation and co-citation analysis (NOAA central library 2019). It is a valuable tool for identifying prolific papers and evaluating the article's impact (Moed, 2006). Different software used for conducting citation analysis such as HistCite, Pajek, Gephi and VOSviewer. HistCite only operates with Web-of-Science output besides Pajek restricted by" Net" format, and Gephi needs file preparation with another software. Accordingly, we opted to use VOSviewer similarly to the previous section because it does not require preparation, and it has been used widely on network analysis (Van Eck & Waltman, 2014).

5.1 Direct Citation Analysis

It is an analysis that conveys how many times other articles have cited an article. VOSviewer provides different units of analysis, such as "Documents", "Author" and "Country".

Initially, we select " Documents" to conduct the citation network analysis. Approximately one hundred articles have at least four citations. Table 5 demonstrates the top ten highly co-cited articles. As a general rule, highly cited articles have sufficient time from publication date. Thus, to evaluate more recently published articles, we compute "citation per year" (Fahimnia et al., 2015). For instance, as table 7 demonstrates, Kshetri (2017 a) is ranked No. 2 highly cited paper while fewer citations per year. In the following tables, supply chain management refers to the management of whole supply chain functional areas.

Table 5. Top cited publications and its number of citations as well as citations per year.

Publication	No, of citation	No, of citation per year
Kshetri (2018)	345	172
Kshetri (2017a)	110	37
Saberi (2019)	100	100
Toyoda et (2017)	98	33
Kim & Laskowski (2018)	94	47
Lu (2017)	87	29
Ivanov (2019)	80	80
Apte & Petrovsky (2016)	56	14
Queiroz & Wamba (2019)	54	54

Secondly, we select "Author" as the unit of analysis to support the co-authorship and "Document" citation analysis results. Kshetri is the most cited author with three publications, followed by Kouhizadeh and Sarkis with five papers.

Table 6. Top 5 cited authors and the associated number of publications and citations.

Author	No, of publication	No, of citation
Kshetri, N	3	326
Kouhizadeh, M	5	149
Sarkis, J	5	141
Han, J	1	108
Tischhauser, E.W	1	108
Saberi, S	2	103
Shen, L	1	100

A similar analysis was applied to examine the journals. Table 9 illustrates the top ten journals. IEEE Access has the highest citation with twenty-three publications. At the same time, half of the list has less than five papers. To consider the journals with fewer publications and high citations, we compute citations per publication (Li & Ho, 2008). This indicates that Future Generation Computer System and International Journal of Environmental Research and Public Health journals ranked as the least published journals while having high citations per published article.

Table 7. Top journals contributing to publishing blockchain in supply chain field.

Journal	No, of Citation	No, of publications	No, of Cit per publication	Impact factor (2018)	Subject area
IEEE Access	348	23	15	4.098	Computer Science
International Journal of Production Research	238	14	17	3.199	Management Science
Intelligent Systems in Accounting, Finance and Management	136	4	34	1.19	Management Science
International Journal of Information Management	129	13	10	5.063	Computer Science
Sustainability	91	9	10	2.592	Environmental Science
Transportation Research Part E: Logistics and Transportation Review	61	5	12	4.253	Management Science
Supply Chain Management	59	4	15	4.296	Management Science
Business Horizons	59	4	15	2.828	Management Science
Future Generation Computer Systems	54	2	27	5.768	Computer Science
International Journal of Environmental Research and Public Health	52	2	26	2.468	Environmental Science

Many countries are investing in research to modernize their economy (Merigó et al., 2016), and blockchain is a prospect for developing economies (Dorofeyev et al., 2018). Accordingly, we select "Countries" as the unit analysis to identify the most contributed countries in this field. Seventy-four countries appeared in the investigation. Many countries exist in the article pool. To extract the top twenty, we limit the minimum number of papers and citations to five and seventy, respectively. Graph 5 demonstrates the top twenty countries in the citation analysis. The circles' size is proportional to the countries' contribution, and the distance between them indicates the relatedness of the countries (Van Eck & Waltman, 2014). The most cited articles are from the US, followed by China and India. The funding statistics from the previous section recalls that China funded eighty percent of the studies. But the citation analysis results demonstrate the US is the most contributed country. Therefore, China's desire to surpass the US research and development industry may require restructuring and substantial investment (Moiwo & Tao, 2013).

