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Industrial Revolution 4.0 and Supply Chain Digitization

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ABSTRACT

The latest technological advancements have forced logistics and supply chain digitization in general. Organizations that embrace and prepare for change can survive and maintain a competitive position in the new global business environment. In contrast, the industrial businesses that do not implement the new rules will not survive long and will eventually be obsolete. Therefore, the concept of digitization and industrial revolution 4.0 in supply chain management was intended to be reviewed to determine its trending dimensions. This paper conducted a systematic review of 60 articles on the research topic by considering the publication during the period 2017 to 2021. The paper investigated the evolutionary changes in the supply chain's operational functions in the digital and industrial revolution 4.0 context. The main objective of reviewing articles was to identify the new trend on the search topic. Some trends identified in the current research include the use of blockchain in the supply chain and the nine elements of industry 4.0, the internet of things. The paper is equally significant for researchers and practitioners as it explains industry 4.0 and supply chain digitization trends. Future research can evaluate the mathematical, decision-making, and simulation techniques to support the research domain by increasing its applicability. This research allows us to consider the validation of the digital supply chain models and their components presented preliminary by experts that provide a headway toward emerging and new constructs in this domain.

Keywords: *Supply chain digitization, Industry 4.0, Big data, Blockchain, IoT, Operations*

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Industrial Revolution 4.0 and Supply Chain Digitization

1. Introduction

Supply Chain is a network created between suppliers and organizations to produce and distribute products. It shows steps essential for ensuring the safe and sound delivery of services and products to the ultimate customers. The practical and efficient management of the Supply Chain is crucial because it enables organizations to reduce costs, save time and increase outputs (Hugos, 2018). However, in the traditional supply chain practices, specific essential attributes are missing that are needed for the betterment of future businesses. One of the drawbacks of the traditional supply chain was the existence of isolated mechanisms and processes that lack integration. In response to this, there is a need to shift from the traditional supply chain to the Digital Supply Chain, which is, in other words, a transformation of systems from the former into highly interconnected and integrated work systems. The digital supply chain systems do not imply based on the tangibility and intangibility of products and services but rather deal with how the supply chain operations can be better managed (Agrawal & Narain, 2018). Industry 4.0 terminology was thought up for marking the fourth industrial revolution. This new concept was introduced when the Internet of Things (IoT) was enabled in the manufacturing and production environment. Industry 4.0 envisions an intelligent workstation where the machines' global networks exchange and control the information autonomously. Industry 4.0 creates an environment where physical-cyber systems allow organizations to operate independently. For instance, by enabling industry 4.0, the manufacturing process will be known to machines that require applying to all the manufacturing plants' products. Also, it enables variations needed to make to the products. This makes products distinctively identifiable, whose route and configuration are unique in the production line. Since the collaboration among manufacturers, customers and suppliers are significant in increasing the transparency at all levels from the origin to the final destination point, it is, therefore, essential to study the effect of Industry 4.0 on the overall supply chain (Manavalan & Jayakrishna, 2019).

There are many definitions of a Digital Supply Chain. Some authors have defined it as an intelligent supply chain that allows organizations to take advantage of technologically advanced operations that help integrate various actors in the Supply Chain (Garay-Rondero et al., 2020). Also, such a supply chain synchronizes various processes, including transportation systems and warehouses, to enjoy web-enabled systems. These types of supply chain networks have the potential to provide effective communication and cooperation between the software and hardware. The main objective of such a supply chain is to synchronize communication and integration among organizations (Shukor et al., 2020). The main objective of the current research was to identify the new trends on the search topic. Section 2 below presents a literature review of the most recent research on supply chain digitization and industry revolution 4.0. Section 3 articulates how the entire research work is carried out and the methods, approaches, and techniques used to analyse the literature reviewed. Data visualization and analysis are presented in section 4 of the paper. The research findings and discussion are presented in the below sections with a detailed explanation of each parameter used for the systematic analysis of all literature reviewed. In the current global and technologically advanced era, organizations from various industries show great interest in investing in the digitization of their business activities and operations. Some great examples of the organizations that took initiatives in digitizing their operations are logistics operators, including UPS, FedEx, and DHL. In addition, some e-commerce organizations' examples are Alibaba and Amazon. These organizations invested heavily in digitizing their supply chain operations (Reardon et al., 2021).

Digitization converts physical information into a digital flow by redesigning practices, procedures, and processes to fit the functionality of digital and technological systems (Gremyr & Halldorsson, 2021). Digitalization plays a significant role in the logistics and supply chain industry. The digital supply chain is being used widely for informing the latest requirements for digital standards and infrastructures and the potential to connect device-aware Apps with their supply chains of products and services (Hennelly et al., 2019). Further, digitized logistics service providers play a significant role

in cyber supply chain risk management (CSCRM) processes towards becoming more supply chain-oriented and countering events having higher cyber threats that highlight its importance (Creazza et al., 2021). For this reason, Table 1 expresses a comprehensive definition of digital technologies defined by various researchers to better understand the concept of Industry 4.0.

Table 1: Digital technologies and their definitions

S. No	Digital Technology Definitions	Author
1	The Internet of Things (IoT) is a network of interrelated computing devices connecting humans, machines, and other devices using the ability to gather and exchange data. Over such a network, data is transmitted without human-to-computer or human-to-human interactions.	(Al-Hinai & Singh, 2017)
2	Significant data analytics analysis varied large datasets to determine the concealed meaning and patterns and find relations among them for planning decisions. Such an analysis helps improve efficiency, create business value, and lead to more accurate, faster, and better decision-making. Big data analytics enable industries to access and examine real-time information to forecast production requirements and adopt prescriptive, predictive, and proactive maintenance.	(Ren et al., 2019)
3	Augmented reality (AR) enables industrialists to bring digital factors to life via smartphone video cameras that are famous among leisure-activity users and gamers. In the manufacturing industry, AR wearables offer the operators real-time information and help them make better decisions.	(Monteiro, 2017)
4	Integrated systems help create connections among all industry 4.0 elements and other networks that were working in silos. System integration helps companies increase agility and create transparency in the supply chain processes.	(Weltzien, 2016)
5	Autonomous robots now perform several tasks that are considered dangerous for humans. The robots that also communicate with people are termed robotics.	(Hentout et al., 2019)
6	Cloud computing is the availability of computing power, data storage, software, hardware, and other resources on-demand. For this purpose, several internet-based forums are available that help in increasing business transactions by creating voluminous data from various external and internal sources.	(Mohsen and Woods, 2019)
7	Industry 4.0 enables companies to benefit from 3D simulations during product development. Simulation optimization enables companies to mirror the physical world into the virtual world by incorporating real-time data.	(Vaidya et al., 2018)
8	Additive manufacturing is also known as 3D printing. It is an approach used in production for creating more robust systems and lighter parts. Using such technology provides several benefits to users, including reduced numbers of parts required for assembly, production steps, and material waste.	(Conner et al., 2014)
9	Safeguarding systems from cybercrimes and cyberattacks and securing information is crucial in the diverse fields with network-based connectivity and communication protocols. Some common threats related to cybersecurity include insider threats, crypto-jacking, and IoT-related risks.	(Zhao et al., 2020)
10	Blockchain enables the creation of a system that records information difficult or impossible to cheat, hack or change. It is a digital ledger that records transactions, duplicate them, and distribute that across the network on the blockchain.	(Koeppl and Jeremy, 2017)

