Blockchain Technology in Logistics and Supply Chain Management—A Bibliometric Literature Review From 2016 to January 2020

Benjamin Müßigmann, Heiko von der Gracht, and Evi Hartmann

***Abstract*—As part of business and management studies, research works addressed blockchain technology (BCT) in logistics and supply chain management (LSCM) first in 2016. Increasing levels of interest from researchers and practitioners alike have led to an increasing number of studies from both ends; however, a thorough bibliometric- and cocitation network analysis of BCT in LSCM research has not been carried out so far. To address this gap and to build a basis for future research endeavors, this article provides a bibliometric analysis on BCT, comprising data from 613 articles from academic supply chain research. It is therefore an easy-to-access entry point for academics and practitioners into the topic of BCT in LSCM. This study aims to understand the status of research of BCT in LSCM. To present the results, this article employs a bibliometric analysis methodology. It adopts a citation network analysis and a cocitation analysis. Based on a cocitation analysis, this article classifies the existing literature into five different research clusters, including theoretical sensemaking, conceptualizing and testing blockchain applications, framing BCT into supply chains, the technical design of BCT applications for real-world LSCM applications, and the role of BCT within digital supply chains.**

***Index Terms*—Bibliometrics, blockchain, citation network analysis, cocitation network analysis, logistics, supply chain management.**

I. Introduction

With growing complexity in international trade, leveraged by the internet [1], [2] and globalization [3], [4], uncertainty between business partners has been growing, which increases the importance of trust in global economies [5]–[7]. To lower uncertainties and to establish trust between buyers and sellers, third party authorities are assuming the role of trade mediator between different parties [8]. These entities act as a middleman, performing all the business and transaction logic of every kind of commerce. This includes the authentication and identification of business partners and the recording of their data, which requires a natural level of trust toward the managing middleman. Traditional examples for the middleman role in supply chains are banks or freight forwarders. Even though those entities deliver value to buyers and sellers, the "middleman set-up" has its weaknesses [9]. First, it is founded on a central entity, which creates dependence [10]. Second, it creates a central point of failure in processing the transaction. Furthermore, these entities are slow in processing transactions. An example for slow processing transactions through middleman is the exchange of fiat money [11] between parties, which has also been highlighted by previous researchers [12], i.e., banks in exchanging fiat money with a duration of up to 1–4 working days between parties [13]. Moreover, the middleman takes fees for the services, which lowers margins, e.g., by increasing interchange fees for credit and debit cards [14] or bill of lading fees in ocean freight movements [15]. Furthermore, central entities manage one of the most relevant assets of the future—the complete transaction data [16], [17], which undermines the privacy of all parties involved.

Ozcan and Islam [18] mentioned the relevance of new technology-based entrants. In this context, the question as to whether technology might detach the deep involvement of middleman is being discussed by scholars. Different disciplines, such as finance [19], [20], governmental infrastructure [21]–[24], property, and ownership [25], as well as education [26], are discussing in this context whether blockchain technology (BCT) might leverage the economic benefits of decentralization. Besides the growing interest within these disciplines, BCT is also gaining increasing interest from academics and practitioners in the field of logistics and supply chain management (LSCM). Thus, in this article, we wish to discover the current research status of BCT in the field of LSCM by mapping and streamlining the literature landscape, created by previous scholar works. Therefore, we apply a bibliometric analysis and a cocitation analysis, which results in a clustering of research areas. Furthermore, it provides the first holistic overview of BCT in LSCM, considering 613 collected studies. In the field of LSCM, BCT is in its early stages offering initial research in 2016 for traceability in pharma [27], textile and clothing [28], and food or agricultural supply chains [29]. The global spending on BCT solutions in 2018 amounted to $1.5 billion. For 2019, a global spend of $2.9 billion is forecast, whereas it is expected to increase to $12.4 billion by 2022 [30]. Interestingly, supply-chain-related topics, such as cross-border payments, trade finance, and posttrade

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transactions, are expected to receive the most investment ($ 738 million) [30].

Emerging topics can benefit from a holistic conceptualization of the existing literature [31], and, thus, this study applies a bibliometric analysis to streamline the existing literature of BCT in the field of LSCM research. It provides a map of the existing research on the topic of BCT in LSCM, which will help future scholars identify potential research areas and questions and to gain a better understanding of the influencers and leaders in the field. In a narrow research, the study at hand centers on the status of BCT in LSCM with the aim to structure the existing literature landscape enabling newcomers' easy access to and an overview of the emerging topic.

This article centers around the following main research questions.

RQ1. What are the leading and most influential papers in terms of popularity and prestige in the field of BCT in LSCM?

RQ2. What are the existing clusters of current research within BCT in LSCM?

The rest of the article is organized as follows. Section I presents an introduction to the study and introduces the research questions. Section II provides the background to the growing attention of BCT in LSCM. In Section III, the methodology used (bibliometric analysis) and the criteria for the selected databases are described. Section IV presents the results of the bibliometric analysis followed by a cocitation analysis with a derived analysis on the identified research clusters in Section V. Answers to the research questions are offered in Section VI completed by an outlook for future research on the topic.

II. Background

BCT had its beginnings in the environment of the cryptocurrency Bitcoin [32]. The network of Bitcoin uses BCT as its fundamental technology to manage transactions and information. To explain the original idea behind the technology, it can be described as a distributed ledger that stores a history of assets and transactions between all network participants, also called nodes, connected to a decentralized peer-to-peer network, distributing the transaction data to all nodes equally, which creates a simultaneously recorded version of the transaction [32]. However, BCT is not only a database record, since in its evolution [33] it can also store and manage so-called "smart contracts." Smart contracts are digital programs, stored in a blockchain with a lower risk compared with central databases of downtimes, censorship, or fraud, allowing automated transactions between parties without any third party being involved [33], [34]. Smart contracts excel when predefined conditions are met to manage interactions between entities based on data [35].

As part of business and management studies, research study addresses the topic of BCT to LSCM with initial studies from 2016 [27], [29], [35]. Literature around BCT shows that the technology itself is described in different functional elements and concepts, such as public and private blockchains [36]; however, it remains unclear as to whether all of them are relevant for LSCM [37]. Public blockchains are accessible to everyone with transparency on all transactions secured through encryption [38]. Examples of public blockchains are the cryptocurrency networks of Bitcoin or Litecoin [39], [40]. Even though few researchers see a use case for public blockchains in LSCM [41], private blockchains seem to have appealing applications for LSCM as they can set up privacy rules with predefined, customized conditions [42]. As a subcategory of private blockchains, consortium blockchains can be understood as private blockchains having different predefined authorities within the blockchain network. Unlike in traditional private blockchains, where one member of the network acts as the leading authority, a consortium blockchain provides multiple predefined members as network authorities [43]. An early example of a consortium blockchain in LSCM is the joint venture between IBM and Maersk [44]. Even though there may be a contribution for public blockchains to LSCM, private and consortium blockchains seem to have the more promising application in LSCM to this day [45].

Initial BCT in LSCM literature refers mainly to supply chain traceability and product provenance [46]–[48], transaction automatization [49], [50], and data security [51]. Other researchers have studied the role of BCT in supply chain operations [52], which has been described as a human-centric discipline, where several tasks, such as transport bookings, invoicing processes, and inventory management, lack efficiencies due to manual and labor-intensive activities [53], [54]. In context of data security, Choo [55] mentioned the increasing relevance due to increasing variety and volumes of cyber threats. Conti *et al*. [56] highlighted the relevance of security in Internet of Things (IoT) topics and the related risk of cyber threats. Thus, scholars suggest that the use of BCT improves data integrity, which has a positive impact on data exchange between supply chain partners [49], [57]. Moretto *et al*. [58] and Omran *et al*. (2018) referred to BCT an "IT solution" that can support supply chain finance by managing, controlling, and sharing information [59]. However, backed by the hype around the technology [60]–[62], there are various BCT applications that are not reasonable as they do not leverage the advantages of the technology, such as distributed consensus and information between parties, the transparency increase, and the option to skip intermediaries [42], but leverage the disadvantages, i.e., high energy consumption to create consensus and distribution mechanisms [57] as well as the related change management for organizations, which is an integral part of BCT projects [42].

In LSCM research, scholars are requesting training, citing the lack of understanding within LSCM as a barrier for mass adoption [52], [63]. Staples *et al*. [45] and Francisco and Swanson [64] confirmed that BCT in LSCM is in its infancy and that the technology is "poorly understood" these days. Zhao *et al*. [33] called for more research on BCT in all industries and to see more business research on BCT in the next few years. To further understand the application for BCT in LSCM, it is important to identify and to grasp the status of conducted research and literature. Yli-Huumo *et al*. [65] provided a general literature review on BCT.

