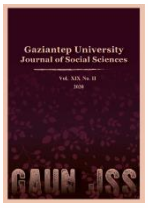

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Araştırma Makalesi ● Research Article

From EDI to Blockchain: A Bibliometric Analysis of Digitalization in Supply Chains

EDI'den Blok Zincir'e: Tedarik Zincirlerinde Dijitalleşmenin Bibliyometrik Bir Analizi

Şemsettin ÇİĞDEM[a]*

[a] Dr. Öğretim Üyesi, Gaziantep Üniversitesi İ.İ.B.F. Uluslararası Ticaret ve Lojistik Bölümü, Gaziantep / TÜRKİYE
ORCID: 0000-0001-9102-8153

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ÖZ

Dijital teknolojilerin işletme süreçlerine dahil edilmeye başlanması yaklaşık yarım yüzyılı aşan bir geçmişe sahiptir. Tedarik zincirinde bu entegrasyonun kökenleri 2000'lere dayansa da işletmelerin 1970'lerde teknolojinin imkanlarından yararlanmaya başladıkları bilinmektedir. 1990'larda ERP'nin ortaya çıkışı tedarik zinciri açısından yeni bir dönemin başlangıcını temsil etmektedir. Artan rekabet ve sürdürülebilirlik baskısı işletmeleri, çevresel koşullara cevap verme konusunda tek başlarına yeterli olmaktan uzak hale getirmiştir. Bu durum etkin tedarik zincirleri oluşturmayı işletmeler açısından zorunlu kılmıştır. Etkin tedarik zincirlerinin temelinde; tedarik zincirindeki akışların gerçek zamanlı izlenebilmesi dolayısı ile olası sorunlara zamanında müdahale edilebilmesi yatmaktadır. Günümüzde işletmeler nesnelerin interneti teknolojisini işletme süreçlerine entegre ederek büyük miktarda veriyi elde edebilmekte, elde ettikleri veriyi bulut bilişim teknolojisi ile bu veriyi daha efektif saklayabilmekte ve aktarabilmekte, büyük veri analitiği ile kapsamlı analizler gerçekleştirebilmekte ve işletme hedeflerine yönelik olarak faydalı çıktılar sağlayabilmektedir. Özellikle son birkaç yılda blockchain'in sağladığı imkanlar ön plana çıkmış ve işletmeler tedarik zincirine bu teknolojiyi entegre ederek kazanım elde etmenin yollarını aramaya başlamışlardır. Dijital teknolojideki bu dramatik değişim tedarik zinciri literatürünün bu konuyla ilgili ne konumda olduğunu araştırma ihtiyacı doğurmuştur.
Bu araştırmada tedarik zincirindeki dijital dönüşümü konu edinen ve Web of Science'ta yayımlanmış çalışmaların bibliyometrik analizi aracılığı ile alandaki akademik duruma ilişkin birtakım bulgulara ulaşılmıştır. Alanda etkin aktörler (yazarlar, kurumlar, ülkeler vb.) tespit edilerek, alana yaptıkları katkılar ortaya konulmaya çalışılmıştır. İlgili çalışmalarda kullanılan terimlerin içerik analizi ile kavramların zaman içerisinde sergiledikleri gelişim ve etkileşimlerde araştırma bulguları arasındadır. Bu çalışma vasıtasıyla hem alanın genel bir görüngüsü hem de gelecekte alması olası yönlere ilişkin çeşitli öngörüler sağlanmıştır.

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ABSTRACT

The integration of digital technologies into business processes has a history of more than half a century. With the integration of technologies in the supply chain, businesses began benefiting from the possibilities as early as the 1970s. The emergence of ERP in the 1990s represents the beginning of a new era of the supply chain. Increasing competition and sustainability pressure have done businesses far from being sufficient on their own to respond to environmental conditions. This situation has made it necessary for companies to establish efficient supply chains. One of the main elements that ensure the efficiency of supply chains is that the flows in the supply chain can be monitored in real-time, and the problems that may arise can be intervened on time. Nowadays, businesses can obtain large amounts of data by integrating the Internet of Things technology into their business processes, can store and transfer this data more effectively with cloud computing technology, and can provide useful outputs for business goals with big data analytics. Especially in the last few years, blockchain opportunities have become more prominent. Businesses have begun to look for ways to gain gains by integrating this technology into the supply chain.
In this study, the current academic situation in supply chain management has been revealed by the bibliometric analysis of studies published on the Web of Science. Important actors in the field were identified, and their primary contributions to the field were revealed. Content analysis of the terms used in related studies and the development and interactions of the concepts over time are among the research findings. Through this study, both a general phenomenon of the field and various predictions regarding the future directions it will take are provided.

* *Sorumlu yazar/Corresponding author*.
e-posta: scigdem@gantep.edu.tr

Introduction

The development in information and communication technologies has changed people's view of life. While two individuals can barely communicate with their writing on a piece of paper before, today we are witnessing a technological transformation that gives objects the ability to communicate with us. The introduction of personal computers into our lives, namely the proliferation of digitalization, has accelerated this dizzying transformation. Today, we live in a cyber world where smartphones, driverless cars, wearable smart devices, and many other objects are connected. With the possibilities that this cyber world provides us, we can access large amounts of data. We can store and spread the data we reach in a way that we have not thought about until now. So, to mean that, we render life every day more digital and visible and interpretable.

Since this digital transformation has profoundly affected the entire human life, there is no question that the industry will not be affected by this change. Supply chains are no exception in this regard. Digitalization, in supply chain operations, involves utilizing digital technology to bring innovations into supply chain operations and receive digital outputs (products and services). Companies are moving to take advantage of new digitalization approaches to adapt to the rapidly changing environment of technology and incorporate digital technologies into production and procurement processes to reduce costs, improve customer service, and improve delivery performance and reliability (Daneshvar Kakhki, & Gargeya, 2019, p. 5318). Manufacturers to suppliers, contractors to shippers, are intertwined in real online networks within supply chains' scope. Now the boundaries between businesses have primarily disappeared, and there is the transparency of joint activities. Today, the products are designed entirely according to customer requirements and can quickly bring new products to market using advanced forecasting and planning methods (Boiko, Shendryk, & Boiko, 2019, p. 67).

Description of the supply chain; "including suppliers, logistics service providers, manufacturers, distributors and retailers to meet customers' needs; among them is a set of elements with a flow of products, information and funds (Tripathi, & Gupta, 2019, p. 2)". Supply chain management will naturally be efficient management of these elements and continuous flows between the components. Therefore, we can briefly sort the supply chain as flows (information flow, product flow, fund flow) between the supply chain parties. Digitalization in supply chains can also integrate digital technologies into supply chain processes to perform these functions more effectively. Because firms use digital technologies to strengthen the flow of information (Raab, & Griffin-Cryan, 2011), to support fund flows through software, hardware, and communication networks (Bhargava, Ranchal, & Othmane, 2013, p. 1637), and to make products and services more valuable (Agrawal, & Narain, 2018, p. 5). Thus, they establish a more robust collaboration and effective communication between chain links. In other words, the digital supply chain is a new process that benefits from digital technological transformation to create a competitive advantage. Digital transformation brings many possibilities for companies. From barcode technology, RFID, and several other sensors to the modern management strategy that comes with ERP, many instruments provide companies with a strategic edge by helping firms rebound from high intense market pressure (Gunasekaran, Subramanian, & Papadopoulos 2017). Companies can create a cyber environment thanks to programming, learning, transmitting, addressing, and, most importantly, associating digital technologies with objects. Digital technologies can ensure that supply chains are fast, flexible, transparent, cost-effective, scalable, and innovative (Göçer, 2018, pp. 5-6).