Source: Literature Review

2. Previous Literature

According to Ali et al. (2021), a case of readymade garments from Bangladesh identifies bid data analytics as a significant influencing factor, and digital technology enhances the supply chain resilience. Creazza et al. (2021) stated that human resource is also significant in improving supply chain-based cyber resilience. Research conducted by Dennehy et al. (2021) demonstrated that the mindfulness of organizations is essential for enabling resilient supply chains. Therefore, the authors use organization mindfulness and extensive data analytics capabilities for advancing knowledge and developing supply chain resilience. Pursuing supply chain resilience by optimizing personnel capacity, logistics infrastructure, data management, and digitalization is recommended for outbreaks or pandemic situations such as COVID-19 (Herold et al., 2021). The only certainty in the current supply chain disruptions is uncertainty, which requires new technology-based solutions. The COVID-19 pandemic situation around the globe reinforced the need for understanding how technologies including blockchain, additive manufacturing, and artificial intelligence help organizations in effectively dealing with emergencies (Wamba et al., 2021).

However, blockchain increases visibility in the supply chain by increasing transparency (Rogerson & Parry, 2020). Rogerson and Parry (2020) summarized their research findings by articulating that technological applications are required for purchasing food products and transferring funds. In this regard, there are a few challenges in the food industry to implementing blockchain technology for digitizing the supply chain. These challenges are consumers' willingness to pay, consumer data access, governance, fraud, and human error at the boundaries and trust of the technology. Therefore, the use of blockchain in the supply chain is increasingly trending in this technologically advanced era. The Internet of Things and other digitized technologies increase the transparency in maintaining the inventory to avoid any shortage or stockpiling (Friday et al., 2021). Furthermore, Gohil and Thakker (2021) argued that the challenge that the global supply chain is facing is the need to use the internet of things. Digitization of process enables organizations to increase their potential to better collect and analyze their big data and improve connectivity and information visibility along with reliable and fast physical networks and delivery options that significantly impact supply chain networks and logistics productivity (Herold et al., 2021). Similarly, Koh et al. (2019) identified big data analytics as the most frequently used technology in industry 4.0. Correspondingly, Koh et al. (2019) and Haddud and Khare (2020) stated that big data analytics is trending, which requires the inculcation of procedures for moving toward supply chain digitization. In contrast to the above discussion, Table 2 presents a summarized literature review on supply chain digitization and industry 4.0.

Table 2: A summarized literature on supply chain digitization and industry 4.0

Citations	Article title	Articles Viewed	Citations	Study focus	Findings
Acioli et al. (2021)	Applying Industry 4.0 technologies in the COVID–19 sustainable chains	150	23	To investigate the impact of technological innovations in industry 4.0 and determine gaps, key challenges, and opportunities that emphasize using new trends in the supply chain digitization.	The findings highlight a challenge related to social inequalities regarding the human workforce position when machines in the labour market replace these. The man-machine relationship as a gap is identified in the research. The authors suggested that society 5.0 or a super-smart society concept provides quality of life by finding resolutions to social challenges.
Bai et al. (2021)	Guest editorial	195	21	To study the technological advancements trend in the recent past.	The technological advancements in the recent past incorporated a massive variety of industry 4.0 and information technologies that take benefit of quantum computing, cyber-physical systems, Internet of Things, mobile technology, predictive analytics, artificial intelligence (AI), and integrate blockchain technology.
Barbieri et al. (2021)	Guest editorial Emerging research and future pathways in digital supply chain governance	128	1	The authors carried out research to identify future pathways in the governance of the digital supply chain.	According to the authors, there is a need to consider a broader range of supply chain issues and parts in understanding digital technology's impact on supply chain governance. Also, they mentioned in their research findings that there is a need for future studies in collaboration with the cybersecurity domain to develop a detailed understanding of cybersecurity in digital supply chain technologies.
Culot et al. (2021)	The ISO/IEC 27001 information security management standard: literature review and theory-based research agenda	96	10	A study was conducted to explore the contemporary technological trend in various industries.	Authors articulated that a change is required due to emerging technology-based opportunities and an interconnected world. Since data is considered the new oil, organizations these days are required to secure their information assets.
Frederico (2021)	Towards a Supply Chain 4.0 on the post-COVID-19 pandemic: a conceptual and strategic discussion for more resilient supply chains	54	15	The author studied the impact of disruptive technologies on supply chain resilience.	Disruptive technologies play a significant role in promptly responding to emergency events such as the COVID-19 pandemic. In this regard, the authors suggested that using supply chain 4.0 as a transformational strategic development is highly effective, most notably for the post-pandemic period.
Friday et al. (2021)	A collaborative approach to maintaining optimal inventory and mitigating stockout risks during a pandemic: capabilities for enabling healthcare supply chain resilience	752	7	A research study was carried out to study the capabilities required to enable the supply chain resilience in health care sectors to mitigate risks associated with risks of inventory stockouts and maintain optimal levels of inventory in the COVID-9 pandemic situation.	The research findings proposed a need to reinforce capabilities via supply chain digitization that will improve mechanisms for determining the optimal levels of medical inventory in the pandemic. In addition, it is articulated in the research that the emerging technologies, including the Internet of Things and other digitalization technologies, increase the transparency in maintaining the medical inventory to trigger any panic and better manage the inventory needs by stockpiling.
Garay-Rondero et al. (2020)	Digital supply chain model in Industry 4.0	213	87	A study was conducted to design a conceptual model containing a few significant components in shaping Digital Supply Chains (DSCs) by the	The authors proposed five crucial components to implement Industry 4.0 technology into Digital Supply Chain Management successfully. The components include the need to manage projects by managing and digitalizing organizations' behavior and culture,

