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Digitalization of the supply chain - a systematic literature review from 2007 to 2022

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Abstract: This study systematically examines 28 publications on the digital supply chain (DSC). Focused on efficiency and value creation, DSC redefines logistics management using cutting-edge technologies such as drones and cloud computing. The articles examine several challenging trends and considerations related to this evolution. This strategic shift offers opportunities for operational reconfiguration, but its success depends on the full integration of technologies and the resolution of certain challenges such as interoperability. This overview underlines the importance of DSC as a competitive lever, while highlighting the essential elements to consider for successful implementation.

Keywords: Digitalization; supply chain; Scopus; systematic.

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1 Introduction

"In the new world, it's not the big fish that eats the little fish, it's the fastest that eats the slowest" - Klaus Schwab[1]. This statement clearly illustrates the scale and renewed interest in digitalization of companies of all sizes, who are not looking to become fragile prey, in the face of other companies of the same size but which have made the digital choice. This digital transformation has profoundly disrupted every aspect of human life, and supply chains are probably no exception (Çiğdem, 2021).

The supply chain is subject to numerous constraints on a daily basis, such as the uncertain nature of demand, the complexity of coordination and collaboration mechanisms between the various players, or the lack of flexibility and resilience in the face of constant changes in the competitive market (Chatzikontidou et al., 2017). The

[1] Engineer and founder of the World Economic Forum.

contemporary supply chain is proving to be more complex than the conventional supply chain due to widespread interruptions, increased pressures, shorter product life cycles and the growing demands of consumers worldwide (Shahadat et al., 2023).

In addition to this myriad of challenges, supply chains have very specific characteristics (Lim et al., 2021). They are characterized by a complex network of actors, including several intermediaries, disparate IT systems, different objectives and strategies emanating from various stakeholders, and consumer pressure (Helo and Hao, 2019). In addition, the repercussions of the COVID-19 pandemic (Zhou and Wang, 2021), the Russian-Ukrainian war (Jagtap et al., 2022) and military coups have left their mark on the global supply chain. Today, the race for competitiveness is between supply chains rather than between companies (Mentzer et al., 2001). Nevertheless, digital technology has abolished the barriers inherent in supply chain management and brought about marked transformations in terms of visibility and efficiency (Ślusarczyk et al., 2020). These technologies have been seen as vectors for enhancing supply chain capabilities, in order to improve business performance (Nekmahmud et al., 2020).