Digital transformation is a process that supply chains use to benefit and a situation where businesses cannot avoid adaptation to ensure sustainability. Digitalization is a paradigm shift

and has changed many things from product to process and strategic approaches (Ben-Daya, Hassini,, & Bahroun., 2019; Hofmann et al., 2019). Supply chains also had to adapt to the digital dominant variable environment to survive. Digital technologies have buoyed the cost in supply chains in the methods used to deal with challenges such as supply chain visibility, risk management, increasing and changing customer demands, and globalization (Butner, 2010, p. 23). For example, digital technology is a handy tool (Swaminathan, & Tayur, 2003) to act together against market risks for companies and improve cooperation to increase supply chain visibility. Also, changing and growing customer demands are a significant problem for firms. Companies are increasing supply chain collaboration using information technologies to deal with this problem (Bongsug, HsiuJu Rebecca, & Chwen, 2005) and overcome the uncertainty that may occur using new analytical methods (Hofmann, & Rutschmann, 2018).

In this study, a general map of the digital transformation in supply chains in academic writing was tried to be revealed. The purpose of developing this map is to recognize current trends of study on the topic, identify shortcomings, and make some suggestions. In this context, the questions that the research is looking for answers are as follows:

- What is the direction of digital transformation in supply chains over time?
- How have academic studies on digitalization in supply chains have changed?

Within the study's scope, a bibliometric analysis was performed on articles on the subject in the Web of Science database published between 1991 and 2021. The research is conducted only on the Web of Science database because both academically top-level publications are in this database, and the database is accessible to everyone. The publication year interval is divided into three periods to see the subject's direction over time in more detail. By examining the distribution of digital transformation in supply chains by time, countries, institutes, and publishers, effective actors related to the subject were identified. Also, as a result of analyzing the keywords, time-related development was revealed, and the subject's missing points were emphasized.

In the ongoing part of the study, the literature on digitalization in supply chains is included. Then there is the methodology and findings section. In the last chapter, the outputs, restrictions, and recommendations obtained from the research are discussed.

Literature Review: A Brief History of Digitalization in Supply Chains

The 1990s are generally considered to be more intensive efforts regarding integrating digital technologies into company processes. Perhaps what is expressed here may be mass awareness and a collective transition rather than definitive start date. Since the 1970s, companies have been using digital technologies to improve their processes and improve their performance (Jacobs, & Wetson, 2007).

In America of the 1960s, requirements such as reducing costs, effective inventory management, and better information flow remained severe for companies. These problems could be solved with information and communication technologies that allowed electronic data exchange (EDI) technology to be developed and used. In 1965, the first EDI message was sent by telex. Many factors make EDI attractive to companies. We can examine these factors in two basic categories; First, EDI provides faster and more consistent information flow. It improves the communication infrastructure between companies to design their processes more effectively (Chopra, & Meindl, 2016, p. 66). Secondly, EDI reduces order completion time, increases deployment flexibility, and provides quick solutions to problems in the distribution process, thereby improving customer service quality (Hansen, & Hill, 1989, p. 404). In 1973, the file transfer protocol (FTP) development took the process to a whole new level. By 1991, almost 12,000 firms in America were using EDI (McCarthy, 2013).

By the 1990s, the ERP revolution had taken place. This revolution has increased the interest of companies in information technologies. The history of digital technology development in the operating processes is a bit of ERP's development history. In the 1960s, it is known that many businesses designed, developed, and implemented computing systems to meet their own needs. Businesses first tried to create some inventory control software using programming languages such as Cobol, Algol, and Fortran (Rashid, Hossain, & Patrick 2002, p. 17). The initial integration of digital technologies into the operating processes was with the emergence of the Material Requirement Planning (MRP) system. The MRP was developed to calculate and plan the materials and time needed in the production line (Klaus et al., 2000, p. 144) more efficiently. Advances in hardware and software in the 1970s brought with it the development of MRP, and by the 1980s, the Manufacturing Resource Planning (MRP II) system was born. The MRP II system increased visibility in operations, allowing both material and capacity calculations, allowing detailed activities to be entered into the system, and converting all activities into financial statements. With all this, the MRP II system remained only internal and could not become a system that communicated with the external environment (Ptak, & Schragenheim, 2003, p. 7). With the emergence of the Enterprise Resource Planning (ERP) system in the 1990s, a new era of firms' opportunities and challenges began. With ERP, all operating functions from production management to human resources, finance to inventory control were tried to be gathered in one center. The system is an application for the company to be in full communication with both internal (inter-departmental communication) and its external environment (Jacobs, & Wetson, 2007, p. 361).

Since the 2000s, cyber-physical systems, RFID, the Internet of Things, big data, 3D printers, augmented reality, blockchain technology, cloud computing, and many other technological components have been involved in supply chains and created new business models. The processes carried out mainly by supply chain management, such as financial transactions, communication, management understanding, and information exchange (Daneshvar Kakhki, & Gargeya, 2019), have changed quite a lot to these technologies. For example, Internet of Things technology has radically changed supply chains' structure (Ben-Daya et al., 2019, p. 4719). Thanks to the Internet of Things, products have gained features that allow communication from person to object, which has made it easier for companies to deal with supply chain visibility and agility problems (Elli, Morris, & Santagate, 2015).

Along with internet of things technology, another pillar of digitalization is cyber-physical systems. In cyber-physical systems, networks are created where objects communicate with each other digitally. Real-time process control can be carried out due to finding, detecting, identifying objects in these networks and collecting and analyzing the data obtained (Hermann et al., 2016, p. 3934). In supply chains today, errors in estimations can be reduced by providing better visibility with RFID technology, and thus inventory optimization can be achieved (Lee, & Özer, 2007, pp. 41-42). Thanks to 3D printers, it can quickly produce low-cost customizable products (Schwab, 2017, p. 153). Thanks to the augmented reality technology, processes can be simulated and optimized (Eli, Gnoni, & Lanzilotto., 2016, p. 187).

When another of the current consequences of digital technologies, big data, will be addressed. As a result of the widespread use of digital technologies, many businesses are trying to develop and use big data analytics capabilities (Davenport, 2014, p. 9) to gain value from increasingly large amounts of data and turn it into a competitive advantage (Wang et al., 2011, p. 99). At this point, supply chains are supported by data collected by advanced network technologies such as sensors, NFC tags, and other smart devices that collect data in real-time. In the current literature, big data analytics is defined as a technological-efficient ability that can

help process large volumes, high-speed and diverse types of data to achieve meaningful and useful insights (Fosso Wamba, Gunasekaran, Papadopoulos, & Ngai, 2018, p. 478).

Especially in the last few years, blockchain possibilities have come to the forefront more. Businesses have started to look for ways to gain benefits by integrating this technology into the supply chain. Blockchain technology can be primarily discussed in the literature to solve supply chain traceability, process automation, and data security problems. Also, researches focused on the possible benefits of blockchain technology in labor-intensive functions such as transportation operations, billing processes, and inventory management (Musigmann, von der Gracht, & Hartmann, 2020, p. 2). As a result of increasing supply chain traceability, it is emphasized as one of the advantages of blockchain technology that it reduces costs by optimizing information flows. Blockchain technology does these benefits by increasing information sharing and ensuring the security of shared information. Besides, blockchain technology can create more secure supply chains by supporting the weaknesses of other industry 4.0 components (internet of things, cyber-physical systems) (Queiroz, Telles, & Bonilla., 2019).

