Digital supply chain: a new opportunity in the post-Covid 19 era? A review

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Abstract: During 2020, supply chains (SC) worldwide experienced an unprecedented series of shocks caused by the COVID-19 pandemic outbreak, a new instigator of SC disruption quite unlike any seen in recent times. Along with the impact of the pandemic and the long-term alterations of the natural environment, other new disruptions have also emerged (such as the Russian-Ukrainian war, growing tensions over the US-China trade war, the rising cybersecurity breaches, the increasing cost of oil, global economic downturn, etc.), multiplying the challenges for SCs, which need to adjust to new and mutable equilibria. As a result, SCs across several industries have been continuously revisited and transformed, also adopting new technologies: SC have evolved into digital supply chains (DSC). Looking at the DSC field of research, many contributions have pinpointed how technological solutions can contribute to managing any disruptions. However, three years after the pandemic outbreak, the academic and industrial communities lack a clear, comprehensive overview showing the new trends that have emerged from DSC literature and the solutions adopted by SC managers to deal with the new scenario. For this reason, the paper develops a systematic literature review (SLR) to identify the latest trends in the DSC literature and the digital technologies and solutions adopted to best address the challenges that have arisen in the post-Covid 19 era, clarifying the current big picture for anyone interested in doing research in this area, while simultaneously providing guidance to managers. By developing an extensive literature review, it was possible to give new insights into the DSC field of research; underline the latest topics (such as the link between DSC and sustainability or resilience), and summarize the digital technologies and solutions adopted to face the disruptions that occurred.

Keywords: digital supply chain; supply chain management; digital technologies; Industry 4.0; COVID-19.

I. INTRODUCTION

Since 2020 the world has experienced an unprecedented series of shocks, starting from the rapid global spread of COVID-19 to the Ukraine war. These have severely disrupted supply chains and have led to the emergence of new challenges and needs for supply chain managers (Ageron, Bentahar and Gunasekaran, 2020). The pandemic has highlighted the vulnerabilities of supply chain networks and has increased the pressure on the industry toward digitalization and strategies to address the changing priorities and requirements in an ever more dynamic and complex environment (Ageron, Bentahar and Gunasekaran, 2020). Supply chains have started to use digitalization to move from a traditional supply chain to a digital supply chain (DSC) to help supply chain managers to gain competitive advantage creating sustainable value for organizations. The DSC has attracted interest from researchers in the last few years, being defined as "the development of information systems and the adoption of innovative technologies strengthening the integration and the agility of the supply chain and thus improving customer service and sustainable performance of the organisation" (Ageron et al., 2020).

According to the latest publication, the adoption of DSC can help supply chains become more agile and increase visibility (Fei Ye et al., 2022) and resilience (Ardolino et al., 2022), leading to improved performance and competitiveness also in terms of sustainability (Ivanov, 2020). As a result, the digital transformation of the supply chain has accelerated, making it crucial to investigate the new trends in digital supply chain management (DSC) in the post-Covid 19 era. The literature has identified several technologies and approaches for digitalizing the supply chain – such as, for example, Augmented reality, Big Data, Blockchain (Ageron et al., 2020), but it is not clear whether these are aligned with the new needs of the post-Covid 19 scenario. Therefore, there is a pressing need to explore the new trends and technological solutions in DSC. This paper aims to contribute to the existing literature by investigating the new trends in DSC and the main technological solutions in the post-Covid 19 era.

The primary objective of this study is to provide insights into the DSC, help practitioners deal with the new challenges that have emerged for supply chain management, and give insight for future directions in the field of research.

The research questions (RQs) of this study are:

1. *What are the new trends in the DSC in the post-Covid 19 era?*
2. *What are the main technological solutions in the DSC in the post-Covid 19 era?*

To answer the RQs, we have conducted a systematic literature review (SLR) on the DSC. The results of this study will be useful for researchers, practitioners, and decision-makers in the supply chain industry, as it will provide them with insights into the latest trends and technological solutions in DSC that can be used to improve their operations.

The paper is structured in five sections. Section 1 is the introduction, then Section 2 outlines the methodology applied to collect and analyse the sampled articles. Section 3 presents the current state-of-the-art, and Section 4 provides conclusions and recommendations for future research.

II. METHODOLOGY

To review the literature on digital supply chain, we applied the SLR methodology (Tranfield, Denyer and Smart, 2003), widely used to locate existing studies, select and evaluate contributions, analyse and synthetize data and report information (Denyer and Tranfield, 2009). This methodology has been widely applied in the supply chain field (e.g., Ali and Phan, 2022; Pfoser et al., 2022), since it helps to effectively explore a specific topic and extract the most important scientific knowledge (Wong, 2021; Ali and Phan, 2022). The methodology adopted in this research is the structured process proposed by Denyer and Tranfield (2009).