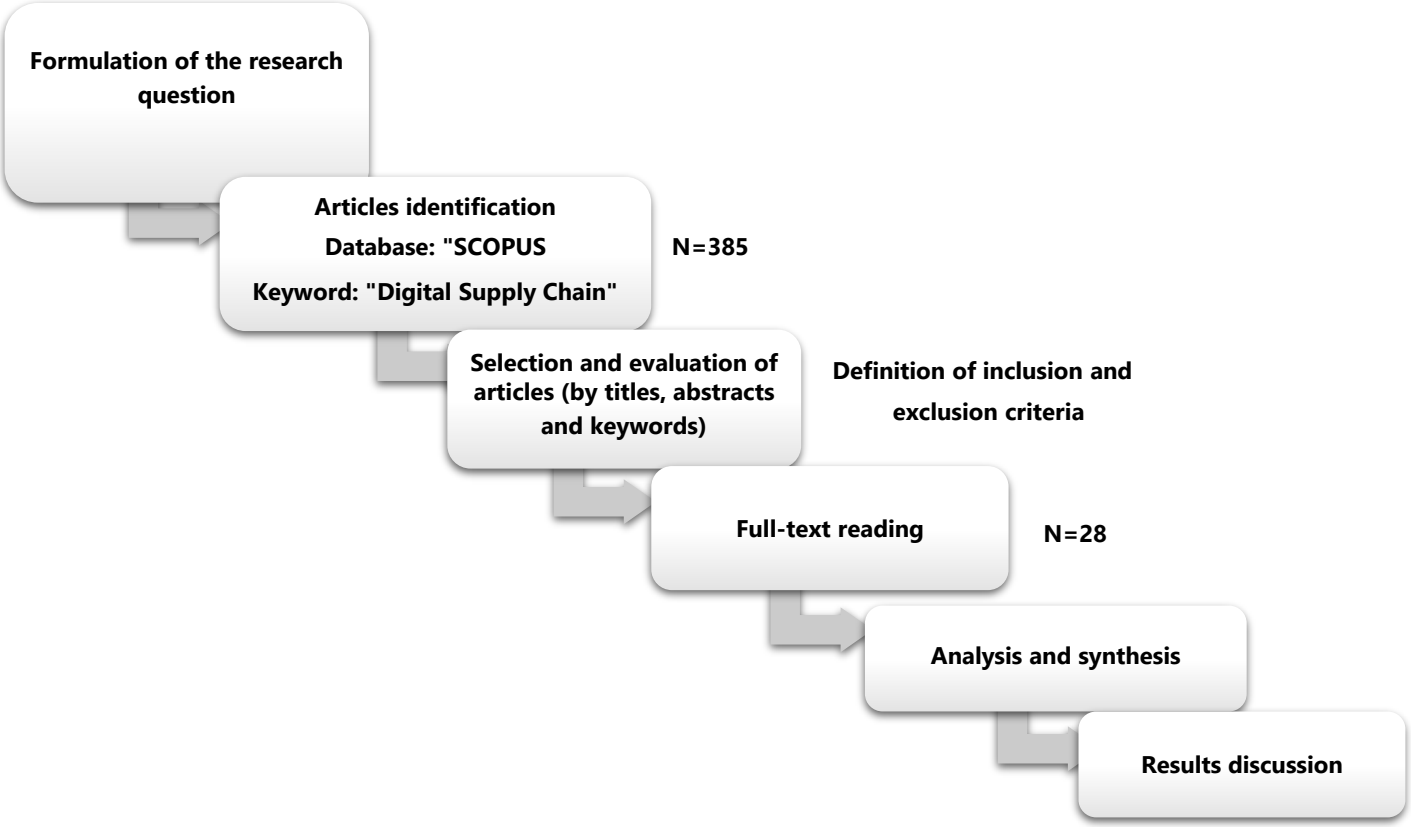
Given the growing scientific interest in supply chain digitalization, it is useful to focus on the main areas of interest in order to guide future research. The existing literature lacks clarity in terms of defining the central structure of supply chain digitization research, the topics covered, those requiring further exploration, how the literature is organized and how the field might progress. A systematic assessment of the literature on supply chain digitalization is therefore necessary to understand its development and theoretical context. This assessment can provide a summary of the body of research and serve as a basis for future studies that will attempt to examine different trends and topics.

This article is organized as follows: this section presents the research area, the study objective and the research context. Section 2 presents the search keyword, filters and inclusion criteria used, and describes the study process. Finally, Section 3 presents the main results of the study, its limitations and possibilities for further research.

2 Methodology

A systematic literature review (SLR) is a well-established examination of the literature that offers transparency, reproducibility, and objectivity (Bryman, 2012). It locates and compiles existing literature in order to draw sound conclusions in a field of research (Boland et al., 2013). The review process was conducted in accordance with the five stages suggested by Denyer and Tranfield (2009): development of research questions; identification of studies; selection and evaluation of studies; analysis and synthesis, and discussion. The main tasks associated with each phase are illustrated in Figure 1 and are described in more detail in the following sections.

Figure. 1 Systematic analysis process



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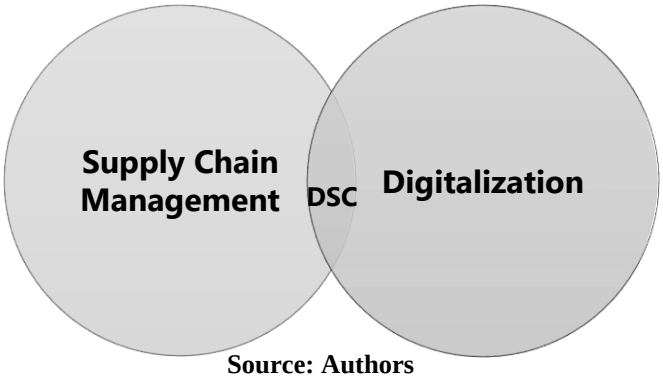
2.1 Formulating the research question

The aim of this first stage is to establish the need and objectives of an SLR. Our first readings of the literature concerning our study problem led us to conclude that a work of synthesis was necessary, given that the objective of the study lies at the meeting point of supply chain management and digitalization, and that these two disciplines are in constant evolution (fig.2). Secondly, our aim is to take stock of what has already been done through conceptual and empirical research on the articulation of these two notions.