				acceleration and implementation of industry 4.0.	technology and human relationship in Digital Supply Chain Management, the information physical Supply Chain Network Systems and technology infrastructure, and the deployment of features and enablers of industry 4.0 technology, and maintaining physical and digital Supply Chain Flow (SCFs) for providing the good digitization.
Garza-Reyes et al. (2019)	From linear to circular manufacturing business models	40	14	To design a business sustainability model or design based on reusing electronic appliances.	The study outcomes presented a model for reusing scrap electronic appliances that include additive manufacturing, reverse logistics and integration of web-based technologies. The study suggested improving business sustainability by reinserting waste in the manufacturing of products.
Gohil and Thakker (2021)	Blockchain-integrated technologies for solving supply chain challenges	55	1	To study the challenges that the global supply chain is facing.	The authors presented some challenges the global supply chain faces and suggested a need to use blockchain technology, the internet of things and artificial intelligence as a solution.
Bai et al. (2021)	Guest editorial	195	1	A study analyses the trend of the state-of-the-art technology used in the industries effectively in an emergency.	The study's finding suggests that the Internet of Things is one of the technologies used effectively during any pandemic situation.
Hennelly et al. (2019)	Reconfiguring business processes in the new political and technological landscape	5	2	To determine how to make managers able to become influential decision-makers.	The study's findings show that the research directly affects educational institutions that produce future managers who successfully work in a data-driven business world.
Hofmann et al. (2020)	Research in business service purchasing: current status and directions for the future	118	2	The authors conducted a study to determine the field's upcoming developments and practical implications.	The outcomes presented recent service purchasing trends that include near-shoring and Globalization; corporate social responsibility and sustainability; external and internal collaboration; hybrid servitization and products; value-driven payment and contract systems; artificial intelligence; big data analytics; and atomization of processes.
Ivanov et al. (2021)	Supply chain resilience and its interplay with digital technologies: making innovations work in emergencies	52	10	A study to find the effect of the supply chain's resilience on small enterprises.	The research suggests that the digitalization of the supply chain is highly characterized by the adoption of digital supply chain tools and the level of digital maturity. Both these levels of adoption and maturity of digital tools have a significant effect on the supply chain's resilience that is more focused on small enterprises.
Jonsson et al. (2021)	Guest editorial: The future of SandOP: dynamic complexity ecosystems and resilience	64	1	A study was conducted to discuss the future of AandOP, dynamic complexity, resilience, and ecosystems.	The authors concluded in their study that the future of Sales and operations planning is highly based on building resilient supply chains by adopting ecosystems and moving towards digitization technologies.
Koh et al. (2019)	The fourth industrial revolution (Industry 4.0): technologies disruption on operations and supply chain management	10	103	To identify principles of industry 4.0.	The authors mentioned five technologies that are frequently used in industry 4.0. The technologies include Big Data Analytics, the Internet of Things (IoT), 3D printing, and Cloud and Robotics Systems.

Ortt et al. (2020)	Implementing Industry 4.0: assessing the current state	11	14	This study focused on the investments made for the implementation of industry 4.0.	Many developed countries, including Europe, the USA and China, are investing in implementing industry 4.0 using different names such as smart industry, smart manufacturing, and intelligent production. These countries are following digitization trends and using information and communication technology to optimize business processes in their countries. However, large and small organizations differ significantly in their process for applying and implementing industry 4.0.
Wamba et al., (2021)	Guest editorial Emerging technologies in emergencies	61	2	To study the impact of industry 4.0 and other effective technologies on company operations in the emergencies such as the COVID-19 pandemic.	Understanding how blockchain, additive manufacturing and artificial intelligence help organizations effectively deal with emergencies.
Delesposte et al. (2021)	Use of multicriteria decision aid methods in the context of sustainable innovations: bibliometric, applications and trends	85	1	Current theoretical approaches and discussions by applying MCDA bibliometric methods for sustainable innovations.	The findings present MIS trends based on the most explored areas, including social or environmental impact, production and distribution, and product development assessment.
Prause et al. (2021)	Digitalization and the third food regime	53	30	To explore how digital technologies' application impacts the food and agriculture system regarding the third food regime.	The result of the study shows that multinational food and agriculture organizations take over the business models of digital technology-driven companies.
Vrana and Singh (2021)	Cyber-Physical Loops as Drivers of Value Creation in NDE 4.0	21	6	To provide an overview of numerous use cases, cyber-physical loops for value creation, key-value streams, and the NDE ecosystem for stakeholders in the system.	Industry 4.0 and NDE (NDE 4.0) provide opportunities for Industries to gain customer groups and adjust value perception accurately. Integrating the cyber-physical loop and NDE enhance the chance for the industry to shift towards a value centre from a cost centre.
Zhang et al. (2021)	Industry 4.0 and its Implementation: a Review	148	3	The research aims to review articles to study Industry 4.0 scope, objectives and implementations, along with the barriers and hurdles in the implementation.	The finding of the research suggests some solutions to overcome the potential challenges and barriers.
Wamba and Queiroz (2021)	Responsible Artificial Intelligence as a Secret Ingredient for Digital Health: Bibliometric Analysis, Insights, and Research Directions	60	6	A study was conducted to explore the dynamics of the interplay between AI and digital health approaches, considering the responsible AI and ethical aspects of scientific production over the years.	The authors, in this regard, articulated that public blockchain can effectively support the areas of the supply chain that lacks institutional interests. In addition, Blockchain help organizations in effectively dealing with emergencies such as COVID-19.
Çalık (2021)	A novel Pythagorean fuzzy AHP and fuzzy TOPSIS methodology for green supplier selection in the Industry 4.0 era	58	52	The study aims to design decision-making approaches based on the elements of Industry 4.0 for effectively selecting green suppliers	An approach is proposed that includes the judgment of various industry experts and is presented by terms that are based on Pythagorean numbers.

