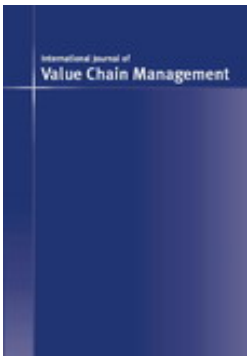

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Bibliometric – thematic analysis and a technology-enabler-barrier-based framework for digital supply chain

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Abstract: Digital supply chain is a proactive, value-driven, and efficient process that helps businesses generate new sources of revenue and business value. From 2000 to 2021, this article covers the evolution of digital supply chain research, outlining critical concerns and trends for the future. This analysis aims to undertake a bibliometric analysis of the literature on digital supply chains to identify emerging trends in this subject through a review of the most influential articles, keywords, authors, institutions and countries. Three software tools were used to accomplish this goal: the R package (Bibliometrix R Package), VOSviewer and SciMAT. According to the research, Germany, Turkey, and the USA have the most publications and total citations. Additionally, a framework based on technology, enablers, and barriers is proposed, and a discussion of the future path of the digital supply chain. This study is the first to analyse digital supply chains' evaluation and give a decision-making framework.

Keywords: digital supply chain; bibliometric analysis; thematic analysis; framework.

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1 Introduction

Today's corporate environment has increased market competitiveness, as established industrial markets have globalised and infiltrated international borders (Balan et al., 2006). At the same time, companies must uncover new digital technologies that may be leveraged to create a new business model and preserve a competitive advantage in the global market. People's perspectives on life have shifted as information and

communication technologies have advanced. Personal computers, namely the proliferation of digitalisation, have expedited this dizzying shift (Garay-Rondero et al., 2019). Today, we live in a cyberworld connected by smartphones, smart clothing, and a range of other devices. We can now access massive volumes of data thanks to the opportunities provided by the internet world. We can store and distribute the data we collect in ways we have not considered previously.

Today's competitive manufacturing environment has driven companies to use cutting-edge manufacturing technologies like 3D printing, rapid prototyping and the internet of things to gather and analyse data. In today's competitive and chaotic climate, every business's goal is to satisfy the consumer by providing the correct product quality, quantity, and pricing in the shortest possible period (Sharma and Gidwani, 2021). Furthermore, the 'internet of things' will connect 26 billion 'things' by 2020 (Hung, 2017).

Digital technologies can improve supply chain procedures and assure client response (Ageron et al., 2020). This is because intelligent products (smartphones, tablet computers, and handheld devices) can convert any electronic message required by legacy systems and facilitate electronic data interchange between firms and supply chain partners. Digitisation has also affected supply chain procedures. Various researchers have contributed in understanding the application and scope of digital supply chain. With advent of internet commerce the supply chain systems is being reshaped in various industries (Vendrell-Herrero et al., 2017). However, to understand comprehensively about different dimensions of research in digital supply chain an in-depth bibliometric research is the absolute requirement. 'Bibliometric research' which refers to studying previously published statistical analyses on a specific topic helps to quickly process and evaluate hundreds of publications while also finding correlations between papers, citations, co-citations, and keywords (Garcia-Buendia et al., 2020). Thus, the current research paper brings, for the first time, a comprehensive and critical systematisation of various aspects needing attention in order to understand technology-enabler-barrier-based framework for digital supply chain through bibliometric research.

The rest of the paper continues in this vein. Section 2 covers the literature on digital supply chain management. Section 3 explains the methodology used in the paper. Section 4 highlights the Scopus collection's findings. Section 5 employs the VOSviewer to provide a graphical representation of the bibliographic content. Section 6 explores the conceptual foundations and evolution of the field. Section 7 discusses and proposes a framework. Section 8 covers the field's findings and future directions.

2 Literature review

The concept of a digitised supply chain is still in its infancy (Kayikci, 2018). A digital supply chain is defined as "an intelligent best-fit technological system built on the capability of massive data storage and excellent collaboration and communication for digital hardware, software, and networks to support and synchronize interaction between organizations by increasing the value, accessibility, and affordability of services while maintaining consistent, agile, and effective outcomes" [Büyüközkan and Göçer, (2018), p.165]. It has been said that the digital supply chain is an intelligent, customer-centric, system-integrated, globally networked, and data-driven mechanism that makes use of new technologies to produce more valuable products and services at a reduced cost

(Bhargava et al., 2013). Success in the digital supply chain has yielded numerous advantages, including improved speed and flexibility and worldwide connectivity and intelligence and transparency (Schrauf and Berttram, 2016).

Recently, there has been an increase in interest in the digital supply chain because of enabling technologies such as big data analytics and cloud computing and 3D printing, drones, and the internet of things. These new technologies are having a significant impact on the operations of the supply chain (Iddris, 2018). Technology has transformed many aspects of the supply chain management process, from financial transactions to communication to management expertise and information exchange (DaneshvarKakhki and Gargeya, 2019; Ben-Daya et al., 2019). It is apparent that moving from a traditional to a digital supply chain provides competitive advantage that generates long-term value for enterprises (Barbieri et al., 2021). According to Xue et al. (2013), digital supply chains are inter-organisational platforms enterprises use to digitise their supply chain partners' transaction and collaboration processes. There is a difference between digital and traditional supply chains in that digital supply chains allow organisations to cut internal management expenses while increasing efficiency through digitalisation, both within and between firms (Korpela et al., 2017). Researchers have been working since a very long time on bringing in front various technological adequacies to the traditional supply chain for a numerous reasons and applications. However despite having a good collection of primary and secondary research in digitalisation of supply chain, bibliometric research under this topic is unavailable to the best of the authors' knowledge. Moreover, it has been observed that bibliometrics has been successfully applied in the past for peer areas of research such as supply chain management (Mishra et al., 2018; Xu et al., 2018; Cancino et al., 2019) and lean supply chain management (Garcia-Buendia et al., 2020). Work on the digital supply chain is spread thinly among its many components (such as big data and cloud computing); therefore, the resulting literature appears disjointed and ambiguous. There has not been much work put into doing literature studies on digital supply chains, and those that have been done have tended to be qualitative and narrative, with scant quantitative evidence. This gives a compelling argument for doing comprehensive bibliometric analysis research on the subject of the digital supply chain. Thus, this paper is aimed to conduct a bibliometric analysis to determine the present level of research on this topic during growing awareness of severe worldwide concerns. As a result, the following research questions will be examined:

RQ1 How have digital supply chain articles evolved?

RQ2 Which journals are the most well-known in this field, and what are their impact factors?

RQ3 Which authors are the most influential?

RQ4 Which institutions and countries have written the most on digital supply chain, and what is a country cooperation network?

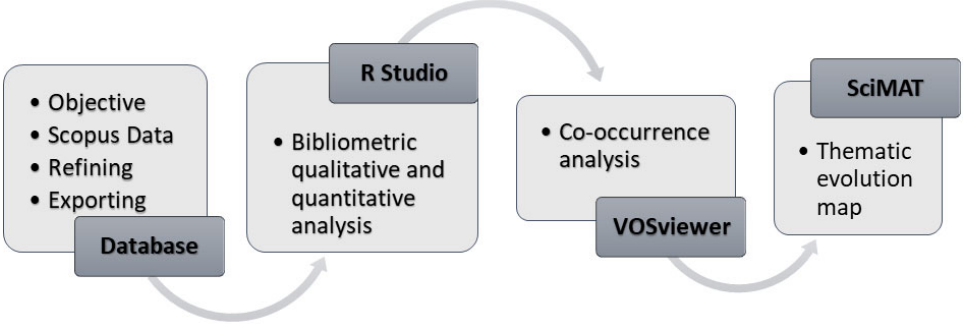
RQ5 What is the research focus of this field's researchers?

3 Methodology

The primary objective of this study is to explore the digital supply chain's thematic landscape. We chose a specific approach for obtaining raw materials that meet our study objectives. We collected data using the best-suited tool for our purposes. Furthermore, in order to answer research questions, we relied on the study objectives. To accomplish this aim, we conducted a systematic review of the literature and bibliometric analysis. By including bibliometric analysis in a systematic review, the rigour of the literature is increased, and researcher bias is eliminated (Phulwani et al., 2020).