Consequently, our objective was distilled into three study questions:

- What literary themes and trends cover the supply chain digitalization (DSC)?
- How has the available literature advanced our understanding of DSC?
- What fundamental ideas or conclusions can be drawn from the existing literature?

Figure. 2 Scope of systematic research



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2.2 Identification of studies

One of the most crucial steps in the process is choosing the data sources from which all relevant publications and research will be collected. The databases to be used must include comprehensive, high-quality articles and surveys that cover the entire research spectrum. In this regard, Scopus is recognized as the primary research source by many SLR articles in the field of SCM (Lamba and Singh, 2017). Unlike other literary resources, Scopus covers more articles and a wider range of domains (Bag and Pretorius, 2020). Many researchers support the use of the Scopus database following favorable experiences (e.g., Zahedi et al., 2016).

Secondly, the usefulness of the literature review depends on how the keywords are defined. We first attempted to use a Boolean search string to include all potential combinations of the two concepts in order to find all articles likely to be related to supply chain digitalization, but the results were not meaningful given that digitalization affects many very different sectors.

This study defined a single keyword as the search criterion, in line with previous systematic literature reviews (e.g., Colicchia and Strozzi 2012). The "*digital supply chain*" was therefore our unit of study.

2.3 Study selection and evaluation

Formulating the search strategy and selection criteria is a crucial step in limiting the number of articles to a level that guarantees the quality of the results. First, it was determined whether the titles, abstracts and keywords of the selected articles corresponded to the study questions. The articles were then read in their entirety, and those that constituted false positives unrelated to the research problem were removed.

Indeed, the establishment of distinct boundaries to frame research is particularly crucial for SLRs. Four significant inclusion and exclusion criteria were established in this respect.

To begin with, we only examined publications in the field of "*Business management and accounting*". This was to eliminate articles irrelevant to the aims of the study (Firmansyah and Umar, 2023), save time and avoid the scope of the study becoming confusing.

Secondly, and in line with Seuring and Müller (2008), only English-language articles were included in the search; publications available in other languages were not considered. According to (Gallo et al., 2021), English is the most widely used language in scientific writing.

Thirdly, although there are many different types of publications, we chose to focus our literature review on academic journal articles, as they can be considered "certified knowledge" (Denyer and Tranfield, 2009) and are the best way to assess the level of knowledge of a research topic (Ramos-Rodrguez and Ruz-Navarro, 2004).

Finally, the number of citations was also used in the present study as an indirect indicator of the relative relevance of works, in order to select the final set of publications to be studied. In line with previous research, the minimum number of citations to be included in the review was set at twenty-five (e.g., Tamm et al., 2011).

At this stage, we did not impose any time constraints to include all potential searches in our list. The database was then subjected to a snowball effect to ensure its completeness. However, no articles were added to our database because they did not match our search criteria or had fewer than 25 citations. In the end, 28 articles were selected.

2.4 Analysis and synthesis

Information was extracted from each study and saved for content analysis. Selected articles were exported to Zotero, a useful program for tagging each article according to its main ideas, taking notes and underlining relevant

information. At the same time, an Excel database containing the following fields was created to code the content of the articles:

1. Article details (title of article, year of publication, authors' names, name of journal, number of citations to article);
2. Research information (link to manuscript web page);
3. An initial assessment (article keywords, digital technologies applied, methodology, research gaps, research questions, main results, future directions);
4. An in-depth review (summary of key ideas, critical analysis).

We thus created a statistical report detailing the evolution of published articles, the number of publications per journal, the geographical distribution and the methodology used. In addition, Microsoft Excel was used to quantitatively analyze the article information and create the various graphical presentations of the results.

3 Presentation of results

The content of the selected articles was analyzed qualitatively through content analysis, which is frequently used and enables evaluative comparisons with predetermined objectives (Drisko and Maschi, 2015).