				by integrating TOPSIS and AHP methods.	
Shemov et al. (2020)	Blockchain applied to the construction supply chain: A case study with a threat model	59	19	The study aimed to determine CSC's challenges in terms of efficiency and productivity.	The results articulate that blockchain is an ultimate solution to various challenges that CSC faces regardless of the robustness and security of the data protection risks and information flow.
Zhang et al. (2020)	Application of blockchain in the field of intelligent manufacturing: Theoretical basis, realistic plights, and development suggestions	49	5	To study the blockchain application in the intelligent manufacturing field.	The research outcomes proposed a theoretical basis for blockchain application in intelligent manufacturing. Also, some realistic plights are pointed out that suggest promoting blockchain applications in the intelligent manufacturing field.
Radanliev et al. (2020)	Artificial intelligence and machine learning in dynamic cyber risk analytics at the edge	63	24	Via literature review, the authors aimed to determine creative methodologies regarding cyber analytics and to identify potential risks that cause disrupting behaviors towards socio-technical systems.	The study's outcomes present a model for interdependencies and connections among system components to internal and external systems and services.
Radanliev et al. (2020)	Cyber risk at the edge: current and future trends on cyber risk analytics and artificial intelligence in the industrial internet of things and industry 4.0 supply chains	173	36	To determine a self-adapting and dynamic supply chain system based on real-time intelligence, machine learning and Artificial Intelligence for cyber risk analysis.	The research findings show that adopting Internet of Things technology depends on cyber recourses. Moreover, the latest new designs enable Small and Medium Enterprises to visualize the resources required for the integration process.
Zhao, Ji, and Feng (2020)	Smarter supply chain: a literature review and practices	68	15	A study was conducted to analyze the literature on a smarter supply chain.	The research findings presented the industrial applications and academic work in Sustainability Supply Chain. However, many significant problems were not examined adequately, including technology-driven supply chain, full data potential realization, multi-dimensional SSCRM, hazard warnings, and data security monitoring that leaves room for future research.
Golan et al. (2020)	Trends and applications of resilience analytics in supply chain modeling: systematic literature review in the context of the COVID-19 pandemic	141	179	To study supply chain resilience research that considers resilience quantification and modeling, and integrates the supply chain with other networks, including command and control and transportation.	The authors presented a comprehensive approach for supply chain resilience network quantification of physical and social networks required to address the critical issues in the field.

Notes: Citations are recorded till November 2021.

3. Methodology

This section describes the process used to search the literature to select relevant articles for the review. In this regard, the main objective was to map and evaluate the available literature to identify futuristic new fields and trends in the study subject. Figure 1 represents the methodology that was used to analyze the study objectives. The study selected articles from two databases (Springer and Emerald). Because these two sources provide a great collection of well-reputed management journals that are peer-reviewed, it is a multidisciplinary database as it covers various subjects, including Marketing and Strategy, Management Science and Operations, Organizational Behavior and Human Resources, Economics, and Accounting and Finance (NCI Library, 2021).

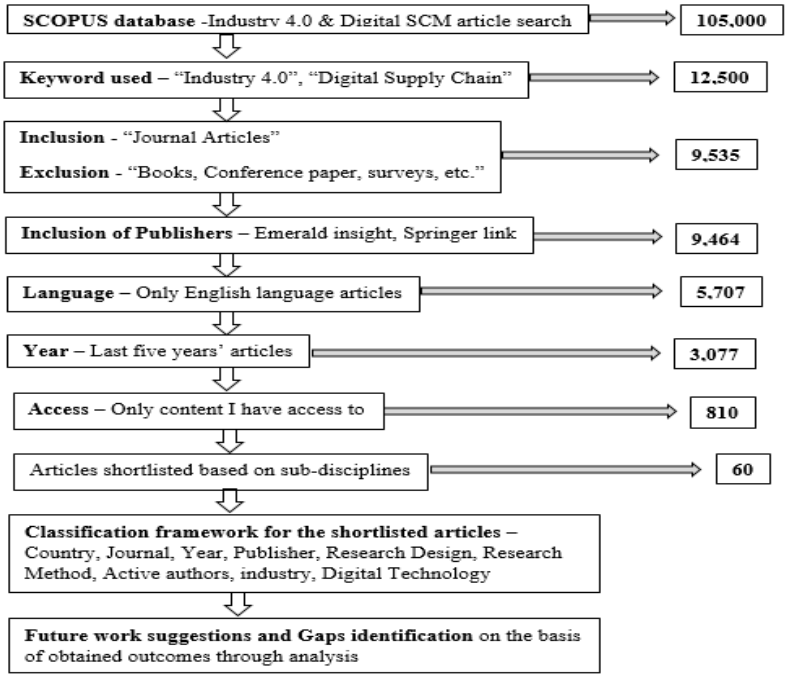


Figure 1: Research methodology used in the study

3.1 Framework for Analysis

This study followed a systematic framework starting with the 1) country contribution, 2) journal, publication year, 3) publisher, 4) adopted research design, 5) adopted research method, 6) active authors, 7) industry, and 8) digital technology. Further, the analysis was developed in chronological order, domains of applications, types of research, and the application of industry 4.0.

3.2 Methodology Implementation

For mapping the existing literature, it was imperative to set the key terminologies to access relevant literature for synthesizing the literature reviews. Therefore, the keywords "Industry 4.0" and "Digital Supply Chain" were considered to extract published articles from 2017 to November 2021. After performing a search cycle, it was found that a total of 26 articles were found relevant to the study topic in the English language from Emerald and 34 articles from Springer. In this regard, Table 3 lists the total number of year-wise publication distribution.

Table 3: Total number of publications

Year	Springer Publications	Emerald Publications	Total Publications
2017	0	0	0
2018	1	0	1
2019	2	4	6
2020	9	5	14
2021	22	17	39
Total	34	26	60

Table 3 shows that the publications on supply chain digitization and industry 4.0 increased exponentially from 2019 to 2021. The graph trend confirms the utilization of industry revolution 4.0 and digitization in supply chain management.

3.2.1 Classification based on publication year

Figure 2 below shows the year-wise classification of published articles from 2017 to November 2021. In 2017 and 2018, the research trend of industry 4.0 technologies and supply chain digitization was insignificant. Only one relevant article was published in 2018, while there was no relevant publication in 2017. However, the publication drastically increased in 2019, and three industries, including manufacturing, army, and aviation, concentrated on digitization and industry 4.0. However, the topic expanded to other industries, including automotive, healthcare, and logistics manufacturing operations, from 2019 to 2021.