The process is shown in Figure 1 and it is composed of five steps: (1) question formulation, (2) location studies, (3) study selection and evaluation, (4) analysis and synthesis, (5) reporting and using the results.

A. Step 1: question formulations

In the first step the scope of the study is defined through the CIMO (Context, Interventions, Mechanisms, Outcomes) approach (Denyer and Tranfield, 2009). It is used to specify the four critical parts to be investigated in order to proceed correctly to the following phases of the systematic literature review. Applying this logic to the context under study, we find out that a new context has emerged after the Covid-19 pandemic. This means new challenges to deal with and new needs to meet for supply chain managers. One of the disruptions that emerged, according to the literature review of Pujawan and Bah (2022), regards the digitalization of the SC. As suggested, new practices (e.g., new models to optimize the supply chain that includes digitalization, etc.) and new technologies (e.g., new data analysis tools, digital twin, etc.) are necessary in this new scenario.

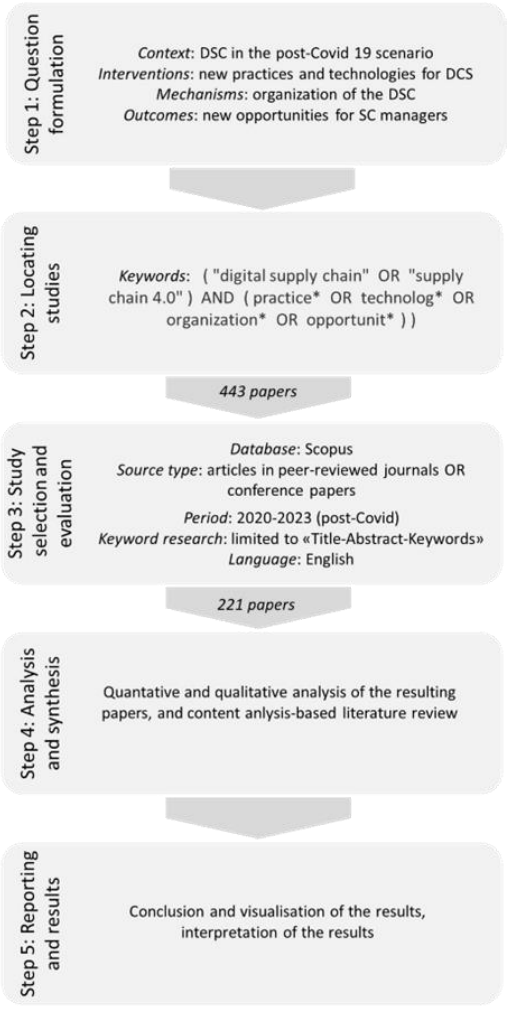

Figure 1. Methodology steps as suggested by Denyer and Tranfield (2009)

This means that the mechanism of interest is the new organization of the DSC, and the expected outcomes are new opportunities for SC managers who implement DSC, in terms of higher performance and enhanced resilience. Hence, the main themes of interest are DSC in the post-Covid 19 scenario (C), new practices and technologies for DSC (I), organization of the DSC (M), new opportunities for SC managers (O).

B. Step 2: locating studies

As described by Denyer and Tranfield, (2009), the most common way to reach a comprehensive list of articles and papers is to investigate the citation database using search strings with keywords. Starting from the objective of the study the keywords identified (i.e., "digitalization", "digital

supply chain", "supply chain 4.0") and their combinations were used as search terms in Scopus, which is the largest abstract and citation database of peer-reviewed literature, used also in the SC management field of research (e.g., Colicchia et al., 2019). The result was 474 documents (analysis performed at the end of April 2023).

C. Step 3: study selection and evaluation

Following this, we set a number of inclusion/exclusion criteria to determine the right set of articles and papers, in line with the objective of the research. The inclusion/exclusion criteria are set in order to follow the requirement for transparency, fundamental requisites for the systematic literature review (Denyer and Tranfield, 2009). We adopted the inclusion/exclusion criteria that are coherent with the aim of the research: (1) only papers published in peer-reviewed journals or conference papers (2) selection of papers published after 2020, (3) selection of papers with restriction on the Search Field, that is "Title-Abstract-Keywords", (4) published in English. The identified keywords, with inclusion/exclusion criteria were used as a search string in Scopus, resulting in 221 articles retrieved. In the following table (Table 1) we reported the top journals ranked according to the number of retrieved papers published in each of them, and the number of papers for each year of publication. The distribution over time shows a growth in popularity.