3.1 Chronological analysis

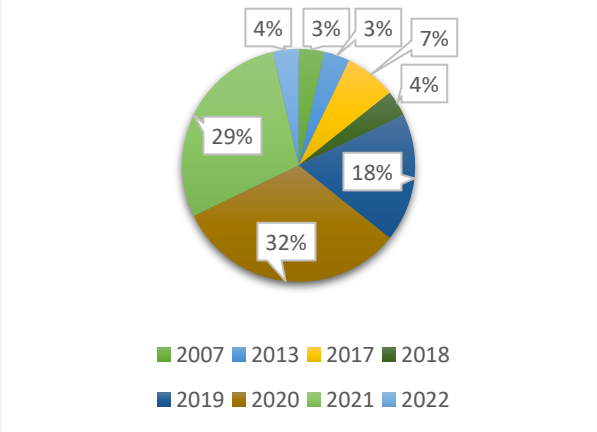
Figure 03 shows the distribution of articles by year of publication. Almost 65% of the 28 articles, or 18 of them, were published within the last three years. While more and more potentially crucial innovative technologies have emerged over the last ten years, it is clear that interest in supply chain digitalization is growing over time.

Indeed, the revolution brought about by digitalization and the advent of a new logistics era has not only changed lifestyles, it has also created a new spirit that could not have been conveyed effectively with the existing means nearly ten years ago.

What's more, as far as COVID-19 is concerned, we can also support developments in 2020. With logistics networks damaged and disrupted by the pandemic, academics and practitioners are increasingly interested in the usefulness of digital technologies for end-to-end supply chain visibility and their potential applications for building resilience.

It should be noted that at the time of updating this research, the 2022 data only covered part of the year.