Previous research endeavors provided first reviews on BCT in LSCM [66]–[76], which is summarized in Table I. Some of these studies provide structured literature reviews for BCT in

TABLE I
OVERVIEW EXISTING LITERATURE REVIEWS BCT IN LSCM

Year	Author	Journal	Methodology
2018	Tribis *et al.*[66]	Conference Paper	Systematic Literature Review
2018	Wang, Yingli *et al.*[67]	Supply Chain Management: an International Journal	Systematic Literature Review
2018	Daguerre and Villa Perez (2018)	Conference Paper	Systematic Literature Review
2018	Bermeo-Almeida *et al.*[69]	Conference Paper	Systematic Literature Review
2019	Casino *et al.*[70]	Telematics and Informatics	Systematic Literature Review
2018	Fosso Wamba *et al.*[71]	Production Planning and Control, Forthcoming	Systematic Review of Case Studies
2019	Surjandy *et al.*[72]	Conference Paper	Systematic Literature Review
2019	Yaqoob *et al.*[73]	International Journal of Advanced Computer Science and Applications	Systematic Literature Review
2019	Zhang *et al.*[74]	Conference Paper	Content based Literature Review
2019	Scully and Höbig [75]	Conference Paper	Literature Review
2019	Pournader *et al.*[76]	International Journal of Production Research	Systematic Literature Review
2019	Gurtu and Johny (2019)	International Journal of Physical Distribution and Logistics Management	Literature Review

pharma [73] or agriculture and food [69], [74]. Other works provide reviews on BCT applications in supply chains [70], [76]. Although all existing papers provide literature reviews, none of the studies help with structuring the literature landscape in terms of visualized research clusters. We do this by applying a citation network analysis and derived network clustering. Even though all these studies provide a contribution to BCT in LSCM literature, they still lack the identification of network clusters and contribution relevance within the field. Furthermore, none of the literature reviews provide a database compared with this study with a scope of 613 articles starting with the first literature from 2016 to January 2020.

As every academic research should bring value to practitioners, we expanded the existing literature review research status shown in Table I. Literature around research and knowledge building suggest that grey literature can extend the existing research status [77]–[80]. Thus, in this article, we conduct a bibliometric analysis, including a cocitation network analysis, to gain a visual understanding of the literature, including conference and journal papers, as well as book chapters, excluding white papers, working papers, and students' articles. Bibliometric analysis has been applied by previous researchers, highlighting the relevance of visualization in literature reviews [81]–[82]. This article reveals the most relevant issues in academic research of BCT in LSCM from 2016 to January 2020, which provides a holistic review of the topic, covering 613 selected articles.

III. RESEARCH METHODOLOGY AND DATA STATISTICS

Literature reviews target a structured overview of the literature landscape to recognize research gaps and to identify the boundaries of knowledge [83]. A recommended methodology for literature reviews has been provided by Saunders *et al*. [84], using an iterative cycle of defining search keywords, scanning the existing landscape of literature. As an extension to this approach, Rowley and Slack [85] recommended designing a mind map structure in addition to the literature review. This approach has been accepted by scholars [83], [84], and, thus, we follow a similar methodology, using a five-step methodology for gathering data to identify the most influential researchers and studies of BCT in LSCM, which will help to better understand the current status of research and to identify most relevant content in the field. A similar approach to a literature review has been applied by previous researchers in LSCM [86]. To set a clear time frame for our study, the data collection finished on December 31, 2019, which means that papers with an online availability status dating from January 1, 2020, were not considered in this article.

A. Defining the Search Terms Used

As our focus is on contributions of BCT in LSCM, we considered it necessary to cover both the technological part of BCT and the supply-chain- and logistics-related aspects. First, we defined keywords for our search criteria. The BCT-related terms could be defined in a convenient way due to the novelty of the topic and the consistent lingo in literature, whereas the LSCM-related keywords necessitated some iterative reflection between the scholars as the domain of LSCM has various components and related terms [87]–[90], such as supply chain, transport, warehousing, procurement, production logistics, and distribution activities. We reflected on a multitude of keywords and search terms that should be considered in the bibliometric study. To avoid a narrow focus on partial components of LSCM and to provide a general basis for our BCT in LSCM analysis, the final defined keywords consisted of the generic terms of "Supply Chain" as well as "Logistics" and "Transport." Thus, our data collection was based on a narrow list of keywords, not taking distribution-, warehousing-, production-, and procurement-related terms into account. As our keyword definition was two sided, covering the supply chain and the BCT parts, we also rediscussed our used keywords with regards to BCT. Although "Blockchain" as a term was clear, we further extended our search to the term "Distributed Ledger Technology" as the term was also used by scholars referring to BCT. During the data collection process, we identified some studies that refer to blockchain as "Block Chain" so we added the term to our keywords used. To combine our two-sided search streams and the technology terms with the supply-chain-related terms, we combined three different search scenarios using title, abstract, and keywords, including

1) supply chain OR logistics OR transport AND blockchain;
2) supply chain OR logistics OR transport AND block chain;
3) supply chain OR logistics OR transport AND distributed ledger technology.

B. Defining the Database Used

During our first literature collection, we identified that no single database covers a significant amount of papers (as shown in Table II). Significant in this context means that in the year

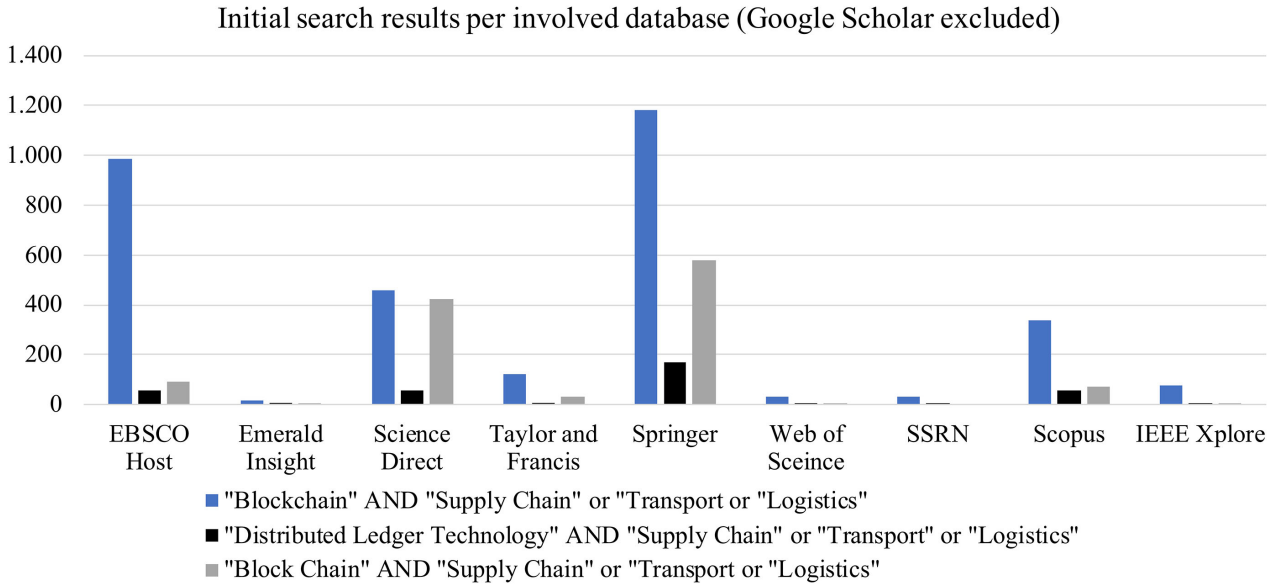

Fig. 1. Initial search results per database.

TABLE II
COLLECTED ARTICLES PER DATABASE

	Database	# of papers	% contribution
1	Scopus	238	38,83%
2	Google Scholar	132	21,53%
3	Web of Science	74	12,07%
4	Springer	61	9,95%
5	IEEE Xplore	49	7,99%
6	Science Direct	18	2,94%
7	SSRN	12	1,96%
8	Taylor & Francis	11	1,79%
9	Ebsco	9	1,47%
10	Emerald Insight	9	1,47%
	Total	**613**	100,00%

2019, no single database covers enough papers to provide a holistic review of the literature landscape of BCT in LSCM. Even though other bibliometric studies, such as Fahimnia *et al*. [86] or Gaviria-Marin *et al*. [91], focused on single databases, such as Scopus or Web of Science (WoS), we chose an approach using multiple databases. We conducted another brainstorming session to identify the most relevant databases for our study. The following ten databases were used for the data collection: IEEE Xplore, Springer, Google Scholar, Ebsco, Taylor & Francis, Emerald Insight, Science Direct, SSRN, Scopus, and WoS, as they cover a multitude of all relevant academic sources. This searching procedure is commonly accepted and has been utilized in previous reviews [92]–[94].

C. Initial Findings

Using the "title, abstract, keywords" search in these databases, we collected journal and conference papers as well as book chapters for the defined search terms that were written in the English language and had a combination of our keywords within their title, abstract, or keywords. The initial search results per database, adjusted by removing the +16 000 search results from Google Scholar, are shown in Fig. 1.