TABLE I. TOP 10 JOURNAL RANKING AND YEAR DISTRIBUTION

Source title	No. papers
International Journal of Supply Chain Management	*9*
Sustainability (Switzerland)	*8*
International Journal of Production Economics	*6*
Technological Forecasting and Social Change	*5*
Computers and Industrial Engineering	*5*
IFAC-PapersOnLine	*5*
Uncertain Supply Chain Management	*5*
ACM International Conference Proceeding Series	*4*
Procedia Computer Science	*4*
International Journal of Production Research	*4*
Year of publication	**No. papers**
2023	*25*
2022	*74*
2021	*62*
2020	*60*

D. Step 4: analysis and synthesis

In this phase the list of papers is analysed and data and information on the papers are extracted and reported in a table. The main information exported, as suggested by Denyer and Tranfield, (2009) is related to (1) general detail of the study (authors, title, journal, date, etc.), (2) the aim of the study, (3) methodology, (4) findings, (5) contributions. Then, by cross tabulating the studies, key issues were identified. Indeed, the analysis and synthesis step of the systematic literature review requires a grouping of the literature according to similar or related thematic aspects (Pfoser et al., 2022). For the content analysis we used a bibliometric tool, specifically we analysed the keyword co-occurrence network to visualize and discover the research trajectories by examining the links among keywords (Radhakrishnan et al., 2017). We relied on the software package VOSviewer, a well-established tool to conduct this analysis (van Eck and Waltman, 2017). VOSviewer uses the "Visualisation of Similarities (VOS)" clustering technique that provides a mapping of keywords based on the Smart Local Moving (SLM) algorithm, as described in detail in Van Eck and Waltman (2013).

E. Step 5: Reporting and using the results

In this phase, the results of the analysis and synthesis are formalized and interpreted. The results are reported in the next Section.

III. FINDINGS

The results were analysed by conducting a co-occurrence analysis among the keywords related to the papers obtained from the search, so that topics commonly covered by multiple papers could be highlighted, assuming that these keywords were representative of the content of the analysed publications and could be considered for defining the search areas (Ding et al., 2002). Furthermore, a deeper examination of the technologies mentioned in the documents provided insights into their areas of application and benefits, enabling an understanding of how they could support emerging needs and trends.

A. Content analysis of the keyword clusters

Using VOSviewer software, the 221 papers resulting from the research were reviewed, revealing seven clusters of keywords (see Figure 2).

Cluster 1: Red keywords

Documents related to this cluster discussed the support digital technologies offer to organizations. One specific challenge addressed was the increasing occurrence of cyber-attacks (Nygård & Katsikas, 2022). Notably, Blockchain technology, which enables fast and secure transactional database

translation among multiple actors, received considerable attention due to its real-time data sharing and encryption capabilities (Lambourdiere and Corbin, 2020). The digital twin, a system integrating physical and virtual systems through digital technologies, was highlighted also for its sustainability benefits (Kamble et al., 2022). Other popular technologies included machine learning, for data analysis and accurate predictions, and 3D printing for layered fabrication of complex custom components (A.S and Ramanathan, 2021). The emergence of Artificial Intelligence (AI) and Internet of Things (IoT) was also notable for problem solving and integrating technologies. Additionally, RFID technology, facilitating identification and traceability through electronic tags, was highlighted (Barge et al., 2020).

Cluster 2: Green keywords

This cluster focused on digital technologies' role in enhancing the performance and resilience of companies implementing them. Elements such as big data, IoT, cloud computing, cyber-physical systems, 3D printing, Blockchain, RFID, augmented reality, and artificial intelligence were shown to provide transparency, real-time information availability, and automation opportunities in manufacturing and material handling management (Zekhnini et al., 2021). Such improvements were particularly crucial for increased resilience, enabling companies to respond to changes effectively (F. Ye et al., 2022), resolve bottlenecks, improve supplier selection for secure supply, and enhance forecasting quality (Spieske and Birkel, 2021).

Cluster 3: Yellow keywords

This cluster encompassed keywords related to sustainability, emphasizing the importance of technology choices in achieving sustainability goals. Papers explored sustainability aspects within digital supply chains, analysing research, barriers, impacts, and links with the circular economy (Hasanova and Romanovs, 2020; Maha and Akram, 2022; Li, Dai, and Cui, 2020; Skalli et al., 2022). Big data analytics emerged as a technology supporting the circular economy implementation (Edwin Cheng et al., 2022).