Figure 03 Evolution of scientific production on DSC



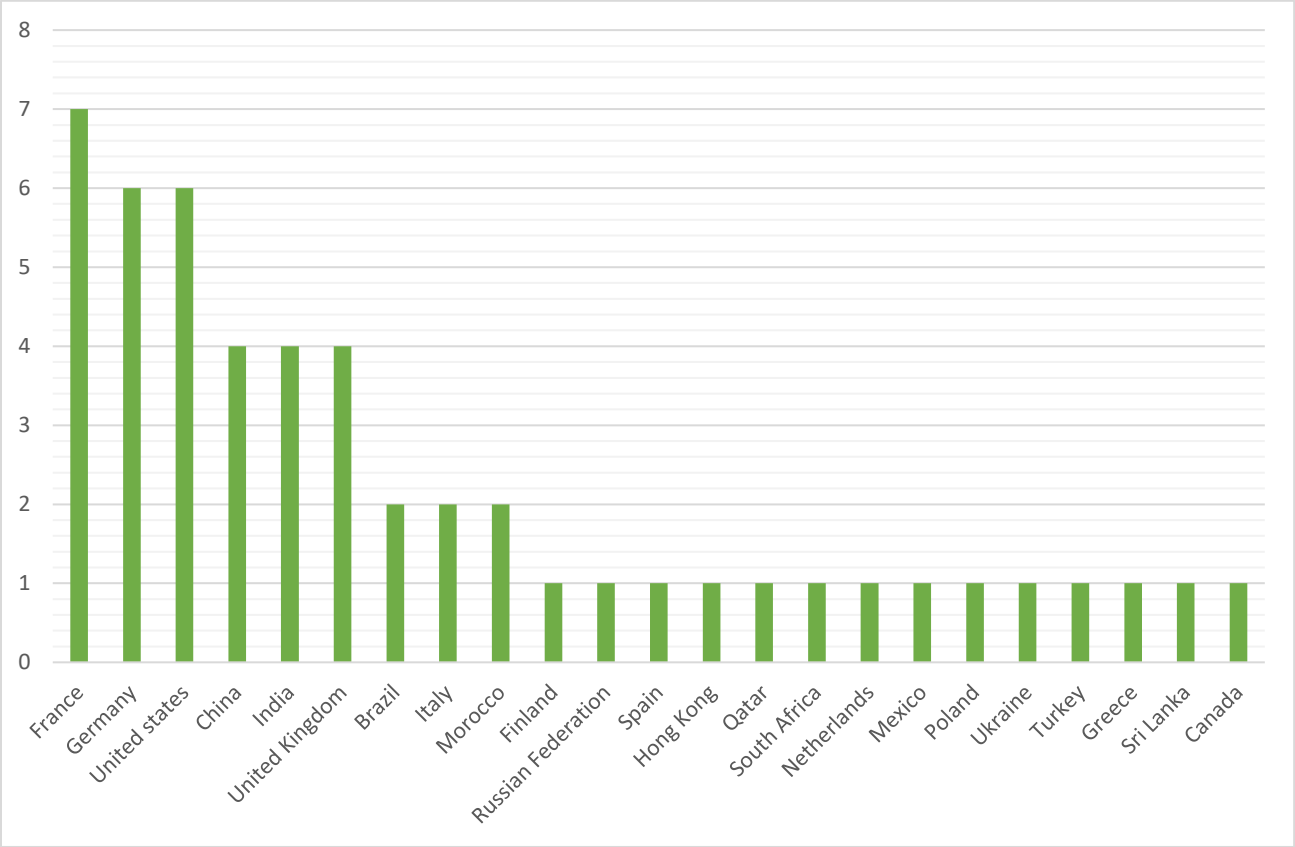
Source: Authors

3.2 Geographical analysis

European countries top the list (fig. 04). This trend can be explained by the fact that several European companies, such as Mercedes-Benz and Volvo, are investing in these cutting-edge technologies. The same is true in Asia, where countries such as China are at the forefront of digitization[2].

What's more, it's clear that the majority of the articles selected come from developed countries, or countries that have invested heavily in digitalization, such as Germany.

Figure. 04 Geographical distribution of scientific production on DSC



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3.3 Research methods

Figure 05 shows that quantitative and conceptual studies outnumber qualitative ones, demonstrating that the phenomenon can still be studied from a qualitative perspective, so that future research can focus more on defining theoretical foundations and proposing comprehensive analytical frameworks.

Surprisingly, we found no mixed empirical studies. The authors mainly adopted a quantitative approach to represent the influence of digitalization on the supply chain, given the substantial extension of technologies in recent years. And for description and understanding in qualitative surveys, they tried to link the digital supply chain to organizational variables.

[2] https://www.fairobserver.com

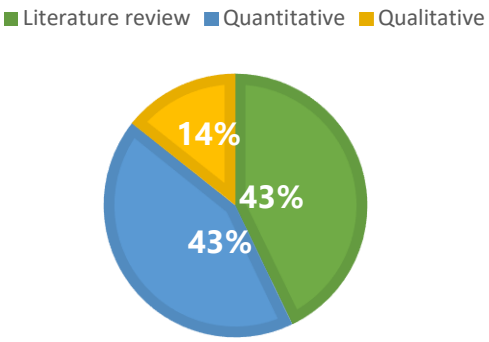
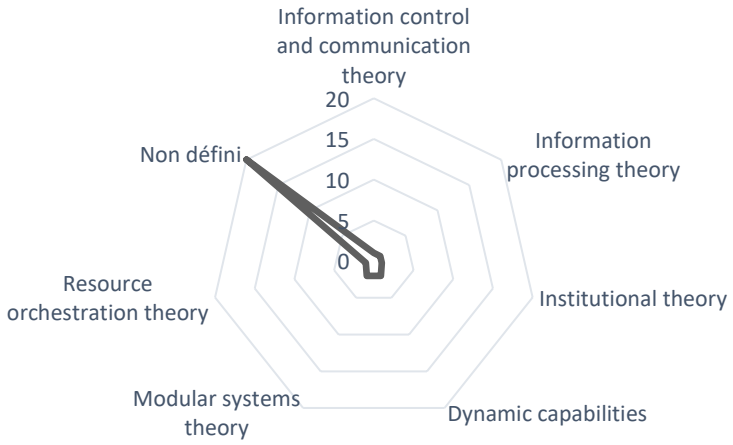


Figure. 05 Methodological approaches used

Source: Authors

3.4 Underlying theories

The theories used in the studies were examined. Surprisingly, 20 papers were not based on any theory, and most



of these were conceptual papers. The analysis also revealed that dynamic capacity theory and modular systems theory were used twice each. The other theories were mentioned only once (fig.06).