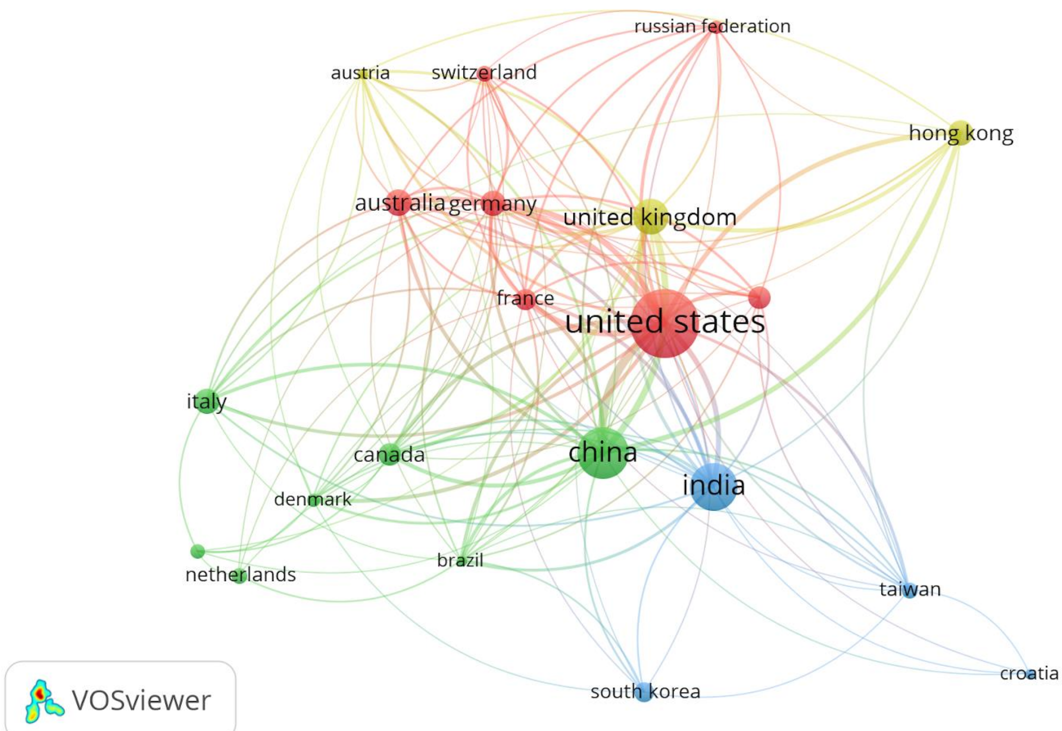

Fig 6. Top 20 highly cited countries and their connection network map

5.2 Co-citation

Co-citation analysis enables the evaluation of co-citation's relationships between articles (Small, 1973). Co-cited documents are two different papers that are cited by a third document (Shiau & Dwivedi, 2013).

As citation analysis may not be sufficient (Boyack & Klavans, 2010) therefore, we conducted co-citation analysis that assists citation analysis for identifying key literature. Moreover, co-citation analysis helps researchers find significant transdisciplinary studies (Trujillo & Long, 2018) like blockchain and supply chain management.

VOSviewer provides three units of examination in co-citation analysis, namely "cited references", "cited sources" and "cited authors". We selected "cited references" to identify the top 20 publications. The article pool included 13832 cited references. To indicate the top twenty articles, we set the minimum number of citations at seven, which resulted in twenty-six items. Table 10 shows the top twenty-six articles and each article's specifications.

Table 10. Top highly co-cited publications and associated supply chain areas, technologies, study approach, identified gaps, and contributions.

Author (Year)	No, of co-cits	SC area	Main Tech	Theoretical approach	Gap and future research	Identified Blockchain Contribution
Christidis & Devetsikiotis (2016)	29	Business model	Smart contract, IoT	Conceptual	Blockchain / IoT integration	1) Facilitates resource and service sharing. 2) Automated time-consuming workflows.
Toyoda et al. (2017)	18	Supply chain management	Blockchain	Conceptual	Value creation	1) Elimination transaction cost 2) Enhance executives commitment to shareholders
Francisco & Swanson (2018)	14	Supply chain management	Blockchain	Conceptual	1) Blockchain / IoT integration 2)Intra-organisation interaction	Traceability and transparency applications by end-users
Abeyrante & Monfared (2014)	16	Manufacturing	Blockchain	Conceptual	Implementing the idea at an industrial scale.	Manufacturing in supply chain
Lu, Xu (2017)	12	Supply chain management	Blockchain, Smart contract	Empirical	Blockchain adaptability	Enhancing traceability
Hughes et al. (2019)	11	Information management	Blockchain, Smart contract	Conceptual	Empirical research	Assisting in decision making
Saberi (2019)	11	Supply chain management	Blockchain, Smart contract	Conceptual	Blockchain adaptation.	Barriers of Blockchain
Kshetri (2018)	9	Supply chain management	Blockchain, IoT	Theory building from Cases studies	Stakholder participation and supply chain ecosystem enrichment.	Robust cybersecurity, trust and transparency