The results on Springer and EBSCO, in particular, were relatively inefficient, which lead to several weeks of effort to ensure proper collection of the preset search terms. The inaccurate results on Google Scholar with +16 000 results were not surprising as Google Scholar acts as a metadatabase, linking to content from other primary databases, such as Taylor & Francis, ScienceDirect, Emerald Insight, and IEEE Xplore. We used this as an advantage to avoid any gaps in our data collection. The scan of the search results spanned several months, focusing on our defined search terms within the abstract, title, and/or keywords. To ensure proper data collection, we used a systematic approach based on the approach presented by Rashman *et al*. [95], as shown in Fig. 2. In an initial collection, we found 991 articles that fit our search criteria, not considering white papers, working papers, and discussion papers. In order to assess only relevant articles, we read the abstracts. Articles that seemed nonrelevant were eliminated to ensure a consistent focus of the study. For instance, the usage of the keyword "transport" led to non-LSCM-related results, which created additional complexity to our data refinement. As an example, the abstract by Mohan *et al*. [96] refers to "Blockchain" and "transport mechanisms," whereas the second term refers to data exchange but has no context to LSCM. Another similar example is Lovis *et al.* [97] who referred to "data transportation" tools in their abstract. In other papers, i.e., Xiong *et al*. [98], "logistics" was just mentioned in the abstract as one of different research areas without any deeper reference to the topic. The papers had to demonstrate a distinct connection between BCT and LSCM. This refinement of our paper collection led to a total number of 726 articles. In the next step, an additional focus was set to ensure

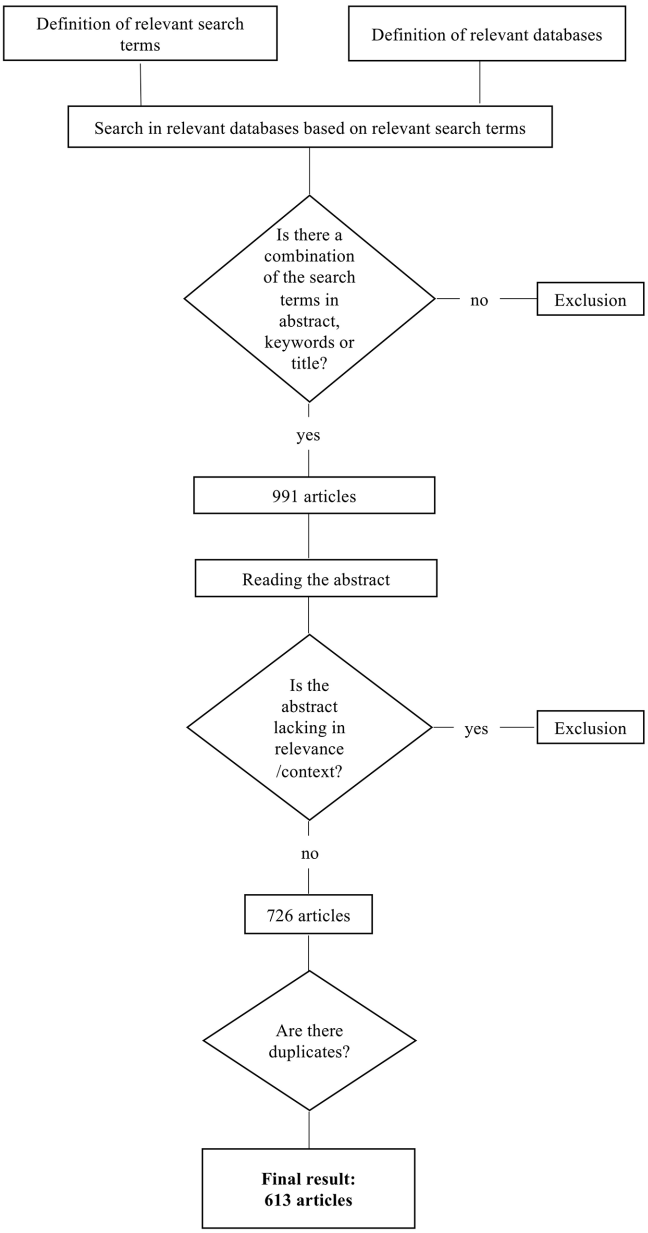

Fig. 2. Data collection process (adapted from [95]).

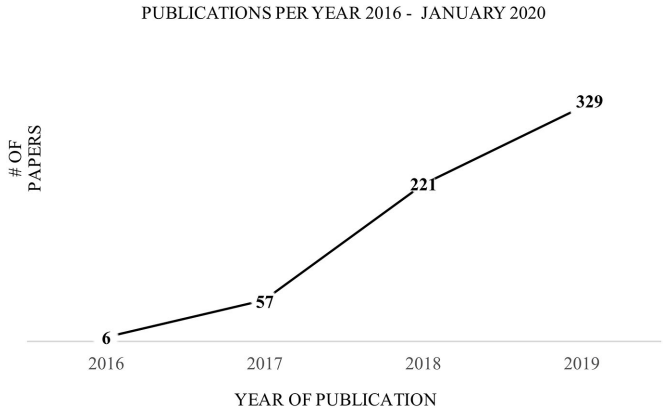

Fig. 3. Publications per year 2016–January 2020.

that no single publication was counted twice and duplicated, meaning that the same paper was shown as a search result in various databases. For example, the work presented by Kshetri [44] was shown on SSRN, Science Direct, and Emerald Insight. To eliminate all duplicates, all relevant papers were carefully reviewed by paper title, author, and abstract. In a total of two reviews conducted sequentially by two junior scholars and two senior scholars, and we deleted another 113 papers that were identified as duplicates, which brought a result of 613 unique articles from conferences, journals, and book chapters. Fig. 2 summarizes the paper collection process.

A significant result of this initial investigation is the high number of studies provided by Scopus, Google Scholar, WoS, Springer, and IEEE Xplore providing 90.37% of all studies contributed. The results of Google Scholar and Scopus are not surprising due to the metadata base design of both platforms, linking search queries directly to the primary database. This first result tells interested readers that they may focus on these five databases for initial comprehensive research into the literature landscape. The results are summarized in Table II.

Due to the novelty and the emerging nature of BCT in LSCM, the number of publications per year shows a range starting from 2016 to January 2020 when the study finished. Gartner [60]–[62] mentioned the hype in 2016, 2017, and 2018 for BCT. This observation can be confirmed from the ankle of LSCM with a rising number of contributions starting from 2016. All papers were published between 2016 and January 2020, whereas 2019 reflects the peak of research to this day. In 2019, including December, 329 papers were collected. Fig. 3 visualizes the development. It is worthy of note that the first literature on BCT can be traced back to 2008 [32], signalizing that it took eight years for BCT to enter the supply chain space with initial literature emerging in 2016 [27], [29], [35].

D. Refinement of Data Collection

Traditionally, data collection for bibliometric analysis is organized as follows. The raw data collection for bibliometric analysis is conducted with data from Scopus or WoS [99], [100]. In the next stage, the data refinement is done using software, such as BibExcel [101], which is limited to the aforementioned databases. In our case, the data collection had to be done differently as to this day there is no single database that covers all BCT in LSCM relevant literature, which means that Scopus (238 selected articles) and/or WoS (74 selected articles) were not sufficient for our data collection. Thus, we collected all data manually from the different data sources used. As a next step, we structured the data manually (as BibExcel expects the data in Scopus or WoS format). The data collection as well as the refinement of the data was a pure manual collection process that took several months. Furthermore, the data structuring via software, such as BibExcel [101], poses challenges in regard to the processing of data, such as author names, depending on the source from which data are derived from (i.e., names and prenames can be switched, which leads to inaccuracies when counting the number of papers an author has submitted). Despite

TABLE III
TOP PUBLISHING ACADEMIC JOURNALS

Journal	2016	2017	2018	2019	Total	Peer-Reviewed y/n	Impact Factor 2018/2019	Five Year Impact Factor	ISSN
IEEE Access	1		5	9	15	y	4.098	2.955	2169-3536
International Journal of Information Management			2	11	13	y	5.063	6.327	0268-4012
International Journal of Production Research			5	4	9	y	3.940	2.585	1366-588X
MDPI Sustainability			4	3	7	y	2.592	2.801	2071-1050
IBM Journal of Research and Development				6	6	y	1.380	1.398	0018-8646
Advances in Intelligent Systems and Computing			1	4	6	n	0.370	0.464	2194-5357
IT Professional		1		4	5	y	1.280	1.118	1941-045X
Advances in Computers			2	2	4	y	1.514	0.875	0065-2458
Business Horizons				4	4	y	2.100	1.918	0007-6813
International Journal of Production Economics				4	4	y	4.998	3.922	0925-5273
MDPI Logistics			3	1	4	n	-	-	2305-6290
Supply Chain Management: an International Journal			2	2	4	y	3.833	3.593	1359-8546

the time and effort the manual data collection took, it was the only method to gather all collected data into one format. To ensure careful data handling and collection, different students assisted in the data collection process, reviewing the collected data in iterative circles.

E. Initial Data Statistics

The increasing interest in the research on BCT in LSCM is shown in Fig. 3. When examining the publishing journals that contributed to the area of BCT in LSCM, first journals seem to have developed a pioneering role in the field. The leading journals by publications are IEEE ACCESS (15), *International Journal of Information Management* (13), *International Journal of Production Research* (9), and *MDPI Sustainability* (7). Overall, 12 journals contributed more than 3 articles to the field. These 12 out of 174 journals contributed 81 publications of all 298 published journal articles, which equates to a share of 27.18%. Table III summarizes the top contributing journals with a minimum of four articles published and their peer-reviewed/nonpeer-reviewed status as well as their impact factor. It can be deduced that 10 out of the 12 listed top contributing journals are peer-reviewed, which gives an initial indication of the quality of the leading contributing journals. It is worth noting that our data collection consists of an additional 292 conference papers and 23 book chapters.

F. Data Analysis

The data analysis was obtained in two stages, including a "bibliometric analysis" and a "network analysis" presented in Sections IV and V. This approach has also been taken by previous researchers [86]. The bibliometric analysis presented in Section IV was carried out using Publish or Perish [102]. Publish or Perish provides data statistics to Google Scholar, which collects the citations of all papers, independently of the final source the paper was taken from. The data statistics include author, citation, and keyword statistics. The network analysis presented in Section V was done on "Gephi" [103] to deliver a citation analysis and a content-focused clustering of the existing literature of BCT in LSCM. After several trials with other software, such as CiteSpace [104] or VOSviewer [105], Gephi was chosen due to its functionality in working with datasets, and the provision of visualization tools in a user-friendly application environment. Due to the high number of different databases involved, we had no alternative than to manage the data preparation for Gephi manually.