Cluster 4: Light blue keywords

This cluster focused on information systems, improving information flow efficiency, competitive advantage generation, and data analytics' role in digitizing procurement (Agnihotri et al., 2022; Nitsche and Kusturica, 2022; Hallikas et al., 2021; Zeiringer and Thalmann, 2020).

Cluster 5: Dark blue keywords

Keywords in this cluster were associated with specific stages of the supply chain, such as supplier relationships, purchasing, and manufacturing. Papers addressed supplier ranking criteria, digital supplier selection's impact on product and service quality, and the positive influence of digital technologies on sustainable manufacturing (Beheshtinia et al., 2022; Sharma and Joshi, 2023; Shah et al., 2020; Wang et al., 2022).

Cluster 6: Orange keywords

This cluster focused on DSC as an innovation, particularly within logistics. The papers in this cluster were older and dealt with topics that have become outdated. They defined DSC, identified barriers, analysed enablers of smart supply chains, and proposed a roadmap for digital technology implementation in the healthcare sector (Maltagliati et al., 2020; Tripathi and Gupta, 2020; Beaulieu and Bentahar, 2021).

Cluster 7: Pink keywords

Keywords in this cluster referred to theoretical content, including relationship between smart technologies, digital transformation, and relational performance, and the development of a framework for implementing DSC in small and medium-sized businesses (Nasiri et al., 2020; Szopa and Cyplik, 2020; Daniels and Jokonya, 2020). Some analyses explored changes in consumer behaviour and new needs in the e-commerce sector due to the COVID-19 pandemic (Dos Santos et al., 2022).

B. Time analysis of the keyword clusters

A temporal analysis using VOSviewer (see Figure 3) revealed that the sustainability cluster was the most recent, likely driven by disruptions and the need for increased resilience and economic-financial optimization. Other topics, such as information systems, innovation, and logistics, were no longer of significant interest. Similarly, the focus had shifted from 3D printing, digital economy, and supply chain finance to data analysis and processing, including machine learning and big data analytics.

The technologies in the post-Covid-19 era: application areas and advantages

In the post-Covid-19 era, various articles and scientific papers analyze the main technologies and their relationships, as well as the benefits and challenges of applying digital technology in supply chain management. However, a comprehensive overview of the relationships between technologies,

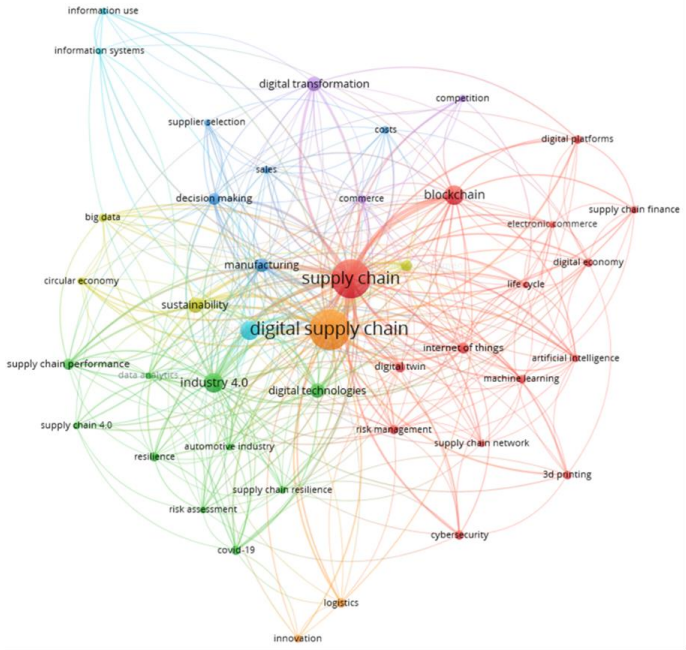

Figure 2: Network obtained from co-occurrence analysis of keywords (7 clusters)