Figure. 06 Theories involved

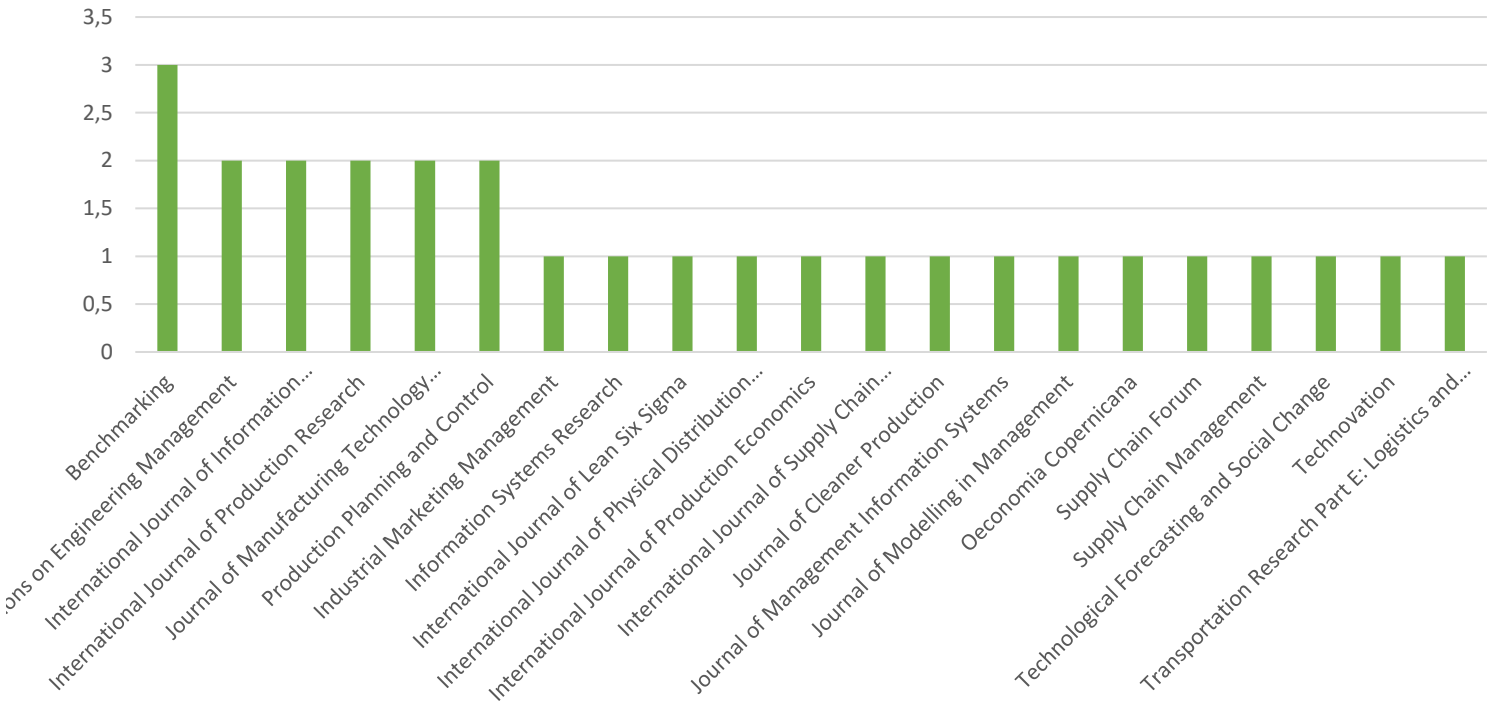
Source: Authors

3.5 Journals of published articles

Figure 07 gives a complete overview of the journals in which the articles listed were published. We can see that the studies are mainly published in several international journals focusing on supply chain management, innovation, manufacturing and so on.

The number of articles published by each journal varies from [1 to 3], so there is no significant variation in the number of articles published in these different journals.

"Benchmarking" is precisely the first and only journal to account for around 11% of all articles published. Five



journals - IEEE Transactions on Engineering Management, International Journal of Information Management, International Journal of Production Research, Journal of Manufacturing Technology Management and Production Planning and Control - occupy second place, each with a share of 7.14%. The remaining journals account for 3.5%.

Figure. 07 Scientific journals dealing with DSC

Source: Authors

4 Interpreting the results

Although few articles have examined the link between the supply chain and digitalization, RSL has nevertheless enabled us to draw conclusions and understand the many aspects of this relationship. The main thematic findings are as follows**:**

4.1 Going digital: from survival to prosperity in the post-COVID-19 world

Many companies and all links in their supply chain, including all stakeholders, have been affected by the rapid and continuous evolution of the world. This dynamic nature has forced companies to innovate, cooperate and rethink their business processes to better adapt to their industry; consequently, this requires the adoption of different technologies and integrated enterprise solutions to manage complicated and complex operations (Majeed and Rupasinghe, 2017).