There are numerous articles in the literature examining the digital transformation in supply chains. The oldest of these publications is from 1984. It is expected that many studies have been carried out on the subject in the past 37 years. Within the scope of the study, 17,856 publications were detected in the query conducted in the Web of Science database only. This amount reveals the importance of the issue. Additional inquiries and manual examinations were carried out on the data set obtained, and studies involving literature reviews and bibliometric analysis on the subject were determined. 115 studies examining the effects of digital technologies have been identified in the supply chain. 76 of these studies were literature reviews that did not include bibliometric analysis, and 39 of them were studies that resulted in the bibliometric analysis.

Table 1: Literature Reviews on Digital Technologies in Supply Chains

Literature Reviews	**N**
Digitalization in Supply Chains and Industry 4.0	16
Big Data – Data Analytics	10
Internet of Things and Connected Technologies (RFID, ...)	9
Additive Manufacturing	3
Blockchain	4
ERP	5
Others (e-commerce, web services, ...)	29
Bibliometric Studies	
Digitalization in Supply Chains and Industry 4.0	8
Big Data – Data Analytics	8
Internet of Things and Connected Technologies (RFID, ...)	4
Additive Manufacturing	1
Blockchain	3
Others (e-commerce, web services, ...)	15

As seen on Table 1., literature reviews of digital technologies in the Web of Science database of supply chains mostly focus on a specific digital technology. Industry 4.0 is an inclusive concept that expresses technological transformation in the classification; it is discussed with supply chain digitization. It has been seen that 24 of the 115 studies examined the digitalization process totally, and only 8 of them used bibliometric methods. In the examination, four studies that may be similar to this study were determined. These studies are

carried out by Seyedghorban, Tahernejad, Meriton, & Graham (2020), Zekhnini, Cherrafi, Bouhaddou, Benghabrit, & Garza-Reyes (2020), Dhamija, Bedi, & Gupta (2020), and Borregan-Alvarado, Alvarez-Meaza, Cilleruelo-Carrasco, & Garechana-Anacabe (2020). These studies are usually documentation of the studies in the field.

This study is similar to other studies mentioned above but differs from others in data set creation, analysis method, and outputs. For example, when obtaining the data set in this study, the query was not performed in a single category in the Web of Science database, but the entire database was scanned. Also, query fields (title, keyword, abstract) are differentiated. Besides, a useful classification was attempted to map and evaluate the studies to give recommendations for the field's future, and a time-based approach was taken in this process.

Methodology

In this study, a bibliometric analysis of 8036 articles published in the Web of Science Core Collection on digitalization in supply chains between 1991 and 2021 was conducted. The Bibliometrics package (Aria, & Cuccurullo, 2017) of the R software was used to analyze and visualize the data. Although many different tools can be used in the bibliometric analysis, R program packages containing most of the analysis needed, and the success of these packages in visualization can also be shown as a reason for their use in this research. Also, Jon Kleinberg's burst detection algorithm was used in burst detection analysis.

The study's findings include the distribution of publications in the data set by years, countries, universities, and journals, thematic evolution map of keywords in the data set. Besides, the citation levels of these publications by year and their contributions to the relevant literature, the journals' impact levels, and the countries' citation levels are also given in the study's findings section.

Data collection and Preprocessing

The data collection process consists of four stages. As a result of the literature review conducted in the first stage, keywords expressing digitalization were determined, and a database query was performed with these words. The query code for determining articles written in related topics is as follows, and the query stages are shown in table 2.

(TS= ("EDI" OR "electronic data interchange" OR "digit" OR "smart" OR "omni channel" OR "augmented realit*" OR "additive manufactur*" OR "industry 4.0" OR "cloud" OR "internet of things" OR "IoT" OR "RFID" OR "radio frequency" OR "information technolog*" OR "information system*" OR "communication technolog*" OR "mobile technolog*" OR "blockchain "OR "sensor" OR "robot*" OR "analytic*") AND (TI=("supply chain*" OR "SCM" OR "logistics") OR AK=("supply chain*" OR "SCM" OR "logistics") OR KP=("supply chain*" OR "SCM" OR "logistics")) NOT (TI = ("literature review" OR "bibliometric*") OR KP = ("literature review" OR "bibliometric*") OR AK = ("literature review" OR "bibliometric*"))) AND DOCUMENT TYPES: (Article OR Early Access)*

Table 2: Data Collecting Stages

1. Stage: database query Result:2,122,384 articles	**Keywords:** - EDI - electronic data interchange - digit* - smart - omnichannel - augmented reality* - additive manufactur* - industry 4.0 - cloud - internet of things - IoT - RFID - radio frequency - information technology* - information system* - communication technology* - mobile technology* - blockchain - sensor* - robot* - analytic*
2. Stage: filtering the database (extraction of publications that are not related to the supply chain) Result: 8712 articles	**Exclusion criteria:** (title, keyword, keyword plus) - supply chain* - SCM - logistics
3. Stage: 2. Layer filtering (removal of literature review and studies involving bibliometric analysis) Result: 8597 articles	**Exclusion criteria:** (title, keyword, keyword plus) - literature review - bibliometric*
4. Stage: Removing studies with missing data from the data set Result: 8036 articles	**Exclusion criteria:** - No date information - No keywords

In the first stage, the database query was performed with the keywords given in the table. As a result of the query, 2,122,384 articles were reached.

In the second stage, it is ensured that the articles reached are related to the research subject. For this purpose, studies that include the keywords "supply chain*", "SCM", and "logistics" in the study title, author keywords, and keywords plus have been queried again. The first stage result was filtered with the result from the second query. As a result of exclusion, the number of articles was reduced to 8712.

In the third stage, studies with the words "literature review" and "bibliometric*" were questioned in the study title, author keywords, and keywords plus. As a result of exclusion, the number of articles was reduced to 8597.

At the last stage, 561 publications that did not meet the analysis criteria were excluded, and a data set consisting of 8036 articles was obtained.

The resulting data set has been reviewed in detail during the data preprocessing phase and ready for analysis. At this stage, some corrections were made regarding keywords. For example, keywords such as "RFID", "RFID-technology", "radio frequency identification", "radio frequency identification technology", "radio-frequency identification technology", "IOT", "internet of things", "internet of things technology" are combined in one keyword that will express the concept. The keywords "supply chain management", "SCM", and "logistics" which were used in the second phase of the database query to ensure the relevancy of publication, were excluded from the analysis. The purpose of removing these words is that they can overshadow other concepts in the analysis. Thus, it is aimed to focus directly on the concepts related to digitalization in supply chains.