This analysis included all Scopus data available as of September 30, 2021. Scopus was used to create 'the world's largest single abstract and indexing database', as well as to serve as the most searchable abstract source for citations and literary searches (Chadegani et al., 2013). In comparison to Web of Science, Scopus has a coverage advantage of over 60% (Zhao and Strotmann, 2015). This study focused on all items relevant to the digital supply chain based on the document's title. As a result, the following inquiry was made: *TITLE (digital AND supply AND chain) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (LANGUAGE, "English"))*. This query returned a total of 342 documents. To limit the number of papers selected for review, we excluded book chapters, reviews, erratums, notes, and books from the search process. Following that, all non-English languages were deleted. Finally, a collection of 300 documents was obtained.

Figure 1 Significant steps of research work



For descriptive bibliometric analysis, we used the RStudio mapping software. Numerous packages relevant to bibliometrics are available in the R environment. The study predominantly utilised Bibliometrix R Package. SciMAT is utilised to comprehend significant thematic focal areas and methodologies and track the discipline's thematic progress. The review of keyword networks in this study is based on Waltman et al. (2010) unified approach to bibliometric network clustering and mapping and the method for visualisation of similarities (VOS) mapping and clustering. Incorporating VOS makes it possible to simplify the presentation of many outputs like a journal and author co-citation, country bibliographic coupling, university bibliographic coupling, and keyword co-occurrences (Tang et al., 2018). The significant steps of the study are represented in Figure 1.

4 Results

The following bibliometric factors are examined in terms of publication, citation, and impact to see how the digital supply chain has evolved: articles published, citations received, geographic distribution, and the most frequently referenced papers and writers.

4.1 Descriptive analysis

Figure 2 depicts the distribution of digital supply chain-related publications from 2000 to 2020. Between 2017 and 2021, the maximum number of papers published is shown in this graph. This indicates that more work has been done on the digital supply chain in the last five years.

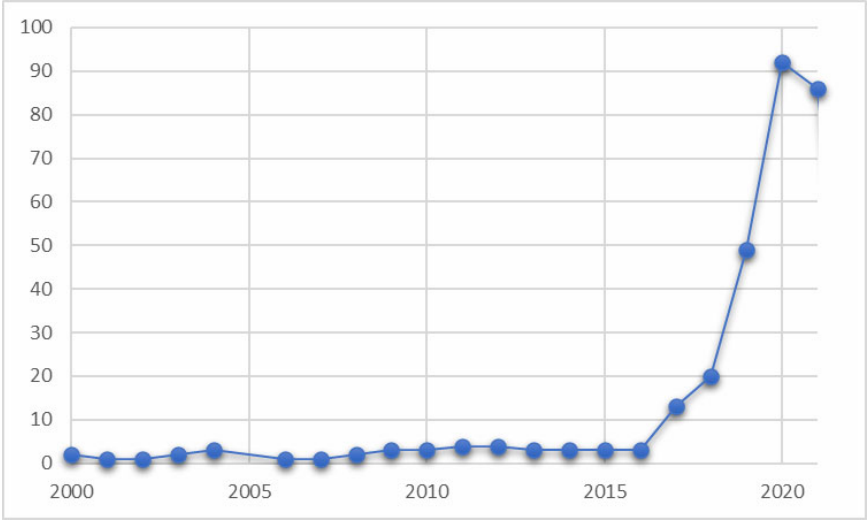
Table 1 Information Summary of various bibliometric entities

Variables	
Sources (journals, books, etc.)	180
Documents	300
Average years from publication	2.49
Average citations per document	9.43
Average citations per year per doc	3.07
References	12,543
Document types	
Article	178
Conference paper	112
Review	10
Document contents	
Keywords plus (ID)	1,334
Author's keywords (DE)	845
Authors	
Authors	807
Author appearances	946
Authors of single-authored documents	30
Authors of multi-authored documents	777
Authors collaboration	
Single-authored documents	32
Documents per author	0.372
Authors per document	2.69
Co-authors per documents	3.15
Collaboration index	2.9

A total of 300 research publications from 807 authors were published in 180 different sources. The average number of publications each year is 2.49, and each document receives an average of 9.43 citations. Each document receives an average of

3.07 citations every year. Additionally, 1,334 keywords and 845 of the author's words have been discovered thus far. Finally, the collaboration index is 2.9, close to the average of 3.15 for the number of writers per document. Table 1 contains this information.

Figure 2 Year wise distribution of published papers (see online version for colours)



4.2 Sources

Table 2 lists the top journals that contribute to this field of research; each journal contributes at least six articles. With 29 articles and 36 citations, the 'International Journal of Supply Chain Management is the field's leading contributor. The top 11 journals include 102 articles out of a total of 300. Numerous journals have made sporadic contributions to this area.

As per Bradford's (1934) law, a collection's concentration/distribution factor can be calculated using bibliometrics. Essentially, it allows for the identification of a subject's most productive nucleus. In addition to a small core of journals dedicated to the topic, it proposes the existence of a vast periphery region divided into numerous zones, each of which contains journals with decreasing representation in the area under study (Alvarado, 2016).

Bradford's law states that "if academic journals are structured in decreasing order of article productivity on a given subject, they can be split into a nucleus of periodical more precisely devoted to the subject and multiple groups of zones holding the same number of articles as the nucleus, when the ratio of periodicals in the nucleus and subsequent zones is 1: n: n^2" The 300 articles were divided into three equal zones for this investigation, as indicated in Table 3. Limited publications publish a large number of articles. One-third of all publications published in the nucleus was found in just 11 journals, as shown in Table 3 (102 records). It's worth noting that zone 2 is dedicated to 70 journals while zone 3 contains 99. Zone 3 has a lot fewer publications than it should, even by theoretical standards (490). This conclusion reflects the topic's newness and immaturity, as evidenced by the fact that few journals have addressed it thus far.

Table 2 List of top contributing journals in the selected theme

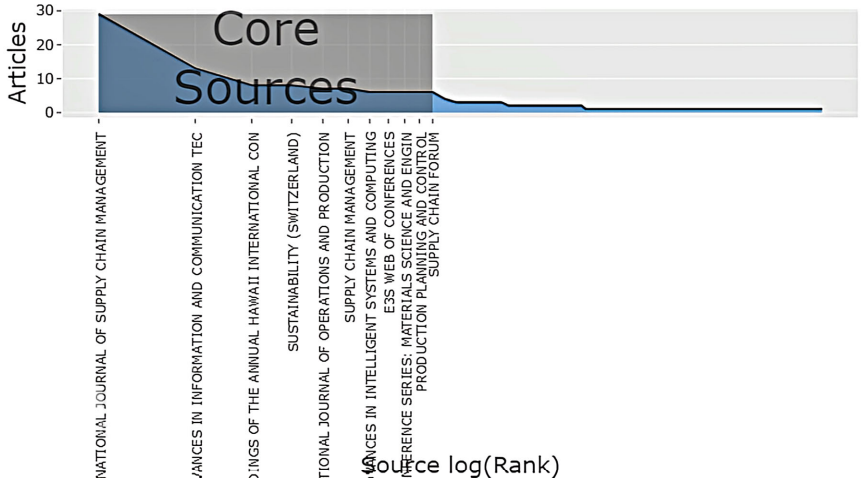
Source	*h*	*g*	*m*	*TC*	*NP*	*PY_start*
International Journal of Supply Chain Management	4	5	1	36	29	2018
IFIP Advances in Information and Communication Technology	1	2	0.2	5	13	2017
Proceedings of The Annual Hawaii International Conference on System Sciences	3	8	0.6	315	8	2017
Sustainability (Switzerland)	3	3	0.75	15	8	2018
International Journal of Operations and Production Management	2	7	0.4	263	7	2017
Supply Chain Management	3	7	0.375	141	7	2014
Advances in Intelligent Systems and Computing	3	4	1.5	22	6	2020
E3s Web of Conferences	2	2	0.67	7	6	2019
IOP Conference Series: Materials Science and Engineering	2	5	0.5	27	6	2018
Production Planning and Control	4	6	0.8	177	6	2017
Supply Chain Forum	3	6	1.5	55	6	2020

Notes: Here, NP = total number of publications, h = h-index, g = g-index, m = m-index, TC = total citation, PY_start = publication year start.