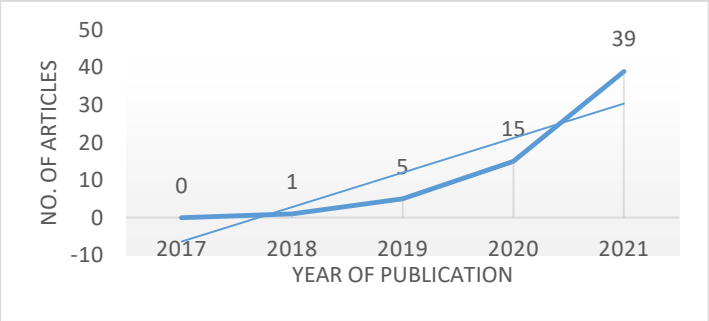


Figure 2: Classification based on publication year

3.2.2 Classification based on journals and publisher

The International Journal of Operations and Production Management published a large number of articles in the selected research domain, which is around 8.3%. However, other significant journals that published most of the articles include Frontiers of Engineering Management, Global journal of flexible systems management, Journal of Manufacturing Technology Management, Modern Supply Chain Research, and Applications, which contributed 5% (each) to this study. The details of articles and their respective publishers, along with their h-index, are presented in Table 4.

Table 4: Articles' classification based on journal

Journal	h-index	Publisher	No. of Articles	%
International Journal of Operations and Production Management	138	Emerald	5	8.3
Frontiers of Engineering Management	11	Springer	3	5.0
Global journal of flexible systems management	31	Springer	3	5.0
Journal of Manufacturing Technology Management	70	Emerald	3	5.0
Modern Supply Chain Research and Applications	4	Emerald	3	5.0
Annals of Operations Research	105	Springer	2	3.3
Environment Systems and Decisions	43	Springer	2	3.3
Information Systems Frontiers	66	Springer	2	3.3
International Journal of Physical Distribution and Logistics Management	111	Emerald	2	3.3
Journal of Nondestructive Evaluation	43	Springer	2	3.3
Management Review Quarterly	17	Emerald	2	3.3
SN Applied Sciences	52	Springer	2	3.3
Supply Chain Management: An International Journal	115	Emerald	1	6.7
Agriculture and Human Values	76	Springer	1	1.7
AI and Ethics	29	Springer	1	1.7
AI Perspectives	154	Springer	1	1.7
Asian Journal of Business Ethics	187	Springer	1	1.7
Business Process Management Journal	81	Emerald	1	1.7
Chinese Journal of Mechanical Engineering	33	Springer	1	1.7
Journal of Cybersecurity	16	Springer	1	1.7
Health and Technology	18	Springer	1	1.7
Industrial Management and Data Systems	103	Emerald	1	1.7
International Journal of Lean Six Sigma	38	Emerald	1	1.7
International Journal of Metal casting	19	Springer	1	1.7
International Journal of Productivity and Performance Management	61	Emerald	1	1.7
Journal of Data, Information and Management	162	Springer	1	1.7
Journal of Enterprise Information Management	61	Emerald	1	1.7
Journal of Fashion Marketing and Management	52	Emerald	1	1.7
Journal of Humanitarian Logistics and Supply Chain Management	25	Emerald	1	1.7
Journal of the Knowledge Economy	27	Springer	1	1.7
Neural Computing and Applications	80	Springer	1	1.7
Operations Management Research	28	Springer	1	1.7
OPSEARCH	20	Springer	1	1.7
Production Engineering	33	Springer	1	1.7
Rajagiri Management Journal	1	Emerald	1	1.7
Russian Engineering Research	19	Springer	1	1.7
Soft Comput	81	Springer	1	1.7
The TQM Journal	67	Emerald	1	1.7
Total			60	100

In continuation of Table 4, Figure 3 represents the proportion of published articles in Springer and Emerald, where Springer contributed most with a percentage of 57%, whereas Emerald contributed 43%. These articles were extracted from the domain of supply chain digitization and industry 4.0 and published in various journals of Springer and Emerald.

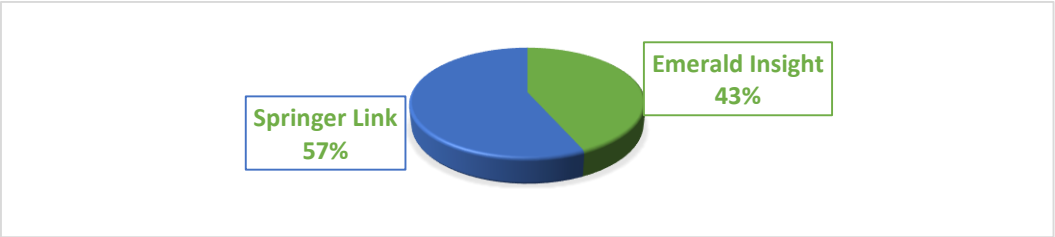


Figure 3: Proportion of published articles

3.2.3 Classification based on publication country

The articles considered in the current research included publications published in 23 countries worldwide. Table 5 below shows a detailed description of articles' classification based on the publication country. Among the 60 shortlisted articles, Germany and U.K. contributed the most, with 23.4% of the total published articles. The U.S.A. followed them with 10% of the research. However,

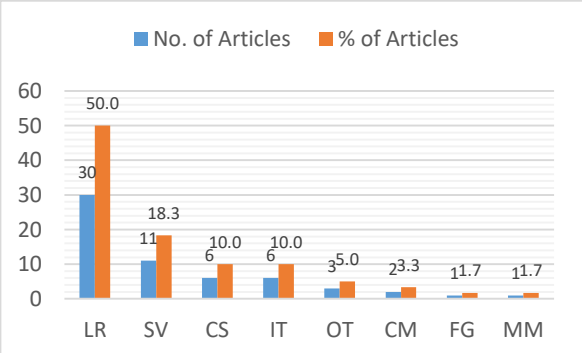
several countries contributed a very low 1.7% each. The countries include Africa, France, Hong Kong, Japan, Mexico, Netherland, Russia, South Africa, Spain, Switzerland, and the UAE. Each of these countries only published one article in the five years time span.