IV. BIBLIOMETRIC ANALYSIS

Different software applications have been used in previous research for bibliometric analysis. All of them show different limitations and functionalities. Based on our research, the most suitable tools include BibExcel [101], HistCite [106], and Publish or Perish [102]. Publish or Perish was chosen due to its high flexibility in working with data from Google Scholar. For instance, BibExcel focusses on data from WoS and Scopus, neither of which showed sufficient publications or links to publications on their databases, whereas HistCite solely accepts data from WoS. The data source for using Gephi was created as a CSV output as Gephi requires a specific format in its data laboratory, containing all author-related information, such as author name, publication year, publishing journal, article name, author university, and country of origin. The following section provides the statistics drawn from our collected data.

A. Affiliation Statistics

With Gartner's Hype Cycle Study for emerging technologies from 2016 to 2018 clustering BCT as one of the technologies at the "peak of inflated expectations" [60]–[62], BCT is attracting attention from business professionals and scientific scholars. During our study, we realized that attention is on a global level with scholars from all over the world contributing to BCT. Diving deeper into the literature of BCT in LSCM, we realized that this is also true for BCT studies in the field of LSCM. To validate and to demonstrate our findings on the global aspect, we extracted university and city locations from our data

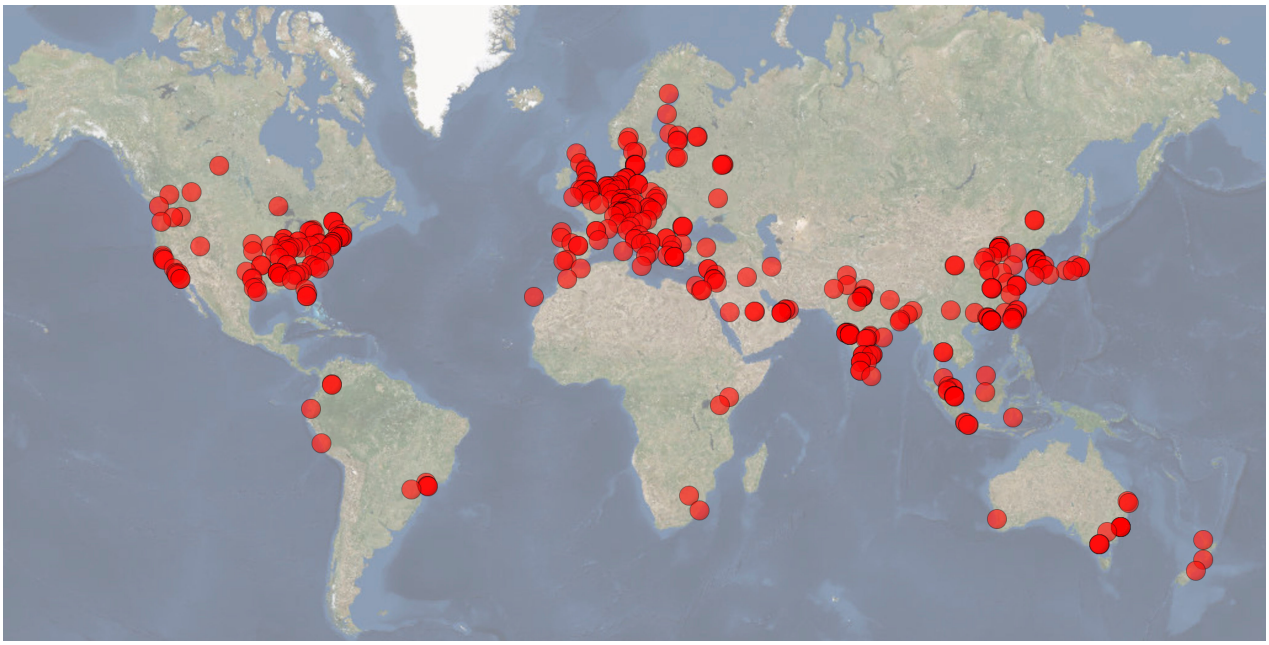

Fig. 4. Global research interest: BCT in LSCM studies.

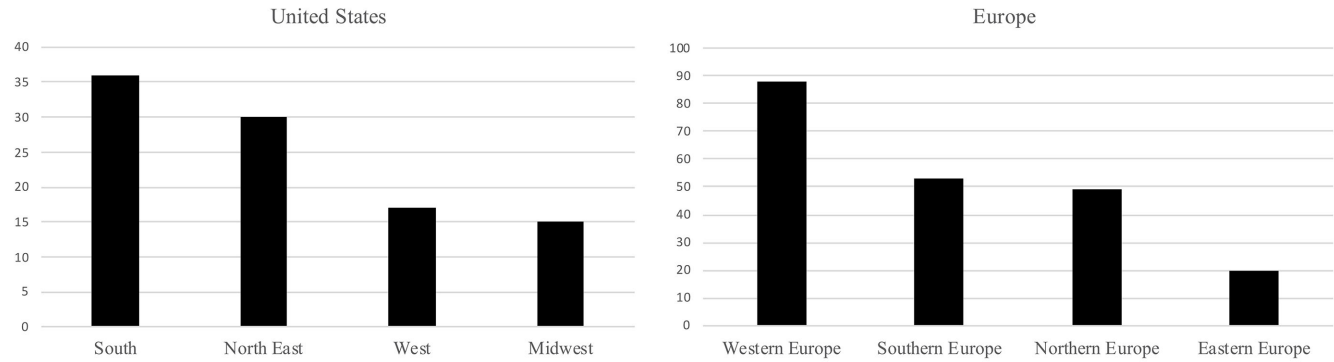

Fig. 5. Geographical spread, United States and Europe.

collection into GPS visualizer [107], using the geo coordinates from all locations. To receive the geo coordinates, we used GPS-coordinates [108], which provides the geo coordinates based on Google Maps. The data were collected carefully by two different researchers. To avoid data failures, we consulted a third junior scholar to review the collected values. Fig. 4 shows the results of the GPS mapping. The circles represent the geo locations of all first author institutions contributing to BCT in LSCM.

The largest density of contributing institutions is found in North East Americas and in Europe. In Asia, China is providing the highest number of institutions contributing literature of BCT in LSCM. In Africa, the topic is practically not discussed by academic institutions with some exceptions in North Africa and a study from South Africa. In South America and Australia, only few academic studies are available. In total, institutions from 68 different countries contributed to BCT in LSCM. Overall, the geographical spread indicates the global interest of BCT in LSCM within academic research with initial leading areas in Western Europe and North East America. A greater breakdown of the studies can be done for the geographical regions of the United States (U.S.) and Europe, providing the highest number of publications. The geographic regions are set out according to the United Nations definition [109]. To outline a more detailed breakdown of the United States, we used the geographical definition from the US Census Bureau [110]. Fig. 5 shows the geographical spread of publications at the top contributing country, United States, and the top contributing Region, Europe, to the literature of BCT in LSCM.

The first institutions are developing a leading role in the issue of BCT in LSCM. The top ten contributing institutions, based on the number of contributed studies, are shown in Table IV.

B. Author Statistics

Table V provides an overview of the leading authors by number of articles contributing to BCT in LSCM. Kshetri (6) [44], [50], [111]–[114] and Hofmann (5) [115]–[118] are the most

TABLE IV
TOP CONTRIBUTING INSTITUTIONS

Institutions	2016	2017	2018	2019	Total
University of St. Gallen		3	4	1	8
University of North Carolina at Greensboro		2	2	3	7
University of Houston		1	4		5
Vienna University of Economics and Business	1	1	3		5
Worcester Polytechnic Institute			2	3	5
Beijing Wuzi University			3	1	4
Delft University of Technology			2	2	4
California State University			1	3	4
Alexandria University			2	1	3
Beijing University of Posts and Telecommunications				3	3

TABLE V
TOP CONTRIBUTING AUTHORS BY NUMBER OF PUBLICATIONS

	Author	# of listings
1	Kshetri, N.	6
2	Hofmann, E.	5
3	Fosso-Wamba, S.	3
4	Petersen, M.	3
5	Meng, M.	3
6	Röck, D.	3
7	Casado-Vara, R., Davcev, D., ElMessiry, A., ElMessiry, M., Gao, Z., Hackius, N., Hald, K.S., Hepp, T., Kim H., Min, H., Laskowski, M., Jayaraman, R., Kim S.K., Li, Z. Qian, Y. O'Leary, D., Queiroz, M., Rejeb, A., Sharma P.K., Tian, F. Treiblmeier, H. Xu, L., Zhu, Q. Kouhizadeh, M., Li, J.	2

TABLE VI
KEYWORD STATISTICS

	Keyword	# of listings
1	Blockchain / Blockchain Technology	298
2	Supply Chain / Supply Chain Management	151
3	Smart Contract	59
4	Internet of Things / IoT	51
5	Traceability	43
6	Distributed Ledger / Distributed Ledger Technology / DLT	37
7	Logistics	29
8	Ethereum	20
9	Transparency	17
10	Sustainability	16
11	Security	14
12	Food Safety	12
13	Trust	11
14	Hyperledger	10
15	Industry 4.0	9

TABLE VII
TITLE WORD STATISTICS

	Title phrase/word	# of listings
1	Blockchain / Blockchain Technology	449
2	Supply Chain / Supply Chain Management	251
3	Applications	53
4	Traceability	52
5	IoT / Internet of Things	51
6	Food	50
7	Blockchain-based	47
8	Smart Contract	38
9	Systems	37
10	Logistics	37
11	Distributed Ledger Technology	22
12	Challenges	19
13	Manufacturing	18
14	Supply Chain Finance	17
15	Block Chain	16
	Security	16

productive authors with regards to the number of published papers. While the majority of the authors with two or more papers have a background in operations research/management and business or finance, another category of researchers is significantly represented in the list: Kshetri [44], [50], [115]–[118], Rejeb [123], [124], Casado-Vara [125], [126], Hepp [127], [128], all come from the computer science and information technology sector. More than half of these leading authors have contributed conceptual research papers or case studies. Hackius and Petersen [129] provided a survey with logistics practitioners, revealing their existing knowledge with regard to BCT in LSCM.