Table 3 Distribution of publications in journals

Zone	*Journal*	*Journal %*	*Articles*	*Articles %*	*Ratio*	*Theoretical ratio (1: n: n^2)*	*Theoretical no. of journals*
1	11	6.12 %	102	34 %	1.1	1	10
2	70	38.88 %	99	33 %	7	7	70
3	99	55 %	99	33 %	9.9	49	490
Total	180	100	300	100			570

Figure 3 Distribution analysis with Bradford's law core sources (see online version for colours)



According to Figure 3, the top core sources with the most publications about the digital supply chain were ten, accounting for 5.6% of the whole sample of sources analysed.

4.3 Authors

Alfred J. Lotka quantified the relationship between authors and their scientific production by examining the distribution of frequencies through Lotka's law map (Lotka, 1976). This method has been widely adopted for bibliometric analysis in current times. According to the research paper, there were a total of 807 authors. Thus, the key authors were investigated using Lotka's law map (see Figure 4) this study were analysed.

Figure 4 Frequency distribution of scientific productivity (see online version for colours)

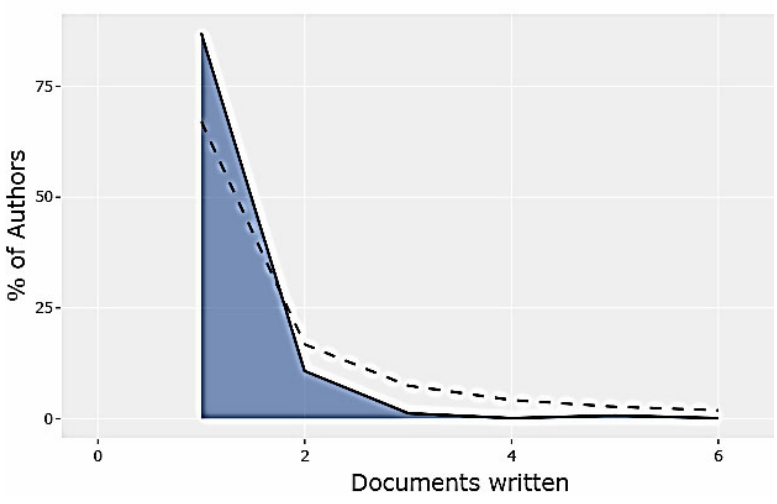


Table 4 Top authors with minimum five papers

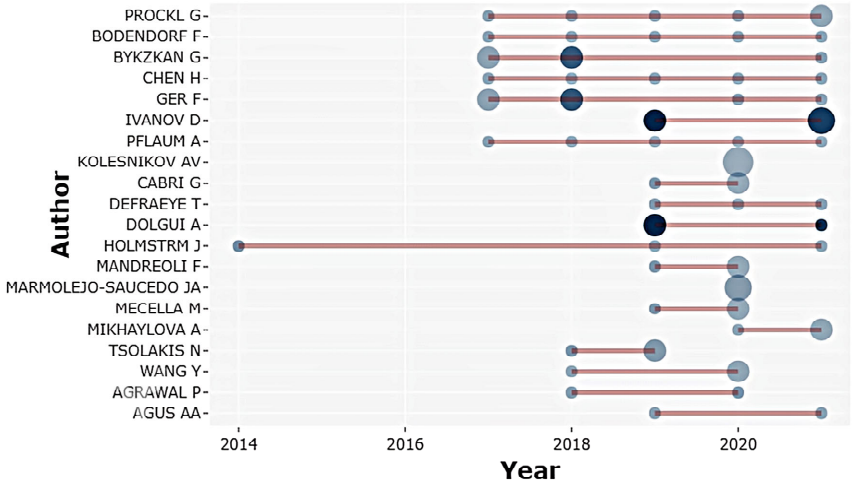
Authors	*Articles*
Prockl, G.	6
Bodendorf, F.	5
Bykzkan, G.	5
Chen, H.	5
Ger, F.	5
Ivanov, D.	5
Pflaum, A.	5

This data implies that 702 authors have published a single paper, accounting for almost 87% of all publications. Eighty-seven writers published two papers, ten authors published three papers, one author published four papers, six authors published five papers, and one author published six papers. The top authors with a minimum of five articles are listed in Table 4. As shown in Figure 4, the authors' frequency of publication in the field of digital supply chain corresponds to the dotted line, which essentially follows Lotka's law. This may indicate that the proportion of authors with a single publication on the

topic is rather extensive. Additionally, this finding reflects that the majority of experts in this field are new to it and that research on digital supply chains may be insufficiently comprehensive.

As indicated in Figure 5 (where the diameter of the circle indicates the number of documents and the shade of the colour indicates the number of citations), most writers wrote papers on the digital supply chain after 2017.

Figure 5 Year wise publications by authors (see online version for colours)



4.4 Main research country

As a general indicator of digital supply chains' effect and importance, articles published in various nations might be used. By and large, the more a country publishes in a given scientific topic, the better its publication volume and citation index are in that field, indicating the impact and quality of its papers. Germany, Turkey, and the USA are the top three countries in total publication volume and citations. The top countries in terms of total citations are summarised in Table 5. Scientific research capacity in developing countries is lower than in developed countries.

Table 5 Top countries publishing articles in the selected theme of research

Country	*Total citations*	*Average article citations*
Germany	485	48.50
Turkey	284	94.67
USA	239	9.96
UK	93	9.30
Malaysia	84	42.00
Greece	61	20.33
China	58	2.76
Mexico	55	13.75
Italy	53	4.42

Figure 6 Multiple country publication (MCP) and single country publication with respect to corresponding author's countries (see online version for colours)

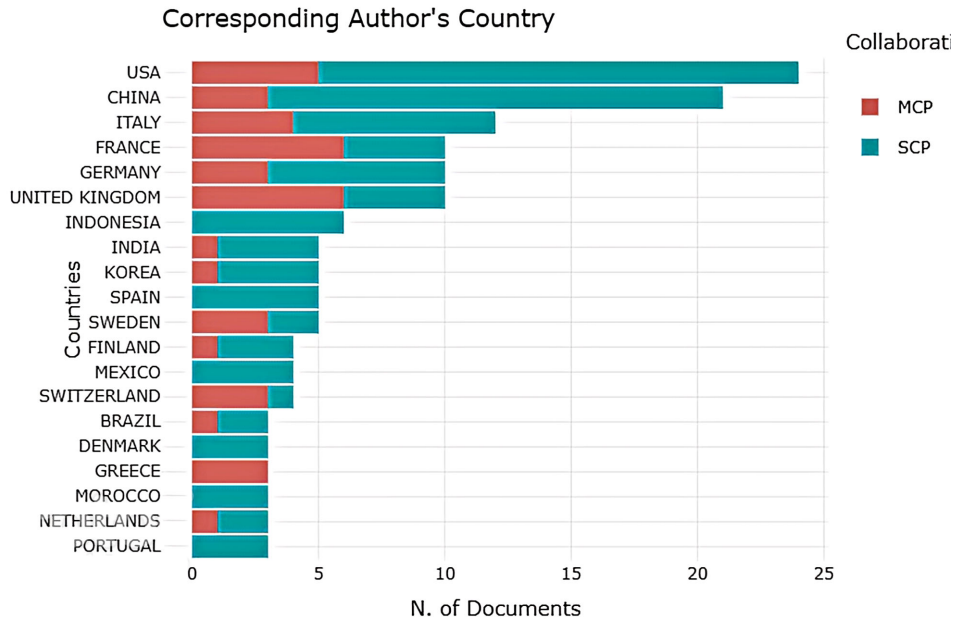


Figure 6 illustrates the number of multiple and single publications. Countries have been abolished based on the author's nationality. The UK, France, the USA, and Italy have all excelled in international cooperative publishing connections. As demonstrated in Figure 6, most articles published in peer-reviewed journals originate in the same country, implying that authors commonly interact with national colleagues. The majority of countries prioritise independent research, and domestic collaborative publications exceed overseas collaborative publications. In the future, bilateral cooperation should be bolstered, and joint publications should be expanded.