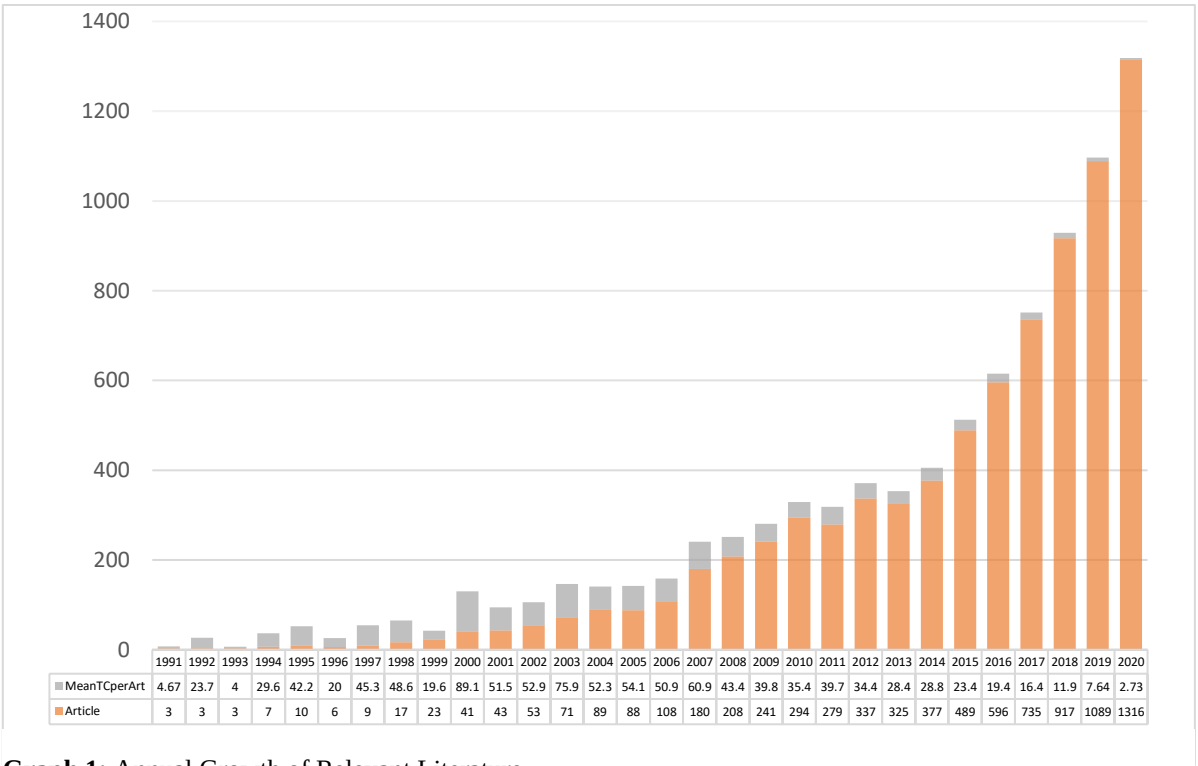
Findings

Bibliometric analysis carried out within the scope of this study covers publications between 1991:2021. The data set consists of 8036 articles. 15126 authors wrote these articles. The number of single-authored articles is 806, which shows that two and more authors wrote 7230 articles.

Table 3. Main Information About Publications

Timespan	1991:2021
Documents	8036
Authors	15126
Single-authored documents	806
Documents per Author	0.531
Authors per Document	1.88
Co-Authors per Documents	3.13
Total Citations	172131
Collaboration Index	2

On Graph 1., the averages of the articles examining digitalization in supply chains and the citations they receive are distributed by year. The orange part of each column in the column chart shows the number of publications made in that year, and the gray part shows the average number of citations per article in that year. Since 1999, both the number of articles and citations related to the subject has increased. The integration of digital technologies into business processes dates back much older. However, the fact that publications were relatively small before 1999 to after this year may be since supply chain processes began to be seen as an area separated from other operating processes since the early 2000s.

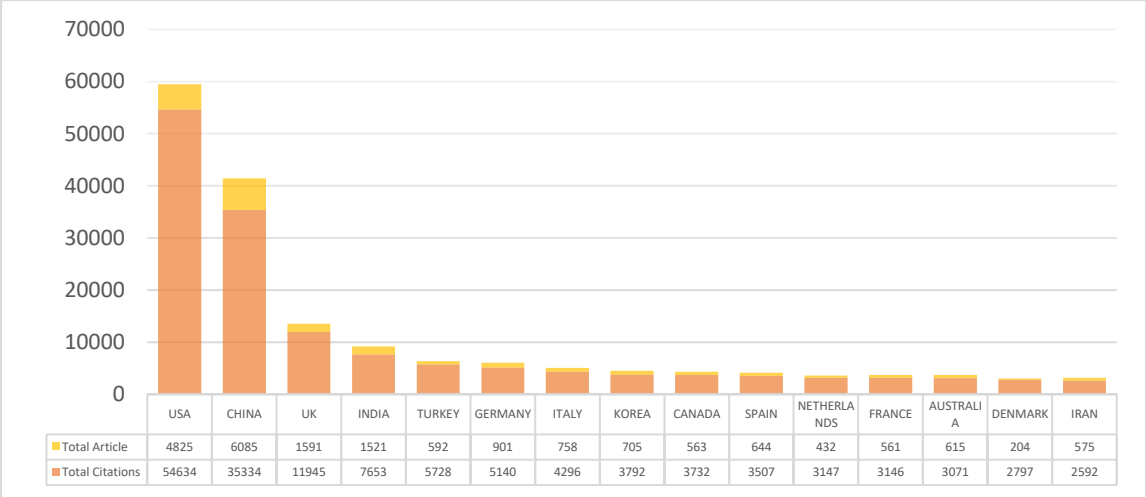


	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
MeanTCperArt	4.67	23.7	4	29.6	42.2	20	45.3	48.6	19.6	89.1	51.5	52.9	75.9	52.3	54.1	50.9	60.9	43.4	39.8	35.4	39.7	34.4	28.4	28.8	23.4	19.4	16.4	11.9	7.64	2.73
Article	3	3	3	7	10	6	9	17	23	41	43	53	71	89	88	108	180	208	241	294	279	337	325	377	489	596	735	917	1089	1316

Graph 1: Annual Growth of Relevant Literature

Countries and Institutes

When the results related to countries are examined, it is seen that China is the country that contributes the most to the publications made. Then comes the UNITED States, Britain,



	USA	CHINA	UK	INDIA	TURKEY	GERMANY	ITALY	KOREA	CANADA	SPAIN	NETHERLANDS	FRANCE	AUSTRALIA	DENMARK	IRAN
Total Article	4825	6085	1591	1521	592	901	758	705	563	644	432	561	615	204	575
Total Citations	54634	35334	11945	7653	5728	5140	4296	3792	3732	3507	3147	3146	3071	2797	2592

Graph 2: Top 15 Countries

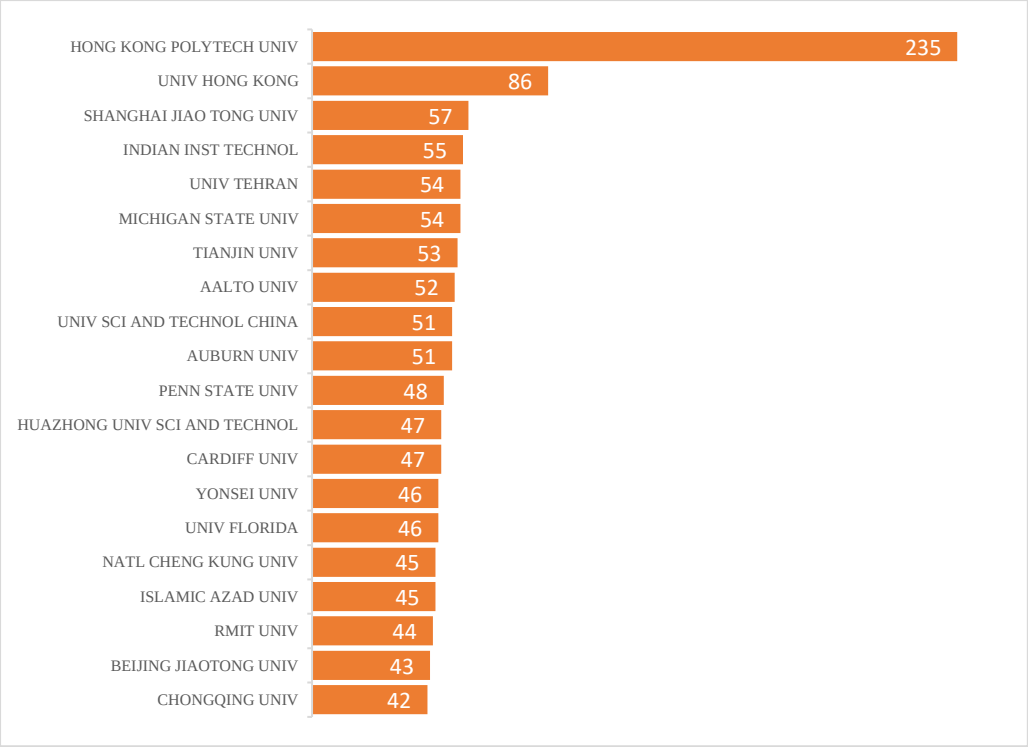
India, and Turkey, respectively. However, when the number of citations to publications is compared, references to the publications of U.S. authors come first. So, we can interpret the U.S. as being more academically effective. Country-based contributions to field are seen on Graph 2.