Comparing Table IV with Table V, we observe that the top leading University of St. Gallen is represented by the authors [115]–[117] and [119], which shows that it only requires the work of two researchers of the same institution to be ranked on top. The same is valid for the University of North Carolina at Greensboro, where Kshetri sets the ranking for his institution with six of seven contributions.

C. Keyword Statistics

The keyword statistics process was conducted manually and was part of the conducted data collection to highlight the most used phrases/words in the study title and in the keyword section. We collected a total number of 2284 keywords, taken from all 613 papers. The most popular keywords are shown in Table VI, summarizing the top 15 keywords used.

In a similar fashion, the most frequently used phrases within paper titles were collected. The results are shown in Table VII.

Comparing the two tables, the keywords are in line with the most frequent wording in paper titles, having “Blockchain” as

most frequently used word and "Supply Chain" being number two in both statistics. It is not surprising that "Blockchain" and "Supply Chain" rank 1 and 2 in the title word statistics as those two terms were also used as search terms in our paper collection. More interesting, "traceability," "transparency," and "sustainability" occur in the listing, indicating that BCT addresses relevant challenges around transparency and traceability as well as sustainability in current supply chains [130], [131]. Another interesting finding is the "IoT"-related terminology, which indicates the role of BCT in IoT issues.

Furthermore, the term "Smart Contract" appears in the top 15 of our title phrase and keyword analysis, which shows the research interest of scholars around use cases for smart contracts in the field of LSCM. Surprisingly, the terms "food safety" and "food" appear as well in our top 15 listings, which indicates the role of BCT in food supply chains, where trust, transparency, and information integrity play a key role for market participants [132], [133]. It will be interesting to pursue future research endeavors in this particular supply chain discipline.

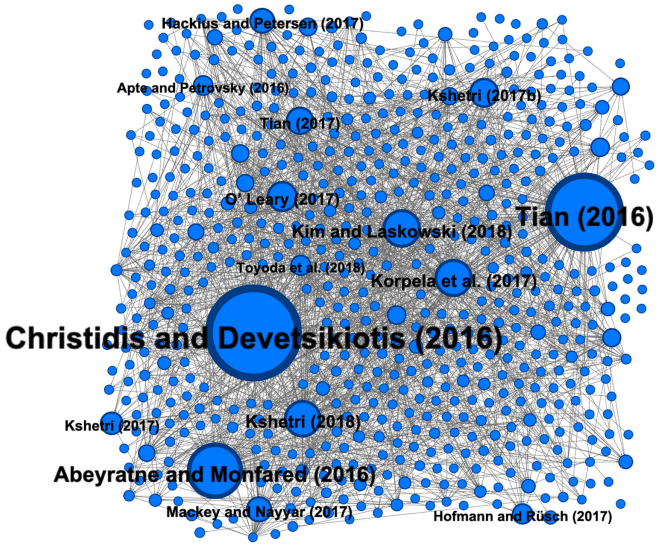

Fig. 6. Citation network with PageRank.

V. Citation Network Analysis

In the next stage of our study, a network analysis was carried out for the selected data sample. Different applications are available for this purpose. The most well-known are Gephi, CiteSpace [104], VOSviewer [105], and Pajek [134]. For our study, we chose Gephi due to its flexibility in the design and layout of our analysis. Furthermore, Gephi is flexible when it comes to data formats. As an example, Pajek has limited capabilities to carry out manual amendments within the network illustration. VOSviewer does not have these limitations, still it only offers limited network analysis tools.

The application of choice, "Gephi," is an open-source software designed to create network illustrations in real-time [103]. Furthermore, Gephi offers filtering, navigating, manipulating, and cluster data functions based on modularity classes [135], [136]. To provide a network analysis in Gephi, the data need to be prepared in a specific format. As a result, the uploaded CSV files illustrate a network, where a node represents a published paper, and the connecting edge represents the citation between those papers. As an example, if paper A cites paper B, both papers are connected via an edge, showing their connectivity in the literature. The preparation of the raw data took several weeks and was reviewed multiple times.

A. Citation Analysis

To examine the connectivity between our selected papers/nodes, the 613 nodes collected were imported into Gephi as a CSV data sheet. The initial analysis in Gephi revealed that 418 papers out of 613 papers have cited each other at least once. The initial result of our citation network is shown in Fig. 6, where one node represents one paper, and the citation is being presented by the edges that connect the nodes. The initial visualization of the network gives an initial indication of the complexity and density of the existing literature landscape. We used PageRank as explained in Section V-B to highlight the leading articles by prestige, which provides a first impression of the literature landscape with most of the papers with low prestige, whereas few papers claim a relevant position in terms of prestige within the field.

Out of 613, 418 have been cited at least once within the network, which equals 68.19% of all papers. In our analysis, we made a distinction between global citation and local citation. Global citation refers to the overall citation, extracted from Publish or Perish [102]. Local citation shows the number of citations within the network and was counted based on the collected raw data in Gephi. The most locally cited papers are listed in Table VIII.

Tian [29] is ranked number two in our global analysis but is at the top of the local citation (111) within our network, which makes his article the most cited paper in the network. Christidis and Devetsikiotis [35] have the highest citation score globally (1516)—still, the citation within our network is ranked number four following Tian [29], Abeyratne and Monfared [28], as well as Kshetri [44]. A key reason could be that Christidis and Devetsikiotis [35] contributed to Blockchain in IoT, discussing LSCM and container transportation as an application of BCT without being dedicated to the field of LSCM in their study. It is apparent that the most cited papers, globally and locally, are papers from 2016 and 2017. Remarkably, Kim and Laskowski [47], publishing in 2018, have a global citation count of 219 and a local citation of 46, ranking them at number seven in our local citation analysis. It can also be seen that the global citation is not necessarily an indicator for our network, with Toyoda *et al*. [138] having more local citations (42) than Kshetri (22) [50], even though Kshetri [50] has a much higher ranking in the global citation (276), which can be explained by the general IoT and BCT approach that Kshetri [50] takes in his study. This indicates the cross-disciplinary interest of researchers working on BCT issues. Interestingly, Apte and Petrovsky (27) [27], Lu and Xu (28) [141], and Mackey and Nayyar (20) [142] do not even feature in the top 15 cited papers from global citation, still they are ranked in the top 15 when it comes to the local

TABLE VIII
CITATION RANKING, LOCAL AND GLOBAL CITATION

#	Author	# local citiations	# global citations	global citation p.a.
1	Tian (2016)	111	412	103
2	Abeyratne and Monfared (2016)	72	237	59
3	Kshetri (2018)	68	260	130
4	Christidis and Devetsikiotis (2016)	66	1516	379
5	Korpela et al. (2017)	52	256	85
6	Tian (2017)	47	167	56
7	Kim and Laskowski (2018)	46	219	110
8	Toyoda et al. (2018)	42	119	60
9	Hackius and Petersen (2017)	34	128	43
10	Bocek et al. (2017)	32	134	45
11	Francisco and Swanson (2018)	31	118	59
12	Lu and Xu (2017)	28	90	30
13	Apte and Petrovsky (2016)	27	81	20
14	Kshetri (2017b)	22	276	92
15	Mackey and Nayyar (2017)	20	84	28

citation analysis of our network. Even though they only have a low global citation, this makes their work a popular paper in the specific field of BCT in LSCM. Surprisingly, the top three locally cited papers come from Europe, whereas none of them come from the top contributing European country, Germany (31). As a general rule to citation analysis, it should be noted that early published papers do have an advantage when it comes to citations as published papers later do not have enough time to establish citation. This is evidenced by the fact that the top three cited papers were all published prior to 2018. In conclusion, the local and global citation counts of Kshetri [44], Francisco and Swanson [64], Kim and Laskowski [47], and Toyoda [138] listed in our top 15 by local citation is remarkable and indicates the relevance of these studies in the field of BCT in LSCM.

To determine the relevance of papers, it remains necessary to show the immediate impact of recently published papers. A method to demonstrate this is to measure the average citation per year (ACPY) by dividing the global citation divided by the number of years since publication. As an example: A publication from 2019 with five citations has an ACPY of 5. We discovered that the paper with the highest local citation, Tian [29], is only at rank 4 with 103 ACPY. Christidis and Devetsikiotis [35] hold the highest average citation with 379 citations per year. Kshetri [44] holds 130 citations per year, followed by Kim and Laskowski [47] with 110 citations per year. We assume that these papers will gain further importance and relevance with time, not only in supply chain research, but also in other disciplines, based on their high ACPY score.