4.5 Relationship

Bibliometrix package provides yet another advantageous function which is the plotting of Sankey diagram. This diagram visualise multiple attributes at the same time. In this study, the three fields plot visualised the relationships between the primary authors' keywords, writers, country, and sources. The diagram's significant elements were denoted in this instance by different-coloured rectangles. The height of the rectangles was determined by adding the relationships between the rectangle element (one of the authors' keywords, authors', and source diagrams) and the diagrams of the other elements. The more relationships an element possesses, the larger the rectangle is possessed by it.

The diagram for digital supply chain research is illustrated in Figure 7, emphasising the relations between the primary authors, their nations and sources. The investigation found which sources digital supply chain authors mentioned the most frequently. According to an analysis of the top authors, countries, and sources, there were four authors (Prockl G, Pflaum A, Bodendorf F, and Chen H., five nations (Germany, Italy,

France, the USA and Denmark) and four sources: *Sustainability* (Switzerland); *International Journal of Operations and Production Management*, *Production Planning and Control*, *Supply Chain Management* and Proceedings of the Annual Hawaii International Conference on System Sciences.

Figure 7 Three field plots for relationship between writers, countries, and sources (see online version for colours)

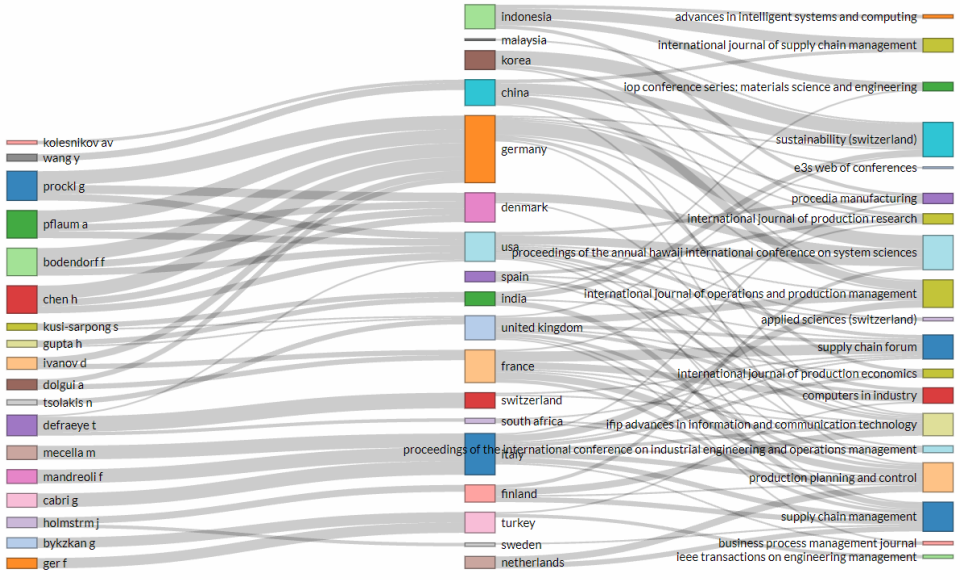
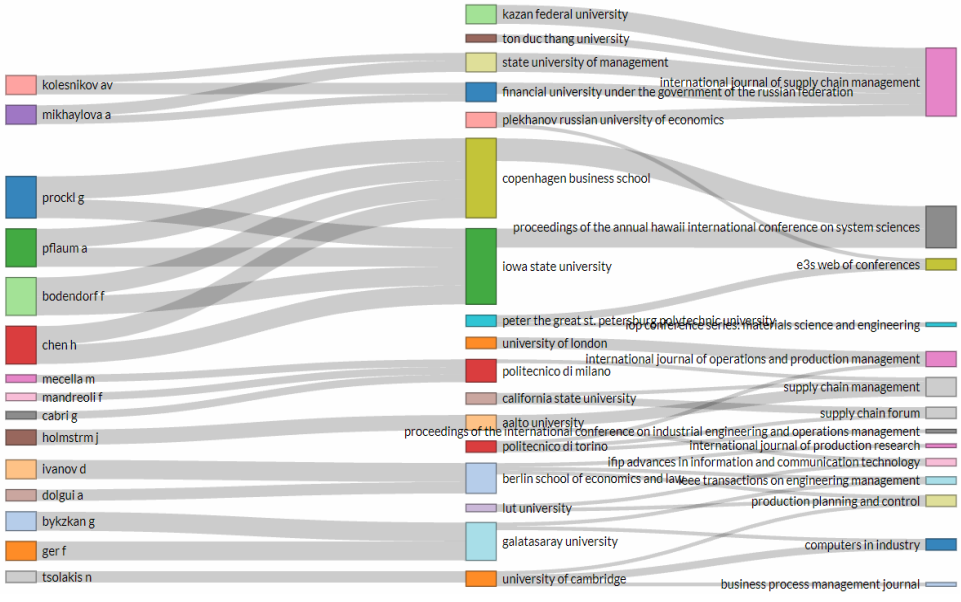


Figure 8 Three field plots for relationship between writers, institutes, and sources (see online version for colours)



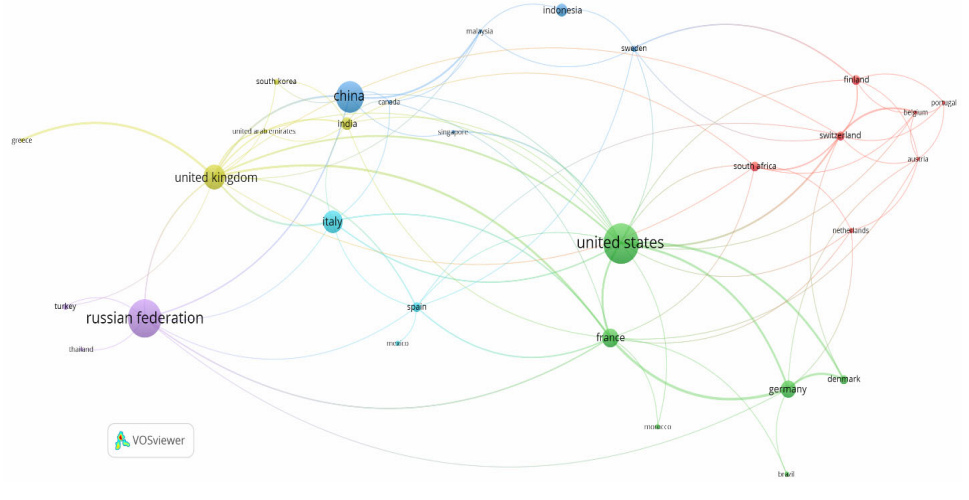
The links between the leading writers, their institutes and their sources are being shown in Figure 8. This chart shows the links between leading writers, top institutions and top publication sources on the advancement of knowledge in the primary themes of digital supply chain literature. The Copenhagen Business School, Iowa State University and Galatasaray University are among the leading institutes publishing papers in the digital supply chain. Most of the Copenhagen Business School and Iowa State University papers are published in Proceedings of the Annual Hawaii International Conference on System Sciences.

5 Mapping results with VOSviewer software

The bibliometric indicators were studied in this area using the VOSviewer application. This application enables us to report on the bibliographical diversity of countries, the citations of authors and articles, and eventually the co-occurrence of the author's keywords.

Figure 9 illustrates the countries' co-authorship of publications. Each connection between two nodes in distinct countries implies that the organisations in these countries collaborate. There are six clusters and 30 connections. Table 6 shows details of clusters. Table 6 shows that the highest link of collaboration is for the USA (17 links), the UK (14 links) and France (13 links). It supports our finding from Figure 6, where the UK, France, and the USA have all performed admirably in international cooperative publishing relations.