Table 5: Articles' classification based on publication country

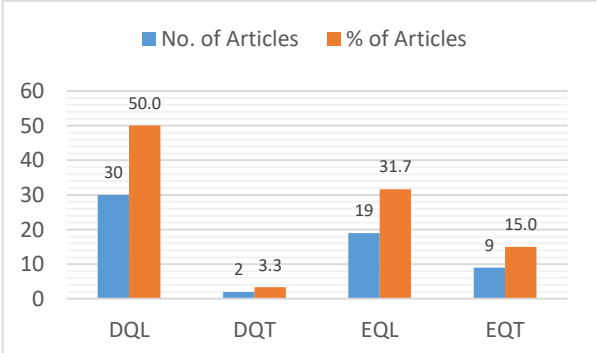
S. No.	Name	No. of Articles	%
1	Germany	7	11.7
2	U.K.	7	11.7
3	U.S.A.	6	10.0
4	Brazil	5	8.3
5	China	5	8.3
6	India	5	8.3
7	Italy	4	6.7
8	Sweden	3	5.0
9	Australia	2	3.3
10	Bangladesh	2	3.3
11	Turkey	2	3.3
12	Africa	1	1.7
13	Austria	1	1.7
14	France	1	1.7
15	Hong Kong	1	1.7
16	Japan	1	1.7
17	Mexico	1	1.7
18	Netherlands	1	1.7
19	Russia	1	1.7
20	South Africa	1	1.7
21	Spain	1	1.7
22	Switzerland	1	1.7
23	UAE	1	1.7
	Total	60	100.0

3.2.4 Classification based on research method and research design

The used research methods in published articles were rigorously analyzed. The most used methods were literature review, survey, and case study. Figure 4 presents the details regarding the research methods adopted by published articles. From the bar graph in Figure 4, it is clear that the literature review method is mainly considered by authors followed by the survey method. Around 50% of the articles adopted the literature review research method, 18.3% of the articles used survey methods, 10% adopted the case study method, and 10% of articles considered the interview method. However, the remaining 11% adopted conceptual models, mathematical models, and some other research models.



Note: LR: Literature Review, SV: Survey, IT: Interview, FG: Focus Group, MM: Mathematical Model, CS: Case Study, OT: Others



Note: LR: DQL: Desk Qualitative, DQT: Desk Quantitative, EQL: Empirical Qualitative, EQT: Empirical Quantitative

Figure 4: Classification according to research method and research design

Desk and empirical research are considered in the current research to classify the research designs of all 60 articles. The details regarding the research designs of articles are presented in Figure

4, where it is clear that authors mainly use the desk qualitative research design in their articles. Following desk qualitative, empirical qualitative is the second most used research design in the articles. Around 50% of the articles used a desk qualitative research design, 31.7% used an empirical qualitative design, 15% used an empirical quantitative design, and only 3.3% used a desk quantitative research design. Besides these four research designs, none of the articles used a practical triangulation design. According to Flick (2018), empirical triangulation enables researchers to include several decision-making, quantitive, and mathematical modeling techniques.

3.2.5 Classification based on industry

According to Ni et al. (2020), any research is incomplete unless its applications are apparent and contribute to the nation's economic development. In this regard, industries play a vital role in contributing to the economy. Correspondingly, it is essential to determine the industries in which the supply chain digitization trends are observed. Assessing supply chain digitization trends based on the industry will enable industry professionals to adopt better technologies for digitization in their specific operations. The application of industry 4.0 technologies and other digitization techniques are reported in Table 6, which shows the trends across various industries. The results in Table 6 show that the research on the manufacturing industry has the most published articles (12), followed by automotive (7), healthcare (6), logistics (6), and food and agriculture (5). Hence, the trend of supply chain digitization and industry 4.0 has become significant for the industries to grow technologically in the rapidly developing world. Besides construction, consulting, fashion, metals, and mining, non-destructive evaluation, services, and textile also experience a technological shift towards industry 4.0.

Table 6: Articles classification based on industry

S. No.	Name of Industry	No. of Articles
1	Manufacturing	12
2	Automotive	7
3	Healthcare	6
4	Logistics	6
5	Food and Agriculture	5
6	Construction	2
7	Consulting	2
8	Fashion	2
9	Metals and Mining	2
10	Non-Destructive Evaluation	2
11	Service	2
12	Textile	2
13	Army	1
14	Digital Aviation	1
15	Education	1
16	Fintech start-ups	1
17	FMCG	1
18	Heavy Engineering	1
19	Metal casting	1
20	Oil and Gas	1
21	Others	2

3.2.6 Classification based on digital technologies discussed in articles

Since the keyword considered for searching in the current research included "industry 4.0" and "supply chain digitization". The articles selected for the research mainly included the elements of industry 4.0 that are; Big Data, Cloud Computing, Additive Manufacturing / 3D printing, Cybersecurity, Simulation Optimization, Augmented Reality, Autonomous Robots, Blockchain technology, integrated systems, and IoT were frequently discussed. Figure 5 shows the detail of articles in which these technologies and their applications are presented proportionately.

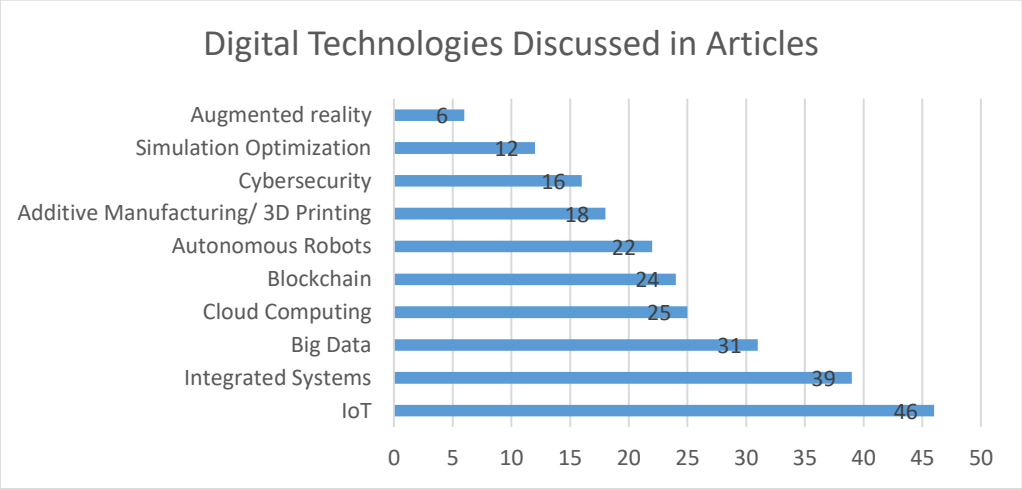


Figure 5: Digital technologies discussed in articles

In Figure 5, it is seen that IoT, integrated systems, and Big Data are discussed in most of the articles. Around 76% of articles (46) discussed the use of the Internet of Things and other technologies as a solution to the technological advancement of the supply chain. 65% of articles (39) articulated the significance of using various integrated systems for supply chain digitization. Thirty-one articles presented the application and significance of big data analytics. Correspondingly some other technologies that are explicitly discussed in the articles include cloud computing (25), blockchain technology (24), and additive manufacturing / 3D printing (18). In addition to these technologies, cybersecurity, simulation, optimization, and augmented reality were discussed in a few articles. These data facts show that the use of these technologies has significantly increased over the five years. Table 7 below shows the literature support for each of the technological trends been researched by various researchers.