B. PageRank Analysis

Although the number of citations can be considered as a popularity indicator, prestige is another indicator in understanding the relevance of a study in a specific field. Prestige per definition is the number of times an article has been cited by other highly cited articles [143]. Even though the number of citations does not necessarily reflect the significance of the work, there is a positive correlation between both measures [86]. To verify the prestige of the selected papers, we use PageRank, which was introduced by Brin and Page [144]. Brin and Page created PageRank to set priority for web pages when a search is done on Google. The original purpose of PageRank—to define relationships between webpages–can be used to research the relationships between networks, such as a network of papers in a citation analysis [144]. Following Brin and Page, we assume that Paper A has been cited by Papers $T_1, .., T_n$. Furthermore, d is defined as a damping factor, set between 0 and 1, to depict the ratio of random walks that spread along the citations. We define $C(T_i)$ as the number of times T_i has cited other articles. Brin and Page [144] calculated the PageRank of paper A (PR(A)) in a network of *N* papers as in the following equation:

$$\mathrm{PR(A)} = \frac{(1-d)}{N} + d\left(\frac{\mathrm{PR}(T_1)}{C(T_1)}\right) + \cdots + \frac{\mathrm{PR}(T_n)}{C(T_n)}. \quad (1)$$

If $C(T_i) = 0$ then $\mathrm{PR}(T_i)$ will be divided to the total number of papers. The PageRanks forms a probability distribution over all papers. Hence, summarizing all papers', PageRanks will result in the sum 1. In the PageRank algorithm of Brin and Page for web pages, the damping factor d is set equal to 0.85 as a standard value, defined by the observation that a user of Google search machine will follow the order of six hyperlinks before the user gets bored with the search result, starting a new search [144]. This observation is equal to a leakage probability of $1/6 = 0.15 = 1 - d$. Chen *et al*. [145] highlighted that in the reference list of a typical paper, entries are collected in shorter paths. Chen *et al*. [145] defined $d = 0.5$, a more suitable value

TABLE IX
TOP AUTHORS BY PAGERANK

#	Author	PageRank
1	Christidis and Devetsikiotis (2016)	0.043763
2	Tian (2016)	0.031181
3	Abeyratne and Monfared (2016)	0.023410
4	Korpela et al. (2017)	0.017291
5	Kim and Laskowski (2018)	0.015972
6	Kshetri (2018)	0.013838
7	Kshetri (2017b)	0.011790
8	O' Leary (2017)	0.011699
9	Mackey and Nayyar (2017)	0.011134
10	Tian (2017)	0.010421
11	Hackius and Petersen (2017)	0.008819
12	Kshetri (2017)	0.008111
13	Apte and Petrovsky (2016)	0.007171
14	Hofmann and Rüsch (2017)	0.007161
15	Toyoda et al. (2018)	0.007089

for PageRank analysis in citation networks, which we have used in our article. The value has been adopted by other researchers, using the same value in their analysis [86]. Table IX shows the top papers by PageRank. Comparing the top papers by PageRank (see Table IX) against the top papers by citation (see Table VIII), we see that the paper by Christidis and Devetsikiotis [35] are ranked at number one. Interestingly, we discovered that 13 out of the top 15 cited papers are also among the top 15 papers determining the PageRank. O'Leary [146] and Hofmann and Rüsch [118] are among the top 15 measuring PageRank, which is interesting as they do not appear in the top 15 of the most cited papers. This indicates their relevance in other highly cited papers.

It is worthy of note that the PageRank is affected by citations of other often cited papers. By nature, later publications have no chance to be cited by earlier publications. As the field grows by number of publications and output, PageRank will most likely give an improved picture of the prestige of publications in the future.

C. Cocitation Analysis

A visualization of cocitation data is a form of exploratory data analysis grounded on graph theory, which helps in understanding large datasets [147]. A cocitation analysis consists of a set of nodes that represent journal articles and edges that represent the co-occurrence of articles in the reference list of a paper [148]. Per definition, papers are cocited if they appear together in the reference list of another paper. Therefore, publications A and B are cocited when both papers are cited by paper C. Papers with high cocitation numbers are more likely to be related, belonging to a similar subject area [86], [149]. We use this concept to map and classify the literature landscape of BCT in LSCM. Using our raw data from the previous network analysis, we extracted all cocitations from our database. The initial cocitation analysis revealed that 176 out of a total of 613 have been cocited by other papers within the network, building the core of our cocitation

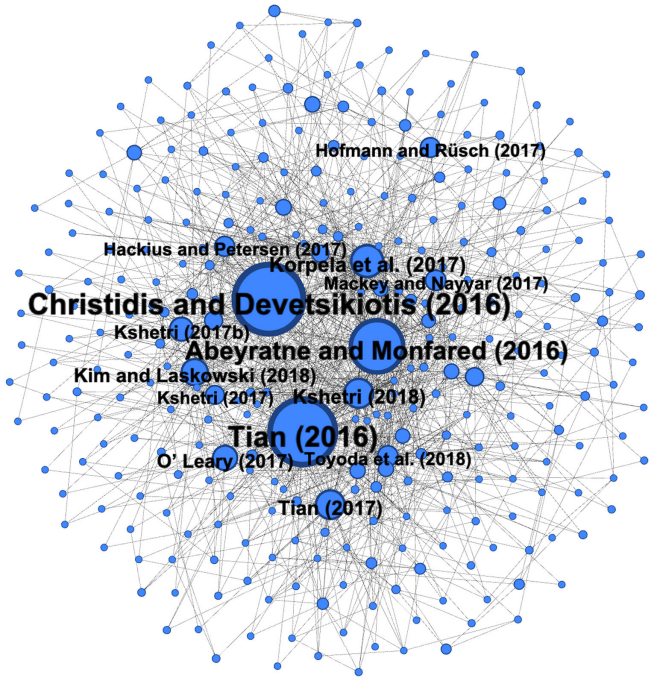

Fig. 7. Cocitation network, Fruchterman Reingold-layout.

network. Due to the number of papers available, we included all papers that contribute at least one cocitation to the visualization of the network. In other words, we included all papers that have a minimum of two articles from our network in their reference list on top of the cocited papers which leads to an overall sample of 296 articles.

When illustrating our CSV file in Gephi initially, the nodes were randomly positioned by Gephi, as shown in Fig. 6. However, the software offers a set of algorithms to create different visualizations. Beside other algorithms, "Fruchterman Reingold" is a force-directed layout algorithm that represents nodes in a circle, where nodes and edges are more or less of equal length without any crossing of edges, which results in an easy to read visualization of the network [150]. With this algorithm, the nodes (=papers) that have the highest corelation are in the center of the network. In turn, the less connected nodes move to the periphery. Fig. 7 visualizes the Fruchterman Reingold layout of our proposed 296-node citation network. The size of the nodes reflects the relevance by PageRank.

D. Data Clustering: Classification of Literature

Data clustering is a tool used to group and classify a set of given papers [151]. It allows for the topological analysis of a network, identifying research clusters and interrelations within the studied network. In our article, data clustering is used to identify research clusters of BCT in LSCM. Due to the increasing attention to modularity being made a research field in social network analysis [152], [153], we will likewise use modularity to cluster the articles in our network.

Again, Gephi was the tool of choice to create modularity. In Gephi, the Louvain algorithm is used as a standard algorithm to calculate modularity. The Louvain algorithm follows

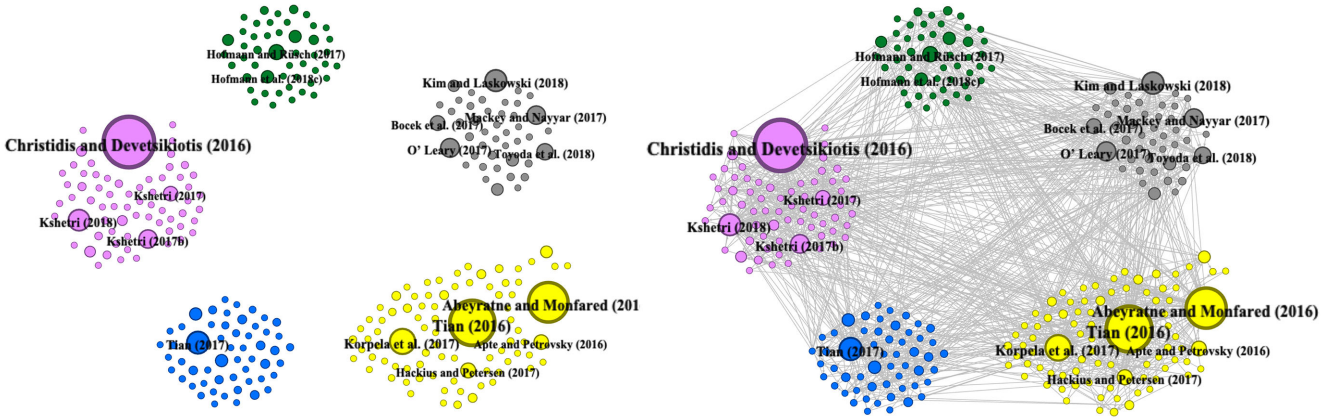

Fig. 8. Cocitation network, five clusters.

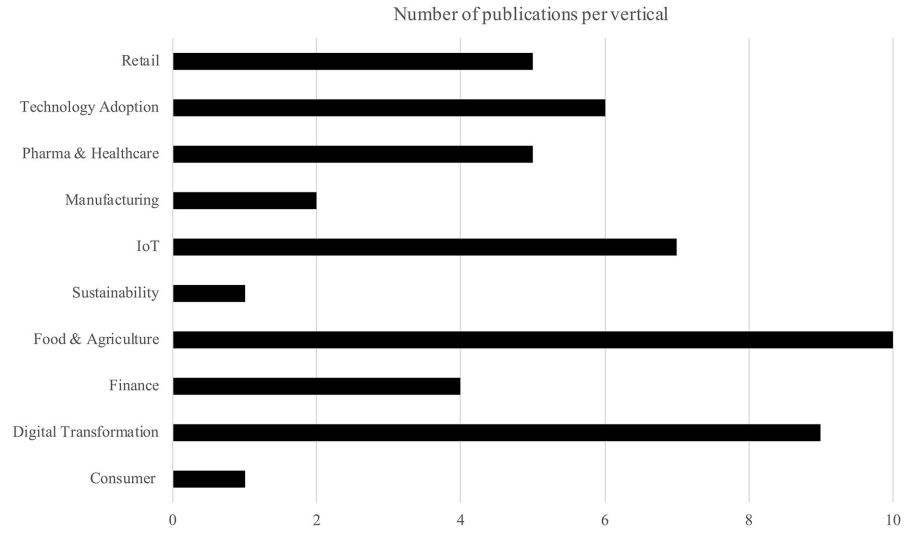

Fig. 9. Number of publications per practitioner relevance field.