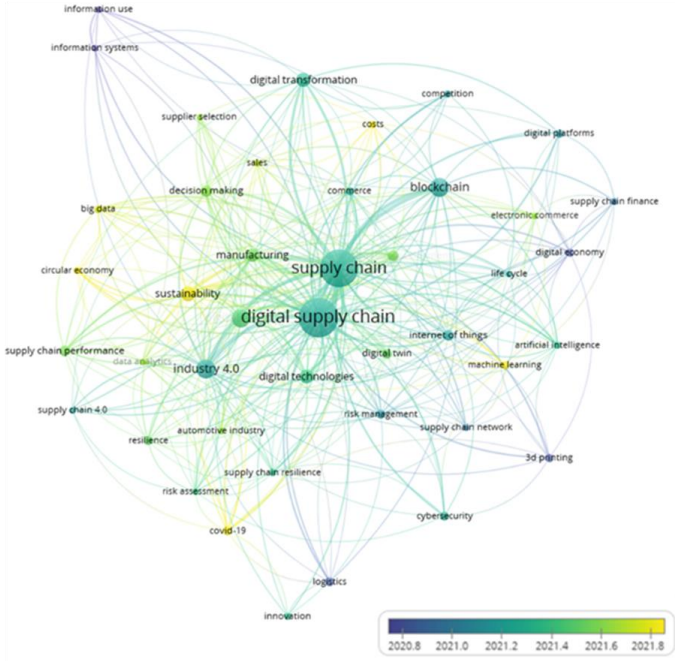

Figure 3: Network obtained from co-occurrence analysis of keywords, with temporal differentiation, conducted using VOSviewer software

their applications, and the post-Covid-19 benefits is lacking. The study highlights how digital technologies associated with the digital supply chain can support emerging trends in the field, leveraging their respective benefits when implemented.

Digital twin enables risk detection, integrates with other technologies like IoT, RFID, and machine learning, and facilitates nondestructive quality control (Ivanov and Dolgui, 2021; Kapustina et al., 2020). It finds application in transportation, network management, cargo handling, manufacturing, risk management, and production planning, particularly in manufacturing (Gerlach et al., 2021; Van Der Valk et al., 2022).

Blockchain enhances communication and collaboration among supply chain actors, increases transaction security, and eliminates intermediaries, thereby reducing time and cost (Mubarik et al., 2020; Lambourdiere and Corbin, 2020). It addresses the need for certification, transparency, and trust in supply chains, providing visibility to all actors (Rana et al., 2021).

Machine learning leverages information analysis, pattern investigation, and decision-making from historical data.It supports business performance across various applications and can contribute to circular economy practices for waste management (Praveena and Prasanna Devi, 2022; Hala et al., 2022).

3D Printing is an effective solution for flexible and cost-efficient component fabrication, addressing supply chain shortages, and democratizing production (Nazir et al., 2021).

AI tackles complex optimization problems and finds applications in transportation planning, including autonomous component transport (Hasanova and Romanovs, 2020).

IoT enables real-time monitoring, bottleneck measurement, and process optimization in digital supply chain management, enhancing process visibility (Hasanova and Romanovs, 2020; Saryatmo and Sukhotu, 2021).

RFID synchronizes supply chain processes, improves inventory management, service levels, cost control, and sustainability practices, while enhancing transparency (A.S and Ramanathan, 2021; Hasanova and Romanovs, 2020; Barge et al., 2020).

IV. Conclusions

The primary objective of this study is to provide insights into the DSC in the post-Covid 19 era, help practitioners deal with the new challenges that have emerged for supply chain management, and inform future research in the field. Indeed, even if the literature shows a number of reviews on DSC (see e.g., Farajpour et al., 2022), there is not a specific analysis on the post-Covid 19 era, considering the shift of needs due to the pandemic and other abovementioned disruptions.

In conclusion, the analysis of literature on digital supply chain management (DSC) in the post-COVID-19 era has revealed several key trends and insights. First, we found that there is a strong emphasis on the use of various digital technologies to enhance supply chain performance, with blockchain, digital twin, machine learning, 3D printing, artificial intelligence, IoT, and RFID being among the most frequently discussed. Second, we observed that sustainability, resilience, and innovation management are among the key topics

related to DSC in the post-COVID era. Finally, we found that there is a clear shift in focus from traditional physical technologies (such as 3D printing) to more digitally oriented ones (such as artificial intelligence, machine learning, and digital twin). Overall, the results suggest that digital technologies have become increasingly important in the DSC post-COVID-19, with a greater emphasis on innovation, sustainability, and resilience. As such, practitioners and researchers alike should continue to explore the potential of digital solutions to help organizations adapt to the new challenges and opportunities in the post-COVID era.

From a theoretical perspective, the results reached the objective of enlarging the body of knowledge on DSC, which still is not very rich (Farajpour et al., 2022) specifically when it comes to the recent trends of resilience and sustainability (Ivanov and Dolgui, 2022). It opens new discussions on the application of technologies in the DSC to face the new scenario and how firms could exploit this concept to add value and create competitive advantage. Moreover, it presents new insights into the DSC field of research for future directions. From a managerial perspective, the findings help practitioners to identify the application areas and the benefit gained by investing in a specific technology and the future challenges for DSC management, i.e., sustainability, resilience, and innovation management.

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