University-based contributions to publications are seen on Graph 3. When the chart is examined, it is seen that the most active university on the subject in Hong Kong Polytech University. According to the top 10 university rankings, Chinese and U.S. universities are ranked high. However, Tehran University, Islamic Azad University (Iran), and Cardiff University (U.K.) are also active universities in this field.

The first examples of the integration of digital technologies into business processes have emerged in the USA. Since it is not conceivable that the academic community will be disconnected from the market, the United States' academic premise on the subject is understandable. Over the years, businesses in other countries have not been indifferent to the issue and have used digital technologies to adapt to the changing environment. According to the results, it can be said that over time, awareness on a country-by-country basis and the importance given to the subject increased more in China than in other countries.

Journal Statistics

In terms of revealing the development of an academic field, it is required to examine the status of academic journals published in that field. The impact of a publication in the field is influenced not only by its subject and its authors but also by the publisher's qualifications and position in the field (Kim et al., 2020). Table 4 shows the number of publications, h-indexes, and citations of the first 15 journals. According to the current parameters, the two most active journals in the field are "International Journal of Production Economics" and "International Journal of Production Research", respectively. These two journals are followed by "European



Graph 3: Top 20 Universities

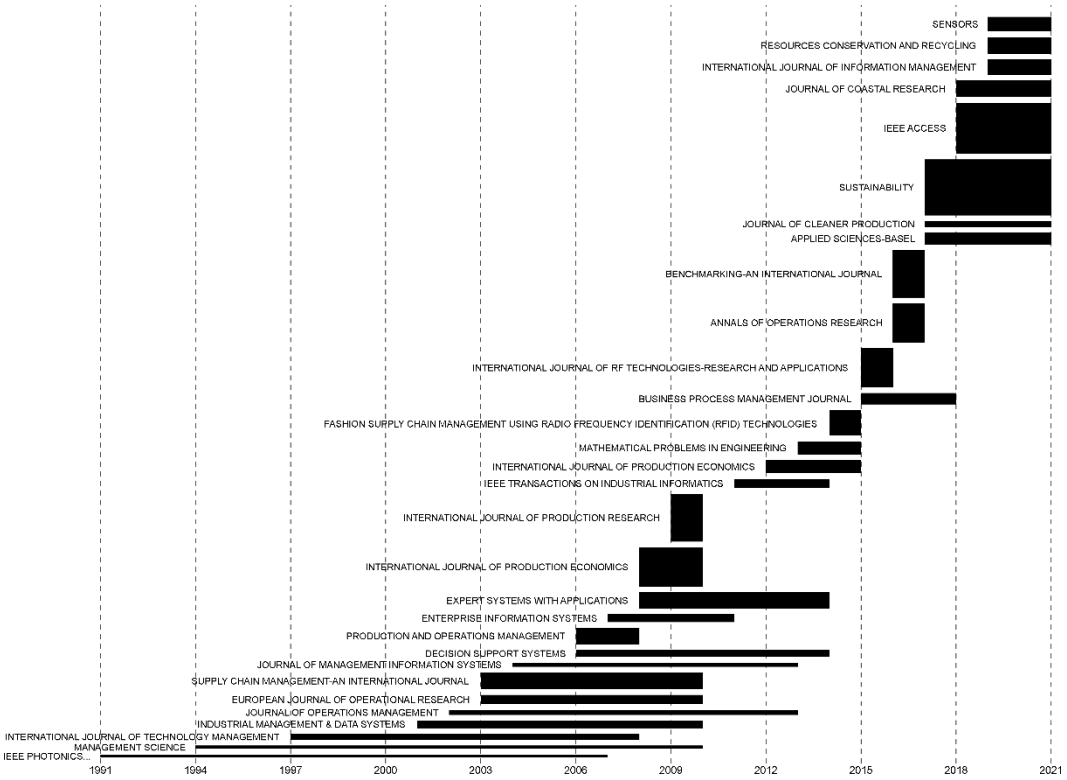
Journal of Operational Research". Although the journals "Journal of Cleaner Production" and "Sustainability" have more publications and appear higher in the ranking in the table, "European Journal of Operational Research" has a higher number of citations and a score of h-index.

Table 4: Top 15 Journals

Journal	h_index	Cit	Pub.
International Journal of Production Economics	71	17399	398
International Journal of Production Research	47	8738	294
Sustainability	19	1483	242
Journal of Cleaner Production	45	7322	213
European Journal of Operational Research	46	7376	204
Computers, & Industrial Engineering	32	4102	160
Industrial Management, & Data Systems	29	3350	147
Production Planning, & Control	31	2982	132
Supply Chain Management an International Journal	41	5342	121
Expert Systems with Applications	40	4622	102
Transportation Research Part E-Logistics and Transportation Review	38	4137	101
International Journal of Physical Distribution, & Logistics Management	30	2422	95
Ieee Access	10	513	91
International Journal of Logistics Management	24	1816	91
International Journal of Operations, & Production Management	33	2853	78

The table shows the total performance of journals for 30 years. While some journals have lost their efficiency last time, early inactive journals must become efficient later. The frequent publications of journals affect the number of publications on the subject. This situation may cause the cumulative results that later began the journal's publication life to move up to the top. On the contrary, a journal that started its publishing life earlier may have published a lot on the subject in the early stages, and therefore its cumulative scores may be high. When a more detailed and time-based analysis is performed, it is possible to encounter a different

picture. For this purpose, a second analysis was performed using the burst detection algorithm developed by Jon Kleinberg. The Burst detection algorithm is an algorithm designed to uncover activities that intensify or decrease over time (Kleinberg, 2003). With this algorithm, the journals' publications on the subject were analyzed according to a specific period. As a result of the analysis, journals focusing on specific periods in the field are shown on Graph 4. In the chart, the horizontal axis represents time, and the black horizontal bars on the vertical axis show the effect sizes of the journals. The elongation of black horizontal bars means that the journal is more effective in the period, and its thickening shows the effect increases.



Graph 4: Journal Bursts by Year

The results in the chart will also contribute to a more accurate interpretation of Table 4. As shown in the chart, there is no absolute effectiveness of a single journal during the time covered by the data set. The effect of "International Journal of Production Economics" ranked first in Table 4. was between 2012 and 2015. Likewise, "International Journal of Production Research" was influential between 2009 and 2010, "Journal of Cleaner Production" was influential between 2017 and 2021, "European Journal of Operational Research" was influential between 2003 and 2010, and "Sustainability" was influential between 2017 and 2021. When the number of articles and citations of "International Journal of Production Economics" is analyzed, it can be seen that the journal has a broad and important influence on the topic during the three years.