TABLE X
LEADING AUTHORS PER CLUSTER, BY PAGERANK

Cluster 1	PageRank	Journal
Tian (2016)	0.031181	Conference Paper
Abeyratne and Monfared (2016)	0.023410	International Journal of Research in Engineering and Technology
Korpela et al. (2017)	0.017291	Conference Paper
Hackius and Petersen (2017)	0.008819	Conference Paper
Apte and Petrovsky (2016)	0.007171	Journal Excepients and Food Chemicals

Cluster 2	PageRank	Journal
Tian (2017)	0.010421	Conference Paper
Yakavenka et al. (2018)	0.006497	MIBES Transactions
Lu and Xu (2017)	0.006490	IEEE Software
Tse et al. (2017)	0.004245	Conference Paper
Leng et al. (2018	0.004139	Future Generation Computer Systems

Cluster 3	PageRank	Journal
Hofmann and Rüsch (2017)	0.007161	Computers in Industry
Hofmann et al. (2018c)	0.006612	Springer Briefs in Finance
Staples et al. (2017)	0.006395	Data61
Saberi et al. (2018)	0.005591	International Journal of Production Research
Chod et al. (2017)	0.004487	Conference Paper

Cluster 4	PageRank	Journal
Kim and Laskowski (2018)	0.015972	Intelligent Systems in Accounting, Finance and Management
O' Leary (2017)	0.011699	Intelligent Systems in Accounting, Finance and Management
Mackey and Nayyar (2017)	0.011134	Expert Opinion on Drug Safety
Toyoda et al. (2018)	0.007089	IEEE Access
Bocek et al. (2017)	0.006302	Conference Paper

Cluster 5	PageRank	Journal
Christidis and Devetsikiotis (2016)	0.043763	IEEE Access
Kshetri (2018)	0.013838	International Journal of Information Management
Kshetri (2017b)	0.011790	IT Professional
Kshetri (2017)	0.008111	Telecommunications Policy
Clauson et al. (2018)	0.005434	Blockchain in Healthcare Today

an iterative optimization model with the aim of creating the optimal number of clusters, maximizing the modularity index [153]. The modularity index of a partition has a value between -1 and $+1$, measuring the density of edges inside a network community versus the edges between the generated clusters. Following Blondel *et al.* (]153], the modularity index can be formulated as

$$Q = \frac{1}{2m} \sum_{ij} \left[A_{ij} - \frac{K_i k_j}{2m} \right] \delta(c_i, c_j) \qquad (2)$$

Here, A_{ij} is the weight of the edge between two nodes i and j, k_i is the sum of the weights of the edges attached to a node i. C_i is the community to which vertex i is assigned, $\delta(u, v)$ is equal to 1 if $u = v$ and 0 otherwise, and finally, $m = (1/2)$ Σ_{ij} A_{ij} [153]. Using this algorithm in our 296-node network results in the creation of five clusters. The number of papers in the clusters varies from 84 papers in cluster 1–41 papers in Cluster 4. Gephi allows different layouts to present the modules. Fig. 8 shows a layered configuration of the five clusters where the articles of each cluster are included in one separate stream. The

TABLE XI
CLUSTER LABELING

Cluster	# of papers	Area of research
1	84	Sensemaking - theory development Challenges, prospects and barriers for technology adoption
2	55	Testing and conceptualizing Blockchain applications Analysis of the impact for industry specific use cases
3	52	Digital supply chain management Role of Blockchain Technology in digital supply chains
4	41	Technical design of Blockchain applications Framework development for real world supply chain applications
5	64	Framing Blockchain Technology in supply chains Interdisciplinary technology and operations research
	296	

TABLE XII
CONTRIBUTIONS PER YEAR, PER CLUSTER

Cluster	2016	2017	2018	2019	percentage growth 2018 - 2019 year-to-date by no. of publications	Total
1	4	10	36	34	-5,56%	84
2		7	17	31	82,35%	55
3	1	12	17	22	29,41%	52
4		4	13	24	84,62%	41
5	2	5	15	42	180,00%	64
Total	7	38	98	153		296

TABLE XIII
TOP CONTRIBUTING AUTHORS BY PAGERANK PER CLUSTER

	Cluster				
Author	1	2	3	4	5
Christidis, K.			1		
Tian, F.	1	1			
Abeyratne, S.	1				
Korpela, K.					1
Kim, H.					1
O'Leary, D.		2			1
Kshetri, N.			3		1
Mackey, T.			1		
Hackius N.	1				
Hofmann, E.	2				
Apte, S.	1				
Bocek, T.				1	

modularity index in Fig. 9 is equal to 0.347 indicating the high interrelationship of the clusters [152]. This result is reasonable when comparing the network illustration in Fig. 8 with and without edges displayed, showing the high connectivity between the clusters.

Based on Hjørland [149], papers that are more frequently cocited are more likely to present the same kind of research areas. Given that papers within a cluster have strong cocitation affiliation, a careful analysis of articles in one cluster can define the research area and its focus within that particular cluster [148], [151], [154]. Due to the high number of articles in the identified clusters, we completed the content analysis for the top five leading papers of each cluster, identified by the PageRank of the individual papers. This methodology using the "cocitation PageRank" has been shown to be an effective measure to determine the top leading papers in a set of a given cocitation network [86], [143], [155]. The leading papers (by PageRank) of each cluster are shown in Table X.

In the next step, abstracts and content of the leading papers were evaluated to determine the focus area of each cluster. To characterize the clusters, two senior scholars and one junior scholar reviewed the leading papers in parallel for content to create a label for each cluster. In the next step, the separately drafted cluster-labels were discussed and aligned in two sequentially held sessions. This methodology of creating clusters based on content of the top leading PageRank papers has been established by previous scholars, using a similar process to identify and to label research clusters based on content [86]. Table IX gives an

TABLE XIV
TOP AUTHORS PER PRACTITIONER RELEVANCE FIELD, BY PAGERANK

Consumer	PageRank	Manufacturing	PageRank
Lee and Pilkington (2017)	0.004812	Abeyratne and Monfared (2016)	0.023410
Digital Transformation		Madhwal and Panfilov (2018)	0.004105
Korpela et al. (2017)	0.017291	**Pharma & Healthcare**	
Kshetri (2018)	0.013838	Mackey and Nayyar (2017)	0.011134
Hackius and Petersen (2017)	0.008819	Apte and Petrovsky (2016)	0.007171
Staples et al. (2017)	0.006395	Toyoda et al. (2018)	0.007089
Wu et al. (2017)	0.005852	Bocek et al. (2017)	0.006302
Rubio et al. (2018)	0.004129	Clauson et al. (2018)	0.005434
Sharma et al. (2017)	0.003886	**Technology Adoption**	
Babich and Hilary (2018)	0.003536	Wüst and Gervais (2017)	0.006175
Wang, Y. et al. (2019)	0.003428	Petersen et al. (2018)	0.004193
Finance		Peck (2017)	0.004113
O' Leary (2017)	0.011699	Queiroz and Fosso Wamba (2019)	0.003644
Hofmann et al. (2018c)	0.006612	Li, Z. et al. (2017)	0.003612
Chod et al. (2017)	0.004487	Meng et al. (2018)	0.003507
Wang, JunSheng et al. (2018)	0.003712	**Retail**	
Food & Agriculture		Lu and Xu (2017)	0.006490
Tian (2016)	0.031181	Nakasumi (2017)	0.006373
Kim and Laskowski (2018)	0.015972	Francisco and Swanson (2018)	0.006066
Tian (2017)	0.010421	Chen et al. (2017)	0.004366
Yakavenka et al. (2018)	0.006497	Kamble et al. (2018)	0.003463
Biswas and Muthukkumarasamy (2017)	0.004974	**IoT**	
Tse et al. (2017)	0.004245	Christidis and Devetsikiotis (2016)	0.043763
Leng et al. (2018	0.004139	Kshetri (2017b)	0.011790
Galvez et al. (2018)	0.004068	Kshetri (2017)	0.008111
Caro et al. (2018)	0.004005	Hofmann and Rüsch (2017)	0.007161
Casado-Vara et al. (2018)	0.003843	Ivanov et al. (2018)	0.003818
Green Supply Chain Management		Bahga and Madisetti (2016)	0.003703
Saberi et al. (2018)	0.005591	Alzahrani and Bulusu (2018)	0.003459

overview of the labeling result, providing a description of the identified clusters.

Analyzing the contributions per cluster per year, the dominating cluster 1 (Sense making—theory development) has been represented since 2016. 2019 is the dominant year in terms of the total number of contributions, whereas the high number of contributions in 2018 to cluster 1 is remarkable, indicating the developing endeavors in the sensemaking of BCT in LSCM in this year. It is interesting to note that until January 2020, compared to 2018, the number of publications in this cluster has shrunk in comparison with other clusters, indicating a shifting research interest of scholars. One reason could be the increasing interest of practitioners in BCT [156], which demands practical applications. Another reason could be the expanding understanding of the technology, which requires fewer ground floor studies but more practical, tangible adoption research. Thus, it is interesting to note that cluster 2 (testing and conceptualizing blockchain applications) and 5 (framing BCT in supply chains) as well as cluster 4 (technical design of blockchain applications) show an increasing number of papers in 2019: Although all three clusters had a limited number of papers in 2018, they seem to become more relevant in 2019, indicating the developing attempts of researchers in working on real-life use cases for BCT in supply chains. Cluster 3 (digital supply chain management) was showing great development of contributions in 2017, whereas it now seems to flatten compared with the development of the other clusters. The overall lowest number of contributions in cluster 4 (technical design of blockchain applications) can be explained by the technical focus of the studies in this cluster, indicating the need that technology design and understanding of LSCM requirements need to be further aligned. The results are shown in Table XII.