Figure 9 Bibliometric network map of co-authorship with respect to countries (see online version for colours)



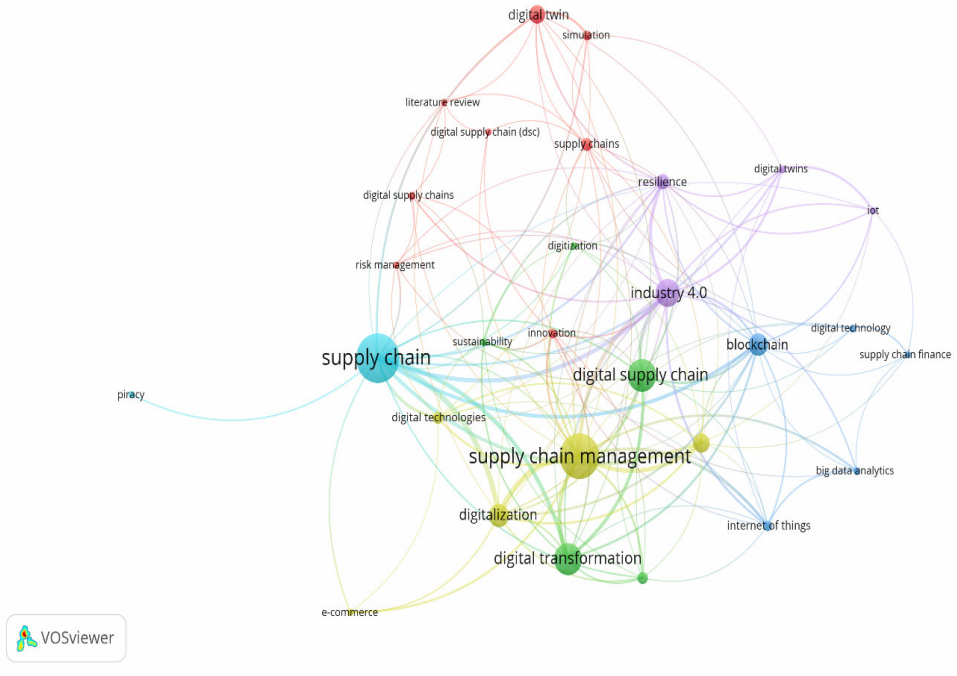
The co-occurrence of keywords is analysed using VOSviewer's network analysis. The minimum number of occurrences for a keyword is set to five. 29 meet the cutoff. Six clusters of 29 keywords have been finalised. Cluster-1 contains a total of eight keywords. In which Digital Twin is the most frequently used keyword. Cluster-2 contains a total of five keywords, where digital supply chain is the most frequently used keyword.

Cluster-3 contains a total of five keywords, where blockchain is the most frequently used keyword. Cluster-4 contains a total of five keywords, where digitalisation is the most frequently used keyword. Cluster-5 contains a total of four keywords, where Industry 4.0 is the most frequently used keyword. Cluster-6 contains a total of two keywords, where supply chain is the most frequently used keyword. Figure 10 illustrates the relationship between the keywords.

Table 6 Clusters for countries' co-authorship for publications

Cluster	*Country*	*Links*	*Documents*
1	Austria	7	4
	Belgium	6	3
	Finland	6	10
	Netherlands	5	5
	Portugal	4	4
	South Africa	7	10
	Switzerland	10	9
2	Brazil	2	5
	Denmark	3	9
	France	13	20
	Germany	7	18
	Morocco	2	5
	USA	17	46
3	Canada	5	3
	China	7	35
	Indonesia	2	13
	Malaysia	5	4
	Singapore	2	3
	Sweden	6	6
4	Greece	1	4
	India	8	13
	South Korea	3	6
	United Arab Emirates	3	4
	UK	14	27
5	Russian Federation	8	43
	Thailand	1	4
	Turkey	2	6
6	Italy	7	24
	Mexico	1	5
	Spain	8	10

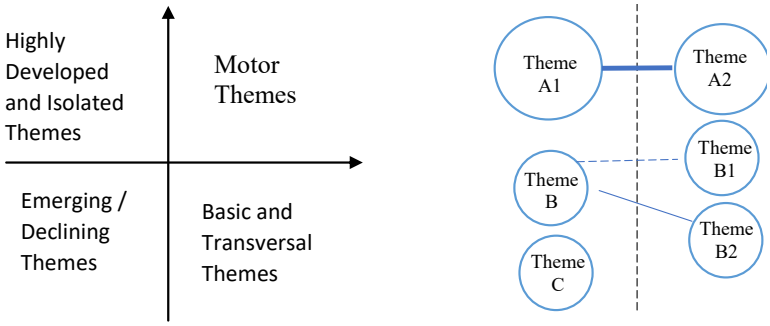
Figure 10 Bibliometric network map of keywords (see online version for colours)



6 Conceptual structure and evolution of the field

Scientists use SciMAT because of its ability to combine the advantages of classic science mapping methods with co-citation and co-word analysis (Martínez et al., 2015). SciMAT employs two ways for visualising themes: strategic diagrams and thematic networks. A strategic diagram [Figure 11(a)] is a two-dimensional graph containing density and centrality. Centrality is a metric that indicates the intrinsic relationship between themes. A high degree of centrality suggests that a theme has a robust internal relationship with other themes and is critical to the development of the research field. Density is a metric used to quantify the external links between themes. A dense pattern suggests that a concept has been well developed (Cobo et al., 2011). Essential themes are classified into four categories by a strategic diagram: motor themes (which are well-developed and critical); highly developed and isolated themes (which are well-developed but less critical); developing or declining themes (which are both weakly developed and marginal), and basic and transversal themes (critical for the discipline but not developed). Figure 11(b) depicts thematic progression. The circles represent clusters of related themes. The circle sizes correlate to the number of documents related to the themes. The straight line connecting the circles of the consecutive periods represents the inheritance link, while the dotted line represents thematic divergence. The thickness of the line is proportional to the degree of connection between the topics as defined by the specified index, and the lack of a line indicates discontinuity.

Figure 11 (a) A strategic diagram and (b) thematic evolution (see online version for colours)



(a) (b)

To more precisely investigate the scientific evolution of the digital supply chain area, eliminate data monotony, and assure cross-period comparison, the entire period (2000–2021) was divided into three sequential phases: 2000–2017, 2018–2019, and 2020–2021. The reason for an unequal periodisation lays in the fact that the research topic being contemporary has been extensively researched after 2017 with number of publications showing an extreme hype from this period (as stated earlier in Figure 2). The following summarises the significant findings for each time period. Each node's size is proportional to the number of publications (at least two) in each strategy diagram throughout the period:

1 First period (2000–2017)

As seen in Figure 12, eight important research issues concerning the digital supply chain are presented: computer-crime, cyber-crime, digital-products, decision-making, information-system, manufacture, information-technology, and digital-supply-chain. The period's motor themes, with ten, three, and four main texts demonstrating substantial centrality and density, respectively, are computer-crime, cyber-crime and digital-products. Decision-making is a well-developed and isolated theme containing three foundational publications. Information-systems, manufacture, and information-technology are all emerging or declining themes. Digital-supply-chain is a basic and transversal theme comprised of five crucial documents. During this time period, information-technology is also focusing on fundamental and transversal themes. Urciuoli et al. (2013) contributes to our understanding of how cyber risks can be used to commit supply chain crimes. As a result, the first subperiod is devoted to computer-crime and information-technology.

2 Second period (2018–2019)

Figure 13 illustrates seven of this period's digital supply chain-related themes: manufacture, technology, supply-chain-management, digital-supply-chain, industrial-research, supply-chain-strategy, and big-data-analytics. During this time span, manufacture, technology, and supply-chain-management evolved as research hotspots, with 4, 2, and 8 core documents, respectively. Industrial-research and supply-chain-strategy are two new themes with three supporting documents. Digital-supply-chain is a well-developed and isolated theme, meaning that it has

evolved but remains of minor significance during this period. Big-data-analytics is basic and transversal themes, implying significant but undeveloped themes.

The motor themes changed dramatically in the second phase, as they had in the first. A new theme arose as a motor theme in place of the previous three themes. With no question, this area of research is very active and will have a significant impact on future research.

3 Third period (2020–2021)

Figure 14 summarises 13 important research themes connected to digital supply chains over this time period. The four main themes are supply-chain-management, metadata, numerical model, and reliability. Enterprise-resource-planning is a highly developed and isolated theme. Environmental technology, industrial management, small and medium-sized business, and electronic commerce are four newly emerging or declining themes. Digitisation and knowledge-management are two basic and transversal themes. Supply-chains is shifting its focus to a motor theme throughout this time period.