Keyword Analysis

Keywords are the most basic relevant element that can give an idea about the content of an article, and they are a summary of the main subject of the article. Several different focus points are used for content extraction during the bibliometric analysis of publications in a

particular area. The publication itself, its summary, or keywords can be counted among these focal points. In this study, keywords were chosen as the focal point to monitor the subject's evolution over time because keywords require much fewer data preprocessing. It is also challenging to make meaningful double and triple word groups in full text or summary analysis. For example, it is a problem for a language processing algorithm to perceive the expressions "supply chain" and "supply chain management" as separate statements with high consistency in a given text. Instead, the algorithm will probably separate all the blocks it sees "supply chain" when asked to do binary grouping, and the term "management" will appear as a different concept. There is no need to distinguish keywords, and the concepts to be reached can be obtained with very high consistency.

The 22 most frequently repeated words in publications are given in Table 5. Accordingly, the word with the highest frequency of observation is "rfid". Then the words "iot" and "blockchain" come respectively. When the frequencies are taken into consideration, it is seen that the most frequently repeated keywords are mostly current concepts that could be caused by the increase in publications over time. More detailed results will be discussed in other analyzes on keywords.

Table 5. Most Frequent Words

Words	Occurrences	Words	Occurrences
RFID	591	simulation	147
iot	286	anp	142
blockchain	263	e-commerce	131
sustainability	248	game theory	123
big data	241	collaboration	117
information technology	197	system	117
industry40	187	optimization	116
inventory management	175	information sharing	113
information system	174	risk management	110
integration	167	performance	108
coordination	166	supplier selection	107

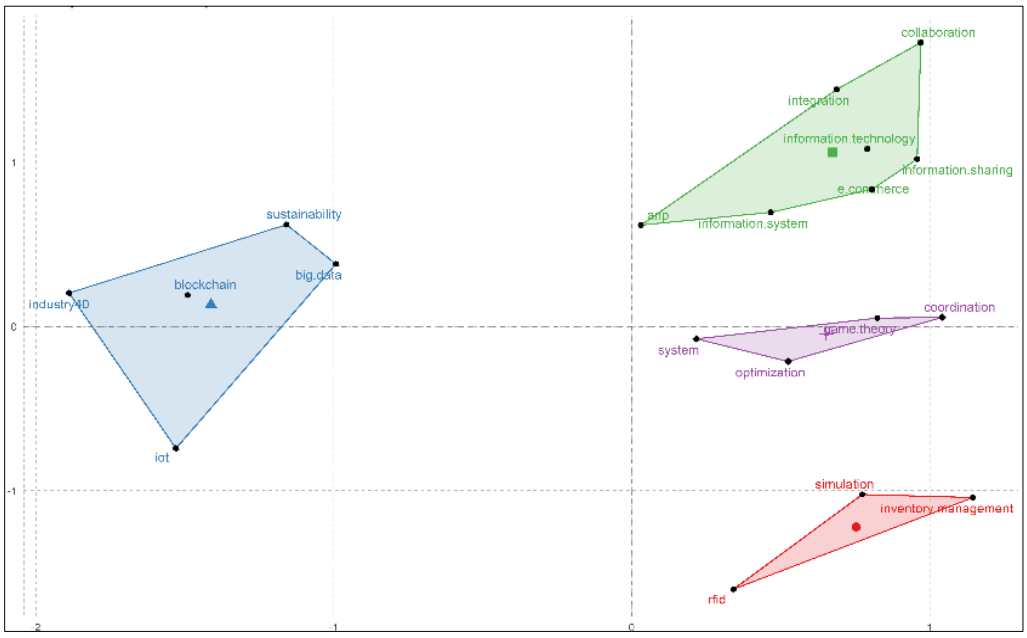


Figure 1: Multidimensional Scaling Analysis of Keywords

Multidimensional scaling is one of the exploratory data analysis methods that reveal the relationship between the phenomena studied. In the graph from multidimensional scaling analysis, the analyzed keywords are distributed across the plane, and the relative position of each keyword reflects the convergence between keywords. The more convergent words form a cluster. To the extent that a keyword is close to the middle of the cluster, it provides a basis for the relevant literature (Hoffman, & De Leeuw, 1992). As a result of the analysis, a factorial map and dendrogram showing the clusters can be obtained. Figure 1 shows the factorial map created according to the keywords' multidimensional scaling analysis. It can be seen the hierarchical association of keywords in the tree dendrogram on Figure 2.

As a result of the analysis, the keywords were formed in 4 main clusters.

Cluster 1 includes the "internet of things", "sustainability", "big data", "blockchain", and "industry 4.0". Blockchain appears to be in a more central position on the factorial map. We can interpret it as examining other keywords concerning blockchain in the studies. Internet of things, blockchain, and big data are components of industry 4.0 (Esmaeilian et al., 2020; Frank et al., 2019). Therefore, it is expected that they gather in the same cluster. The development in digital technologies and the emergence of the industry 4.0 have intensified competition in the market and brought opportunities to cope with this competition and ensure sustainability (Esmaeilian et al., 2020; Ghobakhloo, 2020).

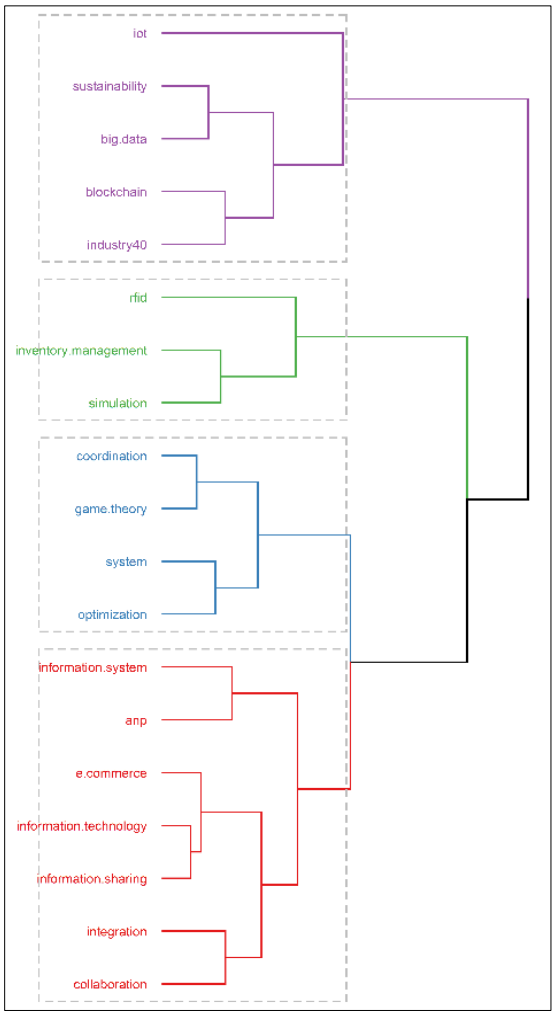


Figure 2: Tree Dendrogram of Clustering Analysis of Keywords

Cluster 2 includes "rfid", "inventory management" and "simulation", and inventory management is located close to the center. It can be said that rfid technology and simulation are essential in terms of inventory management. Rfid technology enables real-time tracking of inventory, thus reducing transaction times and labor requirements. In this way, it provides the opportunity for process transformation and optimization by providing full visibility of the inventory at all supply chain nodes (Y. M. Lee et al., 2009). The use of a simulation model in studies examining the effects of RFID technology on inventory control (for example (Saygin, 2007), (Ustundag, & Tanyas, 2009)) may have caused this keyword to come to the fore.