To extend our bibliometric study, we looked further into the contributing authors per cluster, which provides an indication of the leading authors per cluster. This, in turn, provides easy access for researchers with a specialized focus. Table XIII lists the top contributing first authors by PageRank per cluster. Most of the prolific studies contributed to clusters 1, 3, and 5, while the majority of them have focused solely on one cluster to this day. The only exceptions are the studies of Tian, O'Leary, and Kshetri, who contribute to two different research clusters. A reason for the narrow research conducted

by most scholars might be the novelty of a topic in which every researcher is focusing on a particular research field. It is interesting to note that cluster 4 (technical design of blockchain applications) is underrepresented when it comes to prestige-full studies, which indicates the aforementioned novelty of the cluster.

E. Practitioner Relevance Classification

In order to develop organizations and supply chains, practitioners are requested to build up relevant knowledge within the desired development area [154]. This is also true for the development and integration of digital technologies into business processes. Although cocitation and network analysis as well as data clustering helps to streamline the existing literature landscape, the interest of a broad base of practitioners is focused on certain practitioner fields [155]. Thus, to address this need for practitioners, we opted to take a deeper look into the most prestigious papers. Due to the high amount of studies available, we decided to focus on the top 50 studies by prestige or in other words, PageRank. To identify the fields, all 50 studies were read by the abstract and title. In case neither the title nor the abstract were helpful in identifying a field, we read the entire study. In two sequentially held sessions by two senior scholars and one junior scholar, we ultimately identified on ten different verticals. It is interesting to note that BCT in LSCM seems to touch upon various practitioner fields with the strongest focus on retail, food, and agriculture, as well as in transforming supply chains into digital. Furthermore, pharma and healthcare provide an interesting playground for practitioners from that field. The aforementioned role of BCT in IoT issues has been confirmed from this analysis. Sustainability issues, consumer-supply-chain-related discussions, and manufacturing studies viewing BCT are considered less by prolific researchers to this day, which indicates a research gap within these fields. Fig. 9 gives an overview of the results.

A more detailed breakdown of the practitioner fields is shown in Table XIV, listing the authors, their PageRank, and the practitioner field.

VI. Conclusion and Future Research

A. Research Questions and Findings

This article provided a structured bibliometric analysis of the existing literature landscape of BCT in LSCM. Although a few reviews have been provided on BCT in LSCM by previous researchers, a comprehensive bibliometric and network analysis to analyze and identify objectively influential authors and papers in the field has not been completed to this day. This initial effort visualizes influential contributions to the field by mapping the relationships between the most impactful papers, with regards to our initial research question

RQ1. What are the leading and most influential papers in terms of popularity and prestige in the field of BCT in LSCM?

Our results from Sections IV and V demonstrated that there is a narrow concentration of influential works from a handful of researchers; however, the research domain is in its infancy with additional scholars joining this research discipline of LSCM. The most influential works are from 2016 and 2017, which is not surprising as all the following scholars were sourcing the work of early researchers in their field. The works published from the end of 2018 as well as of 2019 had less chance to gain traction and to establish citation. Our geographic analysis showed that Europe and the United States provided the highest number of publications while other regions worldwide also contributed literature to the field. The level of global interest indicates the potential of the technology holding for future LSCM practice. Measuring popularity by local citations, Tian [29] is the top leading author in our BCT in LSCM network followed by Abeyratne and Monfared [28], Kshetri [44], and Christidis and Devetsikiotis [35]. Tian [29] proposed a supply chain traceability system for agricultural goods to enhance the quality and safety of food products. Based on his conceptual description, he called future researchers to develop blockchain-based systems for real-world use cases. Interestingly, Abeyratne and Monfared [28] conceptualized a similar system for the manufacturing process, asking organizations for an open mindset for developing blockchain-based systems. Kshetri [44] examined whether BCT is likely to affect supply chain management objectives, such as cost, speed, risk reduction, flexibility, as well as sustainability, and illustrates mechanisms by which the technology could help to achieve these objectives. With regards to prestige, measured by PageRank, Christidis and Devetsikiotis [35] are on top, followed by Tian [29] and Abeyratne and Monfared [28]. Christidis and Devetsikiotis [35] provided a study on the role of BCT in IoT, highlighting the relevance of blockchain for data security and process automatization. They called for further research and development of knowledge, considering blockchain as a driver "for significant transformations across industries, bringing about new business models and having us reconsider how existing systems and processes are implemented" [35]. Combining the results from popularity and prestige, Tian [29] can be considered as the most influential paper, which makes it a "must-read" for every starter in the field. Remarkably, Kshetri from the University of North Carolina at Greensboro is listed four times in the rankings according to popularity and prestige, which also makes him an influential author for blockchain in LSCM, focusing on data security in supply chains and the role of blockchain in IoT [44], [50], [115]. Notable, the most relevant papers from Tian [29] and Christidis and Devetsikiotis [35] were published by IEEE Access.

With regards to our second research question:

RQ2. What are the existing clusters of current research within BCT in LSCM?

We identified five different clusters and highlighted the most prolific researchers of every cluster. From this analysis, we identified the following five different research clusters:

1) sensemaking and theory development;
2) testing and conceptualizing blockchain applications;
3) digital supply chain management;
4) the technical design of BCT applications for real-world LSCM applications;
5) framing BCT in supply chains.

We found out that cluster 1 (sensemaking and theory development) is strongly represented in literature, whereas clusters 2 and 3 are equally presented in the current literature landscape with

a lower number of contributions. In terms of number of publications, cluster 4 shows a significantly lower number of papers, which indicates the starting endeavors of researchers in linking technical design questions to business relevant needs within supply chains. Cluster 5 shows a substantial growth since 2017, indicating the growing interest of researchers to frame BCT into supply chains. We also identified studies that frame BCT into LSCM from different perspectives, such as data security, supply chain visibility, supply chain finance and operations (cluster 5), and that BCT has the attention in the space of 4.0 technologies, analyzing the role of the technology with other digital trends in LSCM (cluster 3). Further we found a number of studies on testing and conceptualizing BCT applications, showing first attempts to realize the theory (cluster 2). We also observed that conceptual and empirical studies have set the foundation, representing the most influential works to this day.

Still, we also identified some weaknesses in our results. First, several of our collected papers are conference papers that may also be developed further until they receive final publication. Second, our data collection was based on a narrow list of search terms, not taking distribution and procurement into account. Third, the overall early bibliometric analysis of BCT in LSCM with publications from 2016 to January 2020 provides only a limited set of papers, limiting the cocitation network. Another interesting field for future research will be the deeper analysis of keyword relationships to further understand the development of the field. We are looking forward to conducting a similar study of BCT in LSCM in five–ten years, depending on the development of the field in academic research. This could also include dynamic cocitation analysis to understand the development of the identified research clusters. To measure the number of quality journal publications, we used the impact factor as one of the most relevant measurement tools to evaluate scientific journals. It needs to be highlighted that other relevant measurement techniques, such as SCImago Journal Rank, the Eigenfactor, or the h-index, could be considered as well and may lead to different results.

From an overall perspective, the low number of influential scholars can be identified as a weakness in the field, which may result in a stagnant view within the discipline. We hope that this is not the case and trust that additional and diverse scholars will further contribute to the field and will drive research into interesting directions. Furthermore, the low number of non-Western and non-Asian researchers can be considered problematic as technology adoption is relevant to global supply chains and the competitive advantage of its participants. Without the research of less developed countries, technology adoption in the specific case of BCT in LSCM might provide further advantage to companies from more developed countries. The number and locations of countries where BCT in LSCM is being researched needs to be expanded.

B. Summary

Timing plays a key role in the adoption of technology. According to Bower and Christenson [157], a certain technology can be defined as a "disruptive technology" if it plays a critical role in a disruptive innovation, changing the bases of competition. Even though BCT is described as a "disruptive technology" in literature, we consider that it might be too premature to judge as digital supply chains still lack certain fundamental building blocks, such as harmonized data quality and availability (158) and the adaption of real-life use cases including BCT. The infrastructural gap around data quality could be addressed with the rising number of IoT devices in supply chains. Radio-frequency identification (RFID), GPS, smartphones, and other IoT applications might fix the data quality gap that most supply chains still face. Thus, the evolvement of IoT in combination with BCT technology as an underlying technology is an interesting playground for future research.

Overall, the field of BCT in LSCM is growing significantly. We expect this development to continue, reducing the hype and developing real-world applications that can support the automatization of processes via smart contracts or product provenance, providing decentralized consensus between supply chain participants, possibly reducing the need for central entities. In terms of capabilities and vision, BCT shows promising concepts with the use of smart contracts to automize operational processes and thus reducing labor and administrative costs, which can be one of the main incentives for supply chain actors. Cargo owners could drive efficiencies and compliance matters through the enhanced visibility and traceability that BCT concepts provide. From a consumer perspective, the technology could close traceability gaps that remain in today's supply chains (e.g., the detailed background of a product). These factors give the technology a promising value proposition to LSCM. Still, BCT as a technology needs further development in the field of LSCM. Ongoing research in the field will help to determine the role of BCT in LSCM and the impact for different supply chain participants.

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