Perboli (2018)	9	Business Modelling logistic	Hyperledger, Blockchain, IoT	Designing use cases	Contribution of all different SC members is needed to implement Blockchain	Increase the inbound logistic efficiency and traceability also decrease waste in the food supply chain
Min (2019)	8	SC risk management and security	Blockchain	Conceptual	Integration of Blockchain with AI, cloud computing and business analytic.	Enhance supply chain resilience
Queiroz & Wamba (2019)	8	Logistic and SCM	Blockchain	Empirical	Testing the proposed model in more countries. Acceptance and Use of Applying Technology(UTAUT) moderators expectancy	Enhance transparency and trust among stakeholders.
Ying (2018)	7	Supply chain management (E-Commerce)	Blockchain	Empirical	How Blockchain enables organizations in practice.	Protects sensitive information, eliminates intermediates, provides a reference point.
Sikorski (2017)	7	Finance	Blockchain, IoT	Conceptual	Smart contract, licensing and IoT. Modeling with J-Park Simulator.	Facilitates the establishment of an M2M electricity market.
Kouhizadeh & Sarkis (2018)	7	Supply chain management	Blockchain	Use cases	Detailed theoretical evaluation research of Blockchain in sustainable supply chain.	Contributes to greening the suppy cahin.
Tapscott (2017)	7	Finance and governance	Blockchain, smart contract	Conceptual	Integration and execution barriers	Facilitates transactions and enhances transparency
Kim & Laskowski (2018)	7	Supply chain provenance	Blockchain, smart contract	Conceptual	The conversion from ontology representations to blockchain	Enhances traceability to transparent provenance.
Nowinski (2017)	7	Business model	Blockchain	Conceptual	Possible applications of Blockchain on entrepreneurial ecosystems.	Contribution to the business models.

This study categorizes the obtained articles content into five main areas, such as blockchain's application area in the supply chain, main technologies, gaps, future study opportunities, and contributions of blockchain in supply chain.

5.2.1 Supply chain area

Forty percent of the highly co-cited articles studied the whole supply chain from supplier to customer that represented as supply chain management in the table. However, two publications focus on only the logistic section of supply chain. The highest co-cited paper study the business model, and two articles focus on finance. Also, four publications consider risk management, security, information management, and manufacturing, respectively. Concisely, Supply chain management is the most repeated function for implementing blockchain in supply chain, followed by finance, logistic, risk management, information management, and manufacturing, respectively.

5.2.2 Key technologies

As table 10 illustrates, IoT and smart contract are the key technologies that could be integrated individually and jointly with blockchain. Kshetri (2017) sighted the incorporation of IoT and blockchain facilitates real-time tracking, which results in transparency. Besides, the smart contract could facilitate the implantation of blockchain in supply chain (Saberi et al., 2019). Furthermore, the most co-cited paper declared that IoT and smart contract jointly with blockchain enable us to automate time-consuming work. Briefly, IoT and smart contract are integrated technologies with blockchain in supply chain management.

5.2.3 Theoretical approach

The conceptual approach is the most conducted approach with more than half of the studies, while only three publications are empirical studies. Thus real-world case research is scarce. More empirical studies are required on this topic (Abeyratne & Monfared, 2016; Hughes et al., 2019; Min, 2019). Moreover, theory building, use cases, and review are the least conducted approaches.

5.2.4 Identified gaps and future study opportunities

Lu and Xu (2017) indicate that the adaptability of blockchain in supply chain is crucial. Simiralry, Saberi (2019) confirmed that overcoming the barriers of blockchain adoption should be considered. Furthermore, Min (2019) introduced a concept that required significant adapting consideration.

The second recommended field is the integration of other technologies, such as blockchain-IoT and smart contract-IoT. Future researches would explore how technologies like IoT, which provide information input, can integrate with blockchain (Francisco & Saanson 2018). Likewise, Chiristidis and Devetsikiotis (2016) inquired whether smart contract and blockchain are also a good fit for IoT.

The other proposed future research by the articles is implementing the concepts and theories in a real-world case to understand how blockchain affects supply chain in practice (Hughes et al. 2019, Ying (2018). It could also help us better understand blockchain's adaptability in supply chain (Queiroz & Fosso Wamba, 2019).

All in all, co-citation analysis reflects that adaptability of blockchain in supply chain (Lu & Xu, 2017; Min, 2019; Saberi et al., 2019), integration of IoT and smart contract (Francisco & Swanson, 2018), and real-world empirical studies are the main gaps and potential future research opportunities.