Table 7: Literature support for the most trending industry 4.0 and supply chain digitization technologies

S. No.	Industry 4.0 and Digital Technologies	Literature Support
1	Big Data	(Acioli et al., 2021), (Ali et al., 2021), (Bai et al., 2021), (Barbieri et al., 2021), (Braglia et al., 2020), (Herold et al., 2021), (Dennehy et al., 2021), (Frederico, 2021), (Garay-Rondero et al., 2020), (Gremyr and Halldorsson, 2021), (Hennelly et al., 2019), (Herold et al., 2021), (Hofmann et al., 2020), (Jonsson et al., 2021), (Koh et al., 2019), (Wamba, et al., 2021), (Harris et al., 2021), (Kumar et al., 2021), (Prause et al., 2021), (Hun et al., 2021), (Kaya and Aycin, 2021), (Kamble, et al., 2021), (Zhang et al., 2021), (Wamba and Queiroz, 2021), (Vrana and Singh, 2021a), (Tezel et al., 2020), (Zhang et al., 2020), (Radanliev, et al., 2020), (Hofmann et al., 2020), (Zhao et al., 2020), (Queiroz and Mendes, 2020)
2	Cloud Computing	(Acioli et al., 2021), (Bai et al., 2021), (Barbieri et al., 2021), (Braglia et al., 2020), (Culot et al., 2021), (Garay-Rondero et al., 2020), (Gohil and Thakker, 2021), (Haddud and Khare, 2020), (Herold et al., 2021), (Jonsson et al., 2021), (Koh et al., 2019), (Ahmed, et al., 2021), (Kumar et al., 2021), (Hun et al., 2021), (Kaya and Aycin, 2021), (Vrana and Singh, 2021a), (Kamble, et al., 2021), (Zhand et al., 2021), (Sun et al., 2021), (Vrana and Singh, 2021b), (Shemov et al., 2020), (Tezel et al., 2020), (Radanliev, et al., 2020), (Radanliev, et al., 2020), (Trujillo and Hinders, 2019)
3	Additive Manufacturing / 3D printing	(Acioli et al., 2021), (Barbieri et al., 2021), (Braglia et al., 2020), (Frederico, 2021), (Garay-Rondero et al., 2020), (Ivanov et al., 2021), (Soares et al., 2021), (Vrana and Singh, 2021a), (Kamble, et al., 2021), (Zhand et al., 2021), (Çalık, 2021), (Zhao et al., 2020) (Barbieri et al., 2021), (Dennehy et al., 2021), (Garay-Rondero et al., 2020), (Haddud and Khare, 2020), (Çalık, 2021), (Zhang et al., 2020)
4	Cybersecurity	(Bai et al., 2021), (Barbieri et al., 2021), (Braglia et al., 2020), (Creazza et al. 2021), (Culot et al., 2021), (Garay-Rondero et al., 2020), (Radanliev et al., 2021), (Kumar et al., 2021), (Radanliev et al., 2021), (Soares et al., 2021), (Hun et al., 2021), (Kamble, et al.,

		2021), (Çalık, 2021), (Shemov et al., 2020), (Radanliev, et al., 2020), (Radanliev, et al., 2020)
5	Simulation Optimization	(Culot et al., 2021), (Dennehy et al., 2021), (Garay-Rondero et al., 2020), (Jonsson et al., 2021), (Koh et al., 2019), (Vrana and Singh, 2021a), (Kamble, et al., 2021), (Zhand et al., 2021), (Wamba and Queiroz, 2021), (Sun et al., 2021), (Çalık, 2021), (Shemov et al., 2020)
6	IoT	(Acioli et al., 2021), (Bai et al., 2021), (Barbieri et al., 2021), (Bischoff and Seuring, 2021), (Braglia et al., 2020), (Culot et al., 2021), (Dennehy et al., 2021), (Frederico, 2021), (Friday, et al., 2021), (Garay-Rondero et al., 2020), (Gohil and Thakker, 2021), (Gremyr and Halldorsson, 2021), (Haddud and Khare, 2020), (Hennelly et al., 2019), (Herold et al., 2021), (Ivanov et al., 2021), (Koh et al., 2019), (Ortt et al., 2020), (Rogerson and Parry, 2020), (Wamba, et al., 2021), (Li et al., 2021), (Radanliev et al., 2021), (Harris et al., 2021), (Kumar et al., 2021), (Radanliev et al., 2021), (Prause et al., 2021), (Soares et al., 2021), (Hun et al., 2021), (Kaya and Aycin, 2021), (Chatterjee and Chaudhuri, 2021), (Vrana and Singh, 2021a), (Kamble, et al., 2021), (Zhand et al., 2021), (Wamba and Queiroz, 2021), (Sun et al., 2021), (Çalık, 2021), (Vrana and Singh, 2021b), (Shemov et al., 2020), (Tezel et al., 2020), (Zhang et al., 2020), (Radanliev, et al., 2020), (Radanliev, et al., 2020), (Zhao et al., 2020), (Queiroz and Mendes, 2020), (Trujillo and Hinders, 2019), (Bär et al., 2018)
7	Augmented Reality	(Braglia et al., 2020), (Frederico, 2021), (Haddud and Khare, 2020), (Vrana and Singh, 2021a), (Çalık, 2021), (Vrana and Singh, 2021b)
8	Autonomous Robots	(Acioli et al., 2021), (Barbieri et al., 2021), (Braglia et al., 2020), (Frederico, 2021), (Garay-Rondero et al., 2020), (Gohil and Thakker, 2021), (Hennelly et al., 2019), (Koh et al., 2019), (Ortt et al., 2020), (Prause et al., 2021), (Soares et al., 2021), (Kaya and Aycin, 2021), (Vrana and Singh, 2021a), (Kamble, et al., 2021), (Zhand et al., 2021), (Wamba and Queiroz, 2021), (Çalık, 2021), (Vrana and Singh, 2021b), (Tezel et al., 2020), (Radanliev, et al., 2020), (Zhao et al., 2020), (Trujillo and Hinders, 2019)
9	Integrated Systems	(Bischoff and Seuring, 2021), (Braglia et al., 2020), (Creazza et al., 2021), (Culot et al., 2021), (Herold et al., 2021), (Dennehy et al., 2021), (Garay-Rondero et al., 2020), (Garza-Reyes et al., 2019), (Gohil and Thakker, 2021), (Gremyr and Halldorsson, 2021), (Hennelly et al., 2019), (Herold et al., 2021), (Hofmann et al., 2020), (Jonsson et al., 2021), (Koh et al., 2019), (Ortt et al., 2020), (Rogerson and Parry, 2020), (Wamba, et al., 2021), (Liu and Chiu, 2021), (Delesposte et al., 2021), (Dwivedi, et al., 2021), (Prause et al., 2021), (Soares et al., 2021), (Chatterjee and Chaudhuri, 2021), (Kamble, et al., 2021), (Zhand et al., 2021), (Wamba and Queiroz, 2021), (Sun et al., 2021), (Homayouni et al., 2021), (Çalık, 2021), (Shemov et al., 2020), (Tezel et al., 2020), (Zhang et al., 2020), (Zhao et al., 2020), (Golan et al., 2020), (Queiroz and Mendes, 2020), (Trujillo and Hinders, 2019), (Tikhonov et al., 2019), (Bär et al., 2018)
10	Blockchain	(Barbieri et al., 2021), (Bischoff and Seuring, 2021), (Creazza et al., 2021), (Dennehy et al., 2021), (Garay-Rondero et al., 2020), (Gohil and Thakker, 2021), (Herold et al., 2021), (Hofmann et al., 2020), (Ivanov et al., 2021), (Jonsson et al., 2021), (Koh et al., 2019), (Rogerson and Parry, 2020), (Wamba, et al., 2021), (Chatterjee and Chaudhuri, 2021), (Vrana and Singh, 2021a), (Kamble, et al., 2021), (Zhand et al., 2021), (Wamba and Queiroz, 2021), (Çalık, 2021), (Vrana and Singh, 2021b), (Shemov et al., 2020), (Tezel et al., 2020), (Zhang et al., 2020), (Queiroz and Mendes, 2020)