Cluster 3 includes "coordination", "game theory", "system", and "optimization". In this cluster, game theory is in a more central position. With globalization, requirements such as supply of raw materials from different markets, distribution of products to different facilities and customers, being in contact with suppliers, logistics service providers, and customers from

different regions have made it necessary to design an effective supply chain network. Various models have been developed to optimize the supply chain network to be created in this direction. It is one of the methods used in game theory optimization (Zamarripa et al., 2012). Besides, the lack of coordination in supplier-producer-customer relations in a poorly designed supply chain network can create an environment of conflict resulting in an inefficient supply chain (Zhao et al., 2010). In this context, it is typical for the system and coordination to come to the fore in this cluster.

Cluster 4 includes "information system", "anp", "e-commerce", "information technology", "information sharing", "integration", and "collaboration". Information technology is the closest element of this cluster to the center. Many studies are stating that the use of information technologies increases supply chain performance. Especially in today's complex business environment, information technologies are an inevitable component for the smooth functioning of supply chain processes. Businesses take advantage of information technologies in critical issues such as increasing supply chain agility, short cycle times, and on-time delivery (Fasanghari, 2008). Information technologies provide the necessary infrastructure for critical issues such as information sharing (Fiala, 2005), collaboration (Cassivi, 2006), and integration (Neubert et al., 2004). Also, anp and similar analytical methods, digital processes such as e-commerce become possible and efficient thanks to the development of information technologies. Therefore, the association of the publications in this cluster is entirely meaningful.

When the dendrogram is examined, it is seen that the 3rd and 4th clusters merge in the upper branch, and then these two clusters come together with the 2nd cluster hierarchically. This situation can be interpreted as information technologies and components in supply chains are essential tools for better coordination and optimization. For designing the system efficiently in supply chains, it is necessary to benefit from technology in terms of physical components and optimization of processes.

Through thematic evolutionary analysis, changing rules, evolutionary relationships, and trends in the thematic content, power, and structure of publications can be observed and traced. Through thematic evolutionary analysis, we can see the development in the field, the direction of the change, and predict the new issues that this change will bring up. Each node represents a keyword in the thematic diagram, and the size of the node is proportional to the number of different keywords used in the theme. Connections of a node to other nodes reveal the relational content of the concept. The continuity of these connections shows that the concept continues to be significant over time. The wider the relationship lines, the more shared concepts are. The stronger the link between concepts, the wider the line (Cobo et al., 2011). The literature on the subject has been examined in three periods than the number of publications published at specific intervals. In the first period between 1991 and 2011, it is observed that information technologies related to digital technologies, rfid, information systems, communication technologies, production, transportation, decision support systems related to supply chain processes came to the fore, and other keywords were accumulated around these. According to these results, it is understood that academic interest in digitalization in supply chains turned towards activities and decision support systems in the first period.

In the second period (2012-2017), it is seen that new keywords emerged due to technological developments, and the focus on supply chain processes increased. Rfid and information systems, which were among the technological concepts in the first period, maintain their importance in the second period. Also, big data gained importance in the literature during this period. In terms of supply chain processes, optimization, coordination, sustainability, and risk management gained visibility in the second period. Another keyword brought along by technology in this period is additive manufacturing.

In the third period (2018-2021), blockchain, gis, and iot came to the fore. Besides, integration and risk management have gained importance by being supported by other concepts.

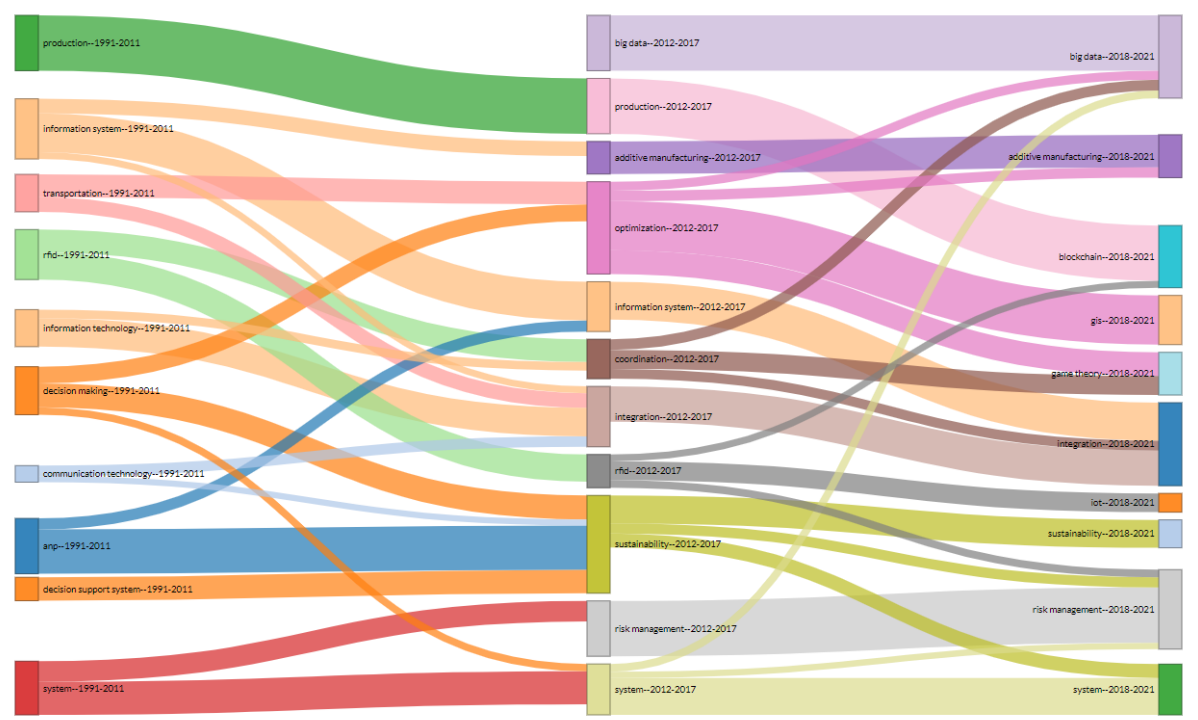
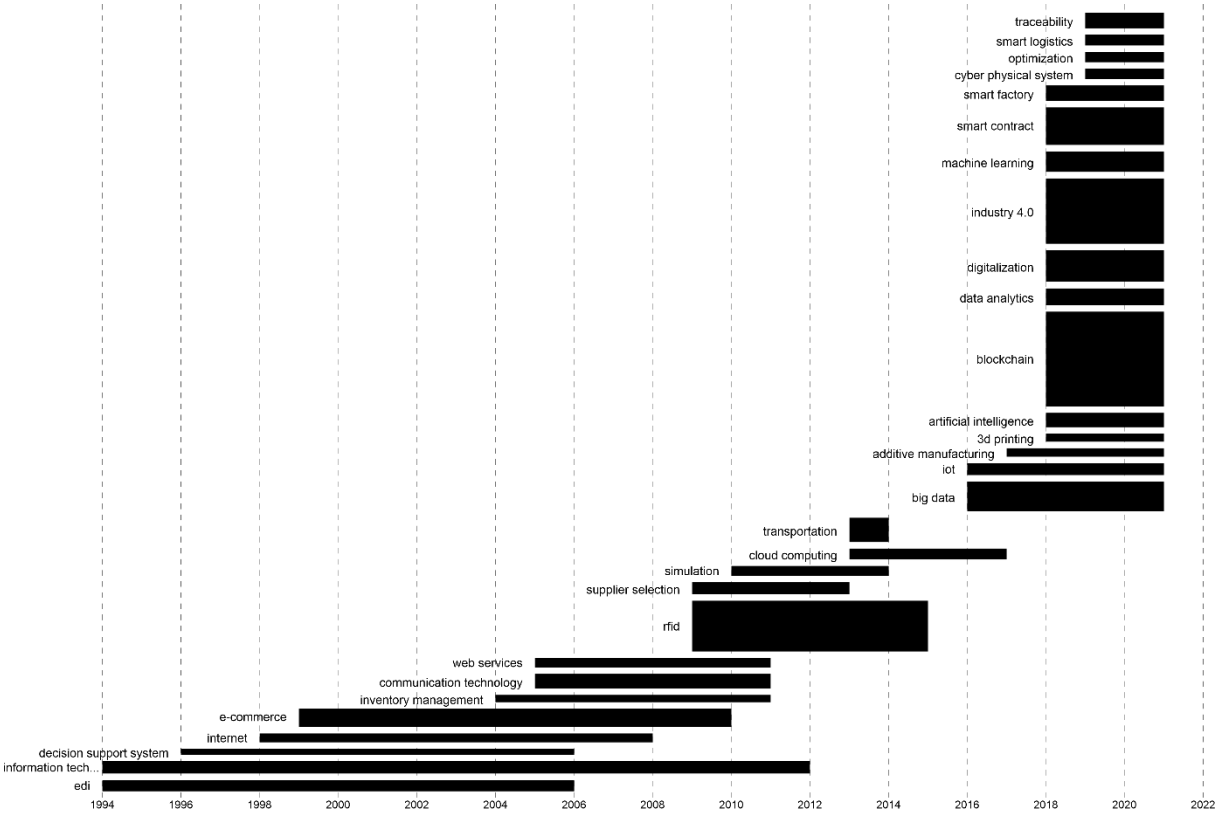