Figure 12 Major themes of the first period (2000–2017) (see online version for colours)

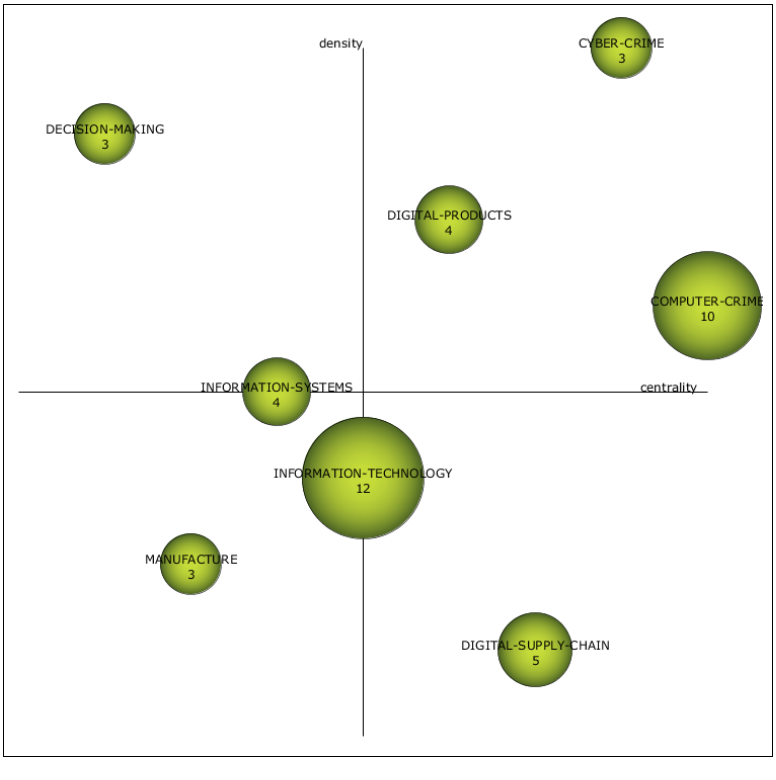


Figure 13 Major themes of the second period (2018–2019) (see online version for colours)

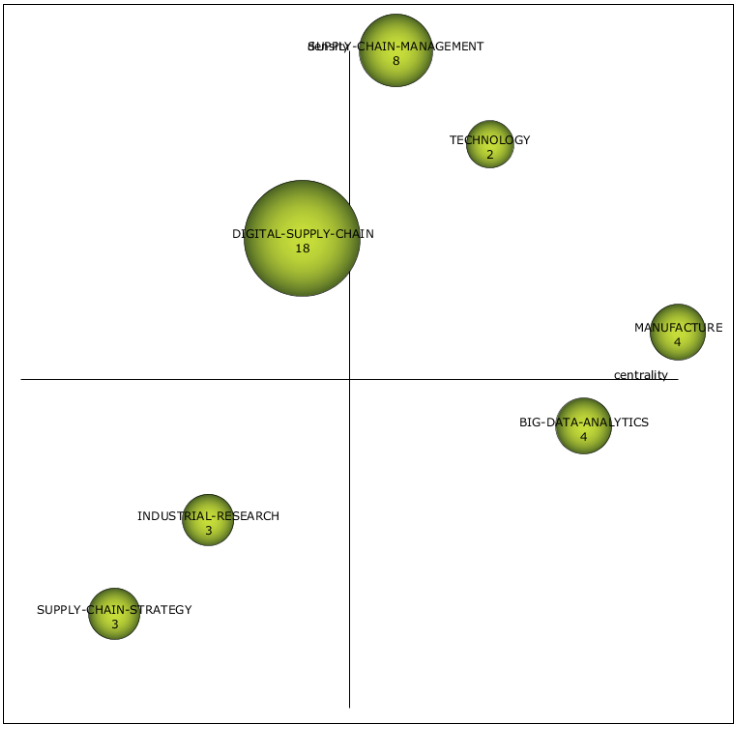
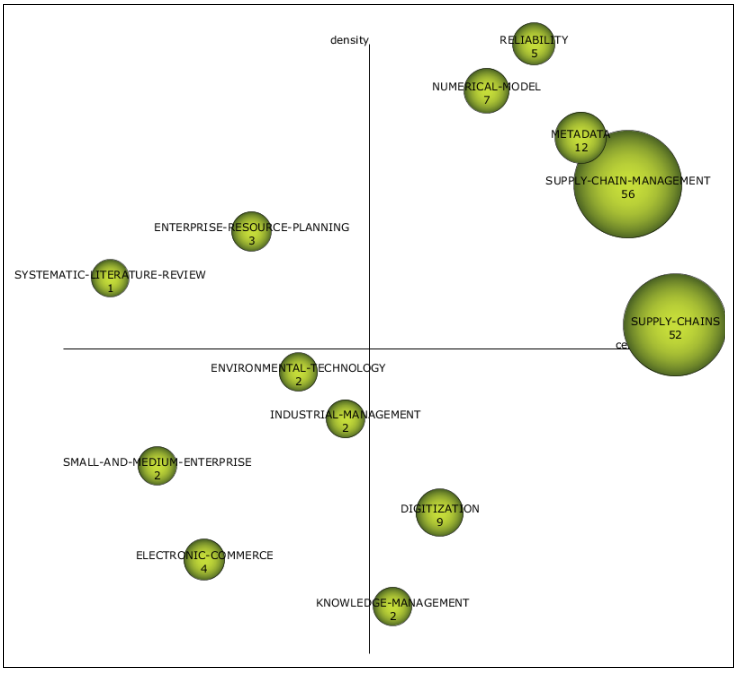
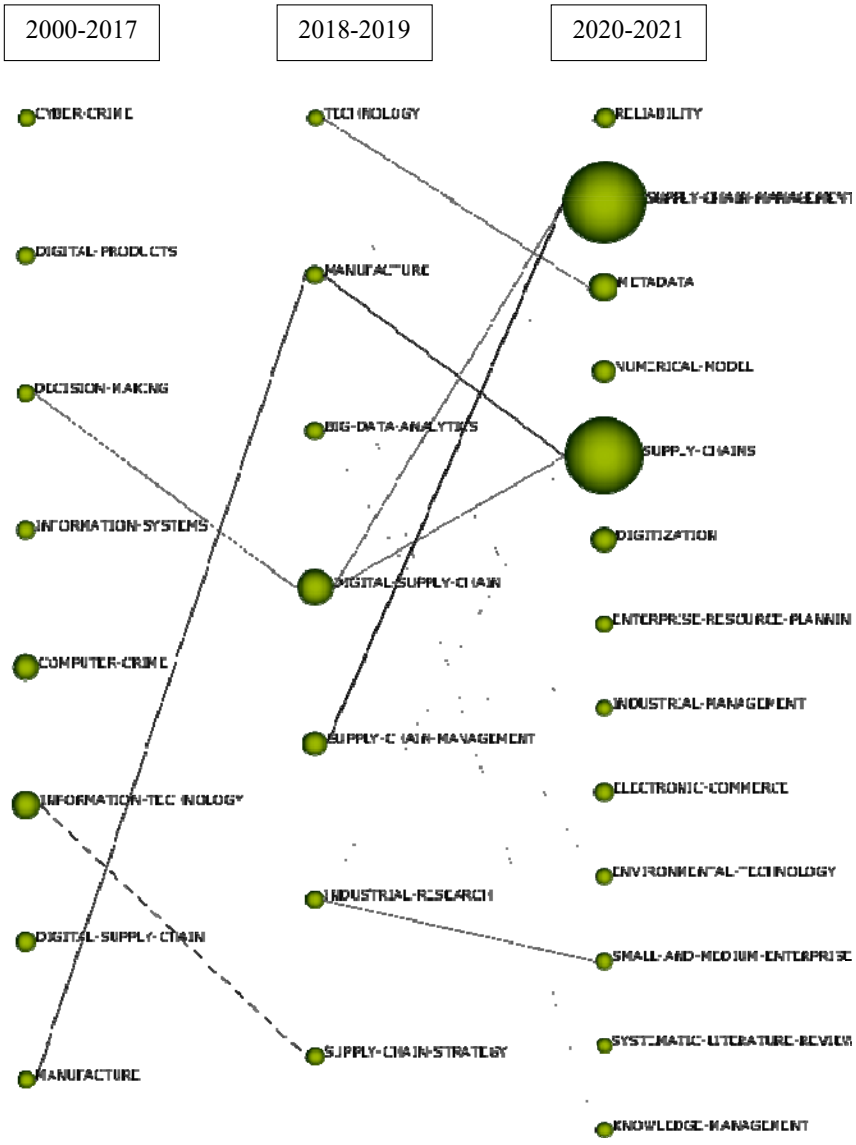


Figure 14 Major themes of the third period (2020–2021) (see online version for colours)



SciMAT was utilised in each period to generate an evolutionary analysis of the themes and their associated keywords. The evolution map (Figure 15) illustrates the field's thematic evolution during the duration of the investigation. The nodal size is proportional to the number of documents in each topic, and the connection thickness is proportional to the inclusion index, which indicates the amount to which two keywords in a topic are the same in successive periods. The solid line shows that a common theme relates the clusters, whereas the dashed line indicates that the clusters are connected by non-common theme elements. As illustrated in Figure 15, the evolution process eliminated the themes of cyber-crime, numerical model and enterprise-resource-planning.