5.2.5 Contribution of blockchain in supply chain

As table 10 indicates, traceability and transparency is the most stated contribution of blockchain in SCM. Lu and Xu (2017) ascertained how it could enhance traceability through the supply chain. Similarly, Francisco and Swanson (2018) designed use cases to illustrate how blockchain could improve traceability, efficiency and decrease waste in a food supply chain.

Furthermore, two highly co-cited articles declared that protecting sensitive information is another contribution of blockchain in supply chain. Kshetri (2018) confirms that blockchain could help achieve robust cybersecurity and increase trust, validated by Ying (2018).

Moreover, facilitating resource sharing and eliminating transaction costs asserted by the first two highly co-cited papers. Christidis and Devetsikiotis (2016) also demonstrated that integrating blockchain, IoT, and smart contract in supply chain could save time and cost.

In summary, co-citation analysis indicates that blockchain in supply chain could contribute to transparency (Queiroz & Fosso Wamba, 2019), traceability (Lu & Xu, 2017), efficiency (Francisco & Swanson, 2018), and information security (Kshetri, 2018).

5.2.6 Network visualization

Visualization of co-cited publications is a mapping technique to clarify the collaboration pattern and illustrate an intellectual structure of publications (Small, 1973; Wei & Zhang, 2020). To map the publication's network by VOSviewer, we selected the "Co-citation" as the type of analysis and then "Cited references" as the unit. After that, we decreased the "Minimum number of a cited reference" to identify the top twenty publications. Graph 5 demonstrates the top twenty-five articles that meet the threshold. The software grouped the publications into four clusters ranging from nine to two items. The biggest proportion (the most linked article) is Chiristis and Devetsikiotis (2016), located in the middle of the graph.

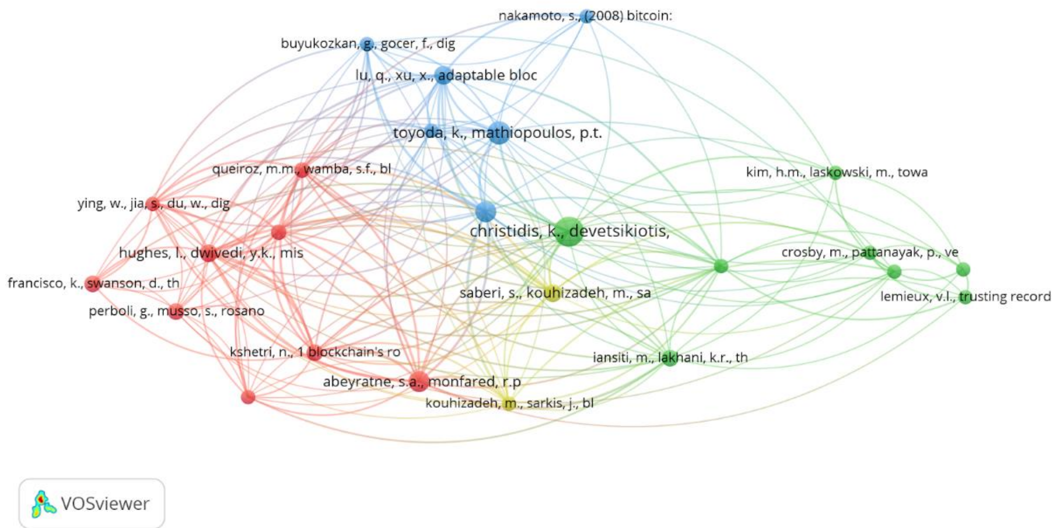

Fig 6. The highly co-cited publications network map.

6. Conclusion

Although some articles have been published about blockchain implication in supply chain, bibliometric and network analysis are scares. This study conducted bibliometric and network analysis to identify the influential studies, leading research groups, institutions and countries. Europe, Austrasia and the US are the most contributed countries while Africa and the Middle-East did not appear. Notably, the US and China are leading countries. Identifying the influential blockchain studies in supply chain allowed us to define the main supply chain areas and other integrated technologies. The map of the country's connection provides a clear view of the participants' relationship. The bibliometric analysis identifies the high occurrences keywords, which indicates the main supply chain areas, integrated technologies, and blockchain's potential benefits. The management of supply chain, finance, logistic, risk, information management, and manufacturing is the primary area that blockchain could bring value. Smart contract and IoT are the other emerging technologies that can integrate with blockchain in the supply chain.

Besides, traceability and transparency are the main contributions that blockchain could bring into the supply chain. Moreover, Blockchain could enhance efficiency, information security and trust in supply chain management. The analysis reveals that most of the articles are conceptual studies, and empirical studies are scarce in this field. Therefore, more studies of implementing blockchain in the real world supply chain are required to understand the contributions and limitations of blockchain in supply chain management.

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