Figure 3: Thematic Evolution of Digitalization in Supply Chains

When Figure 3. is examined, it can be interpreted that information-communication technologies gained importance in some supply chain processes such as decision support systems and transportation in the early periods. Optimization, one of the two most important keywords of the second period, is supported by transportation and decision making. Then the optimization studies in relation to big data, additive manufacturing, and gis studies. Rfid, which is one of the crucial concepts of the subject, has supported both itself and coordination in the second period and has affected many studies in the last period. Studies affected by rfid technology are scattered among big data, integration, blockchain, iot, and risk management.

Burst Detection of Keywords

Burst detection analysis results of keywords are shown on Graph 5. In the first period, information technologies, edi, decision support systems, internet, and e-commerce come to the fore. Of these keywords, information technologies have been active until 2012 and have been the most active concept for the longest time. It is seen that the studies carried out have focused on rfid at a very high level since 2009. The concept of rfid remained important until 2015. High-impact keywords related to digitalization in supply chains have emerged since 2016. These keywords are big data, IoT, blockchain and smart contracts, industry 4.0, smart factories, artificial intelligence, additive manufacturing, etc. In production processes, 3d printing is a subject that is highly emphasized in the literature. However, in the analysis performed, it was concluded that the keyword has a low level of impact. This result can be interpreted as the lack of academic interest in 3d printing applications in supply chain processes.



Graph 5. Bursts of Keywords

Conclusion

Technological development brings significant advantages to businesses and brings a set of challenges that increase competitive pressure and shape the boundaries of the market. The shortening of product life cycles and increasing clock speed force businesses to adapt to environmental conditions to achieve sustainability. There is a strong interest in the subject both in the market and in the academic community. This study aims to obtain a general perspective by revealing the existing knowledge on the subject. It aims to create a guideline for possible areas where future studies may be directed.

In this context, studies on the digitalization process in supply chains have been examined. According to the analysis result, the trend towards the subject is increasing day by day. The most important actors in this trend have been identified as China and the USA. While China is in the first place according to the number of published studies, the USA comes to the references. It is not enough to make inferences on the differences in the number of studies and the number of citations alone and may cause many aspects to be overlooked. For example, it should not be overlooked that the visibility of journals publishing in this field affects the articles they publish to be cited. The journals' image and popularity will increase their credibility and create a sort of Matthew Effect for themselves. Therefore, US-based academic journals have a more deep-rooted history. Academicians living in the USA have easier access to these journals and may have caused more citations to articles published in these journals.

Although the analysis to determine the influential universities on the subject is similar to that for countries, it reveals small differences in results. While the top three countries in the country ranking are the USA, China, and the U.K., it is seen that two Iranian universities are on the list in the university ranking. The top three countries' ranking may be due to their pioneering role in both scientific and technological developments regarding the supply chain. It is usual

for technological progress to follow scientific progress. Therefore, these three countries play a critical role in the know-how process regarding digitalization in their supply chains. The fact that Iranian universities are on the lists indicates that the subject's scientific interest is intensified in Iran.

The quality of academic journals is among the factors determining the articles' visibility, the number of citations, and the level of impact. Therefore, journals should also be considered when examining an area bibliometrically. The most influential journals on digital transformation in supply chains are "International Journal of Production Economics", "International Journal of Production Research", "European Journal of Operational Research", "Journal of Cleaner Production" and "Sustainability". Criteria such as impact factor, indexes, and H-index score are used in academic journals' valuation. The number of studies published on the relevant subject, the H-index score, and the number of citations were evaluated to measure the journals' contributions to the field. Since the citations and h-index score are parameters that can change according to time and activity, "Sustainability" ranked third in the ranking of the number of publications. "European Journal of Operational Research" and "Journal of Cleaner Production" rank higher in h-index score and citations.

In the keyword analysis carried out on the literature's evolution, which is the study's primary focus, first multidimensional scaling was performed, and 4 clusters were obtained. These clusters are shaped around the concepts of blockchain, information technology, game theory, and inventory management. Multidimensional scaling is a useful analysis method to show the effect of digitalization on supply chain functions.

It is possible to reveal the change and development of the subject with thematic evolution analysis. Considering the diversity of issues created by related concepts in the studies conducted in the context of digitalization in supply chains, it can be predicted that there will be more developments in the concept of blockchain in the upcoming period. With blockchain technology, it seems possible to reduce the adverse effects of challenges such as trust, timing, traceability, transparency, and intermediaries, creating significant problems in supply chains. Of course, both the academic knowledge level and the market applications on this subject are still primitive. Despite this, it is thought that the area will continue to progress in this direction.

This study aims to contribute to the literature by creating a general map of digitalization in supply chains in terms of the results obtained. The bibliometric analysis method used in the research is useful in obtaining the general map in question. Thus, it is thought that the study will give the researchers an idea about the full picture of the subject. In this way, the study can help increase the knowledge on the subject, contributing to determining fundamental issues, trends, and directions of scientific evolution.

The methodology applied in the study has some limitations. The most crucial criticism made on this methodology is that the articles' examined specifics (keyword, summary) are too narrow. Therefore, it may not be able to refer to the actual level of knowledge. More comprehensive results can be obtained with more extensive literature reviews on the subject. There is also an advantage of the method applied here. It is not feasible to conduct a comprehensive content analysis on the data set in the current study. The bibliometric analysis provides more consistent results with less effort in data sets of this size. Another criticism is that although it is quite comprehensive, only the WoS database is preferred for analysis.

Despite all these limitations, it is thought that the study will contribute to the relevant literature in terms of understanding how technological developments shape supply chains, identifying and visualizing the current level of knowledge on the subject, and revealing the academic perspective on the subject.

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