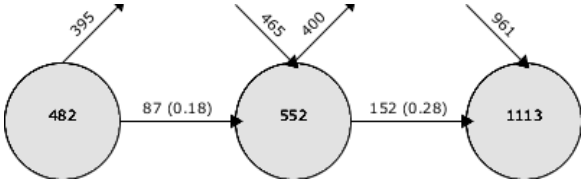
Figure 15 Evaluation map (see online version for colours)



As illustrated in Figure 15, eight research topics were identified during the first period, 2000–2017. It was a formative period in the subject, with academic publications predominantly devoted to digital products, information technology and systems, digital supply chain and manufacture. As the dominating thematic area, computer crime has primarily concentrated on issues of security and interaction with another theme from the first period. In the second period, technology and industrial research arose as a new field. The first period's manufacture theme was carried over to the second period. It is easy to distinguish between subjects with a strong connection to the first period's issues (continuous lines), such as manufacture, digital supply chain, and supply chain management. However, big data analytics and supply chain strategy exhibited weaker linkages (dotted lines) to keywords from the prior period, despite none of these being the second stage's primary themes. Finally, in the third period, 2020–2021, the number of study topics increased again, with the supply chain management theme from the previous era remaining.

Figure 16 depicts the overlay graph, which demonstrates the degree of stability between two subsequent periods. The horizontal arrow indicates the total number of terms that are shared. The number in parentheses indicates the era similarity index. The top-left arrow indicates which terms were deleted from the first era. On the other hand, the incoming arrow indicates the number of newly introduced keywords but do not apply immediately. As illustrated in Figure 16, the number of keywords has expanded dramatically over time (numbers inside the circles). This is consistent with our previous discussion of the field's intellectual basis expanding through time.

Figure 16 Overlay graph



Additionally, the number of terms shared between consecutive periods has increased from 87 to 152, showing some degree of keyword consolidation between time periods. Simultaneously, the number of themes disappearing (outward arrow) and emerging (inward arrow) is large, indicating that the field is constantly evolving. Given the digital supply chain's complexity, dynamic, and uncertain character, this is a natural development.

7 Discussion

7.1 Principal findings

This study is the first attempt to do a descriptive examination of the research activity on digital supply chains from 2000 to September 2021 – we accomplished this task through a systematic literature review in conjunction with bibliometric analysis. The study's findings were presented and examined for the five research questions.

The investigation found trends in this subject of study's publication. We discovered significant authors and periodicals through bibliometric analysis. Citations show the popularity of a field of study and the most frequently referenced articles within it. Co-citation network and content analysis indicated the most active research areas in the subject.

The SciMAT tool is used to decipher the thematic and conceptual progression of the digital supply chain. The period covered by this evaluation is from 2000 to September 2021. This was then divided into three time periods to allow for key field improvements. The first period (2000–2017) corresponds to the field's infancy and the prevalence of sectoral emphasis. The second period (2018–2019) emphasises holistic assessment methodologies. The third period (2020–May, 2021) saw increased progress toward holistic approaches to digital supply chain. The results of the bibliometric study confirm those of the science mapping exercise conducted using the SciMAT software tool.

7.2 Technology, enablers and barriers framework

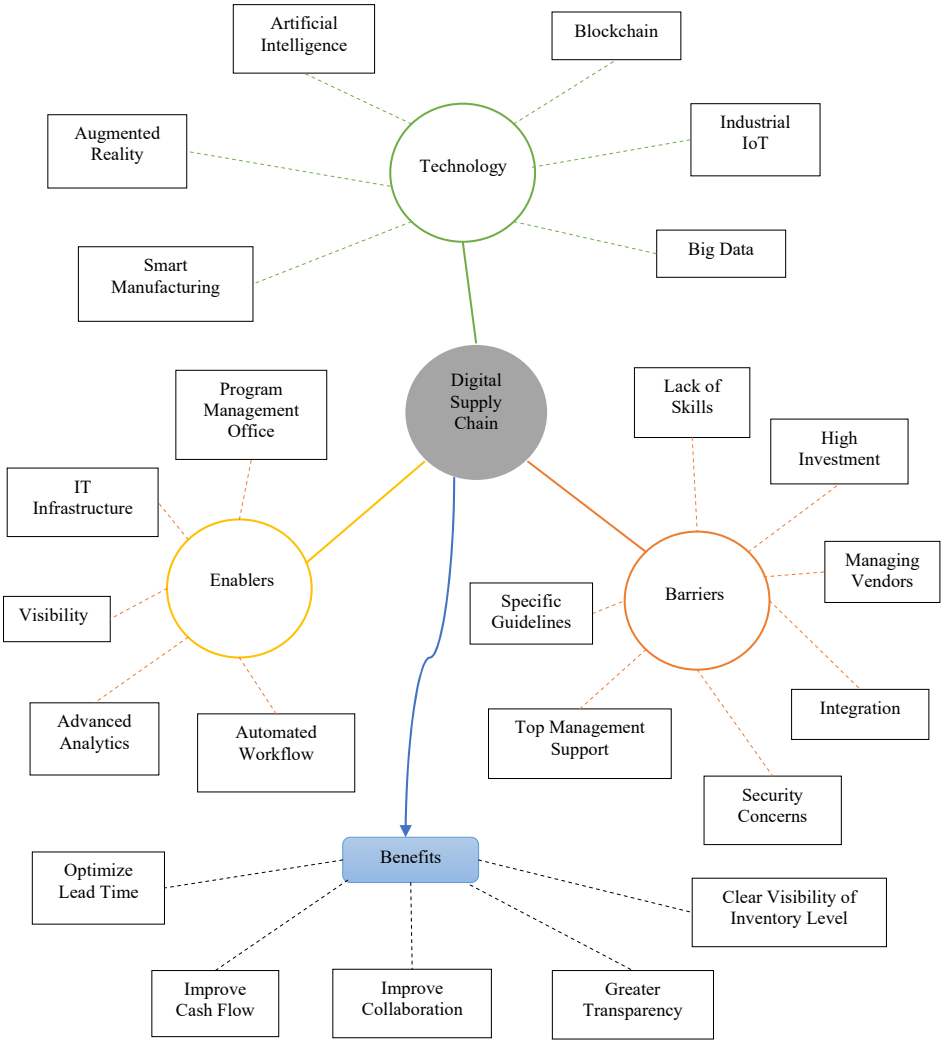
Organisations can use digitalisation to manage their supply chains in a more efficient, adaptable, and responsive manner by implementing and incorporating it (Ahmed Khan et al., 2021). Several enablers can help companies transition from traditional to digital supply chains. While digitalisation of supply chains has various advantages for businesses in all sectors, it can be a risky undertaking for companies because of operational and financial concerns that affect the performance of an organisation over time. However, digital supply chain transformation is hampered by several barriers (Agrawal et al., 2019). A framework including technology, enablers, and barriers is built and depicted in Figure 17 based on the existing research.