4. Discussion

Previous literature discussed various supply chain digitization techniques. However, non of them presented a study based on multiple parameters such as classification based on industry journal, publisher, country, research method, and research design. The current paper considered all these parameters that could be highly advantageous for both practitioners and researchers. In 2019, the awareness of industry 4.0 technologies and supply chain digitization was found to be increasingly trending. The International Journal of Operations and Production Management published a large number of articles in the selected research domain, around 8.3%. Further, the articles considered in the current research included publications that cover 23 countries worldwide. Germany and U.K. contributed the most, with 23.4% of the total published articles according to the publication country. Around 50% of the articles adopted the literature review research method, and 18.3% used survey methods. While around 50% of the articles used a desk qualitative research design, and 31.7% used an empirical qualitative design. The manufacturing industry has the most published articles, followed by automotive, healthcare, logistics, food, and agriculture. The IoT, integrated systems and Big Data were discussed in most of the articles. Around 76% of articles discussed the use of the Internet of Things as a solution to the technological advancement of the supply chain. 65% of articles articulated the

significance of the use of various integrated systems for supply chain digitization. In comparison, 31 articles presented the application and significance of big data analytics.

Therefore, social inequalities regarding the human workforce position when machines in the labor market replace these. The proposed solution is to implement the Society 5.0 or Super-Smart society concept. Organizations face severe challenges during emergency or pandemic situations, such as COVID-19. In this regard, there is a need to understand how technologies including blockchain, additive manufacturing, and artificial intelligence help organisations effectively deal with emergencies. There is a need to reinforce capabilities via supply chain digitization that will improve mechanisms for determining the optimal levels of medical inventory in the pandemic. Some components include the need to manage projects by managing and digitalizing organizations' behavior and culture, technology and human relationship in Digital Supply Chain Management, the information physical Supply Chain Network Systems and technology infrastructure, and the deployment of features and enablers of industry 4.0 technology, and maintaining physical and digital Supply Chain Flow (SCFs) for providing the right digitization. Internet of Things and other digitalization technologies increase the transparency in maintaining the medical inventory to trigger any panic. Data is considered the new oil; organizations these days are required to secure their information assets. Big data analytics enhance the capability for progressing the safety of patients in the health care industry.

5. Conclusion

Organizations face severe challenges during emergency or pandemic situations, such as COVID-19. In this regard, there is a need to understand how technologies including blockchain, additive manufacturing, and artificial intelligence help organizations effectively deal with emergencies. There is a need to reinforce capabilities via supply chain digitization that will improve mechanisms for determining the optimal levels of medical inventory in the pandemic. None of the articles used an empirical triangulation design. Empirical triangulation enables researchers to include several decision-making, quantitive techniques, and mathematical modeling techniques in the article. Eventually, the systematic review performed in the current research identified some trends that have been followed in the last five years. The most significant trends determined in the current research are the extensive use of industry 4.0 elements and blockchain to transform the traditional supply chain into a digital supply chain. Moreover, there is a need to explore society 5.0 to improve the man-machine relationship affected badly during COVID-19. Blockchain increases visibility in the supply chain by increasing transparency. Further, public blockchain can effectively support the supply chain areas lacking institutional interests. Blockchain helps organizations effectively deal with disruptive situations such as COVID-19.

6. Future Research and Limitations

The current research is carried out in the context of a systematic literature review of the empirical evidence and current studies about the elements of Industry 4.0 and the supply chain digitization trends. However, the current research allows future research to consider validating the preliminary digital supply chain models presented by experts. Also, the research recommends future work to consider real case studies from modern service providers or manufacturers. This could enable validation of the digital supply chain components and provide a headway toward emerging and new constructs in this domain. There is a need for future studies that are in collaboration with the cybersecurity domain. It is highly suggested that mathematical, decision-making and simulation techniques be included to support the research domain and increase its applicability. Multivariate techniques for data analysis were rarely seen in the reviewed articles. Several researchers used regression and correlation analysis; however, path analysis, discriminant analysis, and ANOVA were found in a few articles. This shows that most researchers focused on simple problems and did not attempt to focus on complex industry issues. The limitation of the current research refers to the criteria followed for excluding irrelevant articles and performing a review of the appropriate literature. This includes not selecting papers in any language other than English. Also, some terms are ignored as they do not match the search protocol defined for the current research. Only two databases for research were selected for the research.

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