7.2.1 Technology

Farahani et al. (2016) assert that digital technologies are transforming practically every traditional supply chain management area. Additive manufacturing technologies have several implications for supply chains, including enhanced manufacturing flexibility, material waste reduction, and the possibility to decentralise production (Attaran, 2020). Numerous studies consider additive manufacturing a powerful technique for reducing supply chain complexity in various ways (Janssen et al., 2014). Augmented Reality combines the physical world with additional virtual information supplied via mobile devices. It consists of a collection of wearable devices and human-machine interfaces to acquire and transmit audio, visual, and tactile information. Managers may now view production plants, distribution centres, and warehouses in real-time, ensuring that processes are functioning smoothly. Artificial intelligence technologies are used in conjunction with machine learning to create intelligent sensors, edge computing, and intelligent manufacturing systems (Herz and Rauschnabel, 2019). Blockchain is a distributed ledger technology that records transactions in a series of so-called 'blocks.' The Blockchain's information is automatically updated, eliminating the need for a central entity to manipulate data. The blockchain can store information about each component, accessible to each manufacturer during the manufacturing process. Businesses may now look upstream and downstream in the supply chain using blockchain technology (O'Leary, 2017). Smart contracts may be created and executed on the blockchain, and trading partners can be made visible and efficient. One idea behind IoT is that any device

can be linked to the Internet or to another device via a network. Increased asset utilisation and uptime and improved end-to-end supply chain performance, visibility, and reliability are all benefits of it for the supply chain (Pettey, 2019). Big data has already impacted industrial operations, and numerous studies have shown how the digital revolution will have organisational ramifications in industrial practice (Gölzer and Fritzsche, 2017).

Figure 17 Framework technology, enablers, and barriers in digital supply chain (see online version for colours)



7.2.2 Enablers

Workflow automation should make it easier for a business to streamline its processes and uncover more areas to improve efficiency through automation. Whenever possible, workflows should be automated for various reasons, including faster operations and increased efficiency and accuracy (Gillis, 2019). Companies now can collect data on how

well their supply chain as a whole demonstrates a sense of social responsibility. Rather than interrupting current processes or waiting for their changes to take effect, supply chain managers may use analytics tools to ask difficult questions about operations, generate what-if scenarios, and evaluate alternative outcomes (Dubey et al., 2019). Across the entire supply chain, visibility provides real-time, secure, and accurate information on processes, orders, and systems (Cecere, 2015). In order to be successful, supply chain transformations require collaboration across a wide range of departments and functions. This includes finance as well as operations. The Program Management Office coordinates those various groups of people. In order to ensure that the transformation has the intended benefits while causing the least amount of disturbance to day-to-day operations, its primary goal is to actively support and work with top corporate leaders (Sabri, 2019).

7.2.3 Barriers

Hoberg et al. (2017) discovered a considerable digital skills gap in the workforce in their study on digital talent. The digital transition will be slowed or perhaps halted if there is a talent deficit. Because of digitisation, companies will need employees with a variety of skills related to digital technologies and solutions, as well as long-term business intelligence (Liboni et al., 2019).

To assure the availability of new digital technology, resources, a qualified workforce, and new organisational capabilities, significant investment is necessary. It is one of the most critical barriers to developing a digital supply chain (Fitzgerald et al., 2014). Digital technology can put long-standing relationships with trusted vendors to the test. Vendor relationships are likely to be more focused on innovation and customer experience than on cost savings. Advanced digital supply chain management software must interact smoothly with existing systems, such as enterprise resource planning (ERP) systems. Specific platforms may require additional time (and resources) to integrate with existing systems. Incompatibility with existing systems can impair an integrated supply chain ecosystem's operation. The adoption of digital technologies also entails concerns of cyber-attacks and data theft. The deployment of new technologies that carry unknown hazards and a lack of competence to manage those risks might deter digital process adoption. Employees, especially older ones, may resist change if top management does not support it. This is because older employees may not be familiar with the latest technology and its benefits and may be reluctant to learn about it. This mentality of employees cannot be changed unless senior management steps in Büyüközkan and Göçer (2018). Businesses cannot decide which processes in the digital supply chain to convert first, such as internal operations, customer interactions, or business models, because there are no industry-specific guidelines in place (Agrawal et al., 2019).

Numerous benefits accrue as businesses digitise their supply chain activities through modern supply chain management systems (Agrawal and Narain, 2018; Barraco, 2019). The first benefit is that lead times for raw materials can be optimised, manufacturing capacity may be reserved to ensure factory availability at the right moment, and distribution planning can be improved. The more quickly the supply chain moves, the less capital is locked up, which enhances cash flow. The collaboration will be enhanced due to data visualisation tools' ability to effect changes in both the digital and physical components of the supply chain. Efficiency increases and expenses decrease due to the automation of several inventory, ordering and scheduling operations. As the number of

manual interventions decreases, accuracy improves. Workers might focus on strategic and tactical duties rather than repeating efforts, re-entering data, and performing repetitious tasks.

7.3 Future direction for digital supply chain

- Companies with varying industrial histories have developed their own digital supply chain methodologies tailored to their specific use of novel digital technology. As a result, identifying significant trends for future research involves developing a unique roadmap for each to accelerate the digital transformation of their digital supply chain responsibilities.
- For the practical deployment of the digital supply chain in real-world industrial applications, additional modifications are needed to provide a durable, trustworthy and flexible solution.
- Additionally, the benefits and limitations of the digital supply chain can be investigated to gain a deeper understanding of the proposed framework's viability and effectiveness.
- There is a need for qualitative case studies to empirically evaluate the evolution of digital supply chains, as this can result in high-level conceptualisation and theoretical progress in the subject.
- Researchers should concentrate their efforts on under-researched areas such as the digitisation of SME supply chains and public supply networks.
- It is necessary to assess the influence of digital technologies on the benefits of the digital supply chain.
- There have been few studies that have established a relationship between the digital supply chain characteristics that influence implementation.
- Additionally, studies emphasising examining the barriers and facilitators for digital supply chain adoption have received scant attention.

7.4 Limitation of study

The study however has not conducted in-depth analysis of content available in leading papers as retrieved from the above biobliometric analysis. Thus, topic modelling and sentiment analysis is lacking in the current paper.

8 Conclusions

This report examines a substantial section of the digital supply chain's two-decade history in one comprehensive research study to understand the evolution of the research in digital supply chain. Firstly the descriptive analysis confirmed the current publishing trends in this field. Based on the available literature and output analysis, we find that digital supply chain-related research has increased tremendously in the last five years. Secondly, we examined journal contribution and influence and discovered that the

International Journal of Supply Chain Management is the field's leading contributor with 29 articles and 36 citations, followed by the *IFIP Advances in Information and Communication Technology* with 13 articles. Prockl Gis the most influential author in this field, contributing the most papers (6), according to an author-by-author analysis. Holamstrm J began publishing papers in 2014. Most of the authors with a minimum of five papers published after 2016. Germany, Turkey, and the USA are the top countries in publication volume and total citations. The capacity for scientific research in developing countries is less than in developed countries. The UK, France, the USA, and Italy have all performed admirably in international cooperative publishing relations. The Copenhagen Business School, Iowa State University and Galatasaray University are among the leading institutes publishing papers in the digital supply chain. Moreover, keyword analysis enables us to determine the primary research trends in a journal, as keywords can reflect the authors' primary areas of interest. Six clusters of 30 keywords have been finalised. Digital twin is the most frequently used keyword in cluster-1. Digital supply chain is the most frequently used keyword in cluster-2. Blockchain is the most frequently used keyword in cluster-3. Digitalisation is the most frequently used keyword in cluster-4. Industry 4.0 is the most frequently used keyword in cluster-5. Supply chain is the most frequently used keyword in cluster-6.

Thus, the current article is benefits policymakers in the journal by providing thorough information into patterns that can make new judgments or moderate or amend existing policies. The outcomes of this study will aid in answering concerns regarding the current status of digital supply chain research in academia and industry, how future advancements of the digital supply chain will appear and how the current importance of digitalisation can be integrated into the supply chain. A digital supply chain framework is also constructed based on current literature, considering technology, enablers, barriers, and benefits. Academics and practitioners can use the provided research and framework to get insight into their use of the digital supply chain. The study's approach has some shortcomings. The data for the study were extracted solely from the Scopus database. The specifics examined in the articles (keyword, summary) are limited. Comprehensive results can be acquired by conducting in-depth reviews of the subject's literature.

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