The fourth industrial revolution has triggered a profound upheaval that now affects all business sectors. Due to fierce market competition and cost demands, supply chains can no longer be repositioned overnight to acquire, manufacture, transfer or sell the right products in the right quantities to the right locations (Zekhnini et al., 2020). As a result, the proliferation of social media platforms and smart, connected gadgets over the past decade has

radically altered the way customers interact with companies and what they expect in terms of multi-channel availability and response (Agrawal et al., 2019).

In addition, disruption risks include events caused by man-made threats such as terrorist attacks or strikes, as well as natural disasters such as hurricanes, earthquakes or floods. Broadly speaking, disruption risks are low-probability but high-impact events whose nature, magnitude and type fluctuate unexpectedly, which are difficult to detect, assess and predict accurately due to their intermittent nature, and which may have long-term negative effects (Hosseini et al., 2019). The COVID-19 epidemic is proof of this. On an unprecedented scale, it has changed the working environment of many companies and logistics networks. A highly turbulent and uncertain climate has forced companies to learn to operate in this context (Ivanov, 2021).

As a result, organizations need a digital supply chain focused on visibility, sustainability and improved customer experience to meet these challenges (Zekhnini et al., 2020).

4.2 Digital supply chain: clarification and foundations

Academics and professionals alike are focusing on the evolving concept of the "digital supply chain". It is one of the most dynamic and disruptive developments in the industry, directly influencing the way manufacturers, distributors, retailers, and logistics service providers manage their operations (Haddud and Khare, 2020). Agrawal et al. (2019) indicate that one of the areas companies should focus on when it comes to digitalization is the supply chain.

DSC is also the subject of a plethora of definitions in the literature. Those discovered in the course of this study are presented in the table below (table 1).

Table.1. DSC definitions

Définitions	Références	Cited in
"[...] a value-driven intelligent network that leverages new approaches with technology and analytics to create new forms of revenue and business value, through a centric platform that captures and maximizes the use of real-time information emerging from diverse sources."	(Kinnett, 2015)	(Garay-Rondero et al., 2019)
"A technological, intelligent and optimal system based on massive data processing capability and excellent cooperation and communication for hardware, software and digital networks to support and synchronize interaction between organizations and make services more useful, accessible and affordable with consistent, agile and efficient results."	(Büyüközkan and Göçer, 2018)	(Queiroz et al., 2019 ; Garay-Rondero et al., 2019 ; Nasiri et al., 2020 ; Haddud and Khare, 2020 ; Agrawal et al., 2019)
"It involves the adoption of sophisticated, intelligent technological capabilities to make	(Haddud and Khare, 2020)	-

supply chains more connected, collaborative and efficient."		
"It refers to the exchange of information between supply chain players to improve communication and integrate various manufacturing processes to create a seamless system."	(Eljazzar et al., 2018 ; Chaudhary et al., 2018)	(Haddud and Khare, 2020)
"DSC is based on the industry 4.0 concept whereby companies seek to fully implement digital technologies throughout the supply chain."	(Premkumar et al., 2018)	(Haddud and Khare, 2020)
"DSC is a customer-centric platform model that acquires and exaggerates the use of data over time, from multiple sources and enables demand detection, matching and stimulation to optimize performance and mitigate risk."	(Centre for Global Expertise, 2015)	(Agrawal et al., 2019)

Source: Authors

We can conclude that all the definitions, whether proposed by the author himself or based on previous work, have something in common. Indeed, the authors advocate that supply chain digitization involves the adoption of new, sophisticated and intelligent technological capabilities to improve the supply chain.

For example, the definition of (Büyüközkan and Göçer, 2018) underpins the authors' understanding of DSC (Nasiri et al., 2020; Garay-Rondero et al., 2019; Queiroz et al., 2019, Haddud and Khare, 2020; Agrawal et al., 2019). This definition implies a set of stakeholders and new technologies that organizations need to adopt to achieve the best results.

Consequently, a combination of new digital tools, techniques and approaches is required for the digital supply chain. For many players in the ecosystem, including companies and their suppliers, workers and customers, it offers increased accessibility to information and interaction, exponentially better communication and collaborative productivity.

4.3 Digital technologies: a range of tools and applications

The development and implementation of digital technologies has become one of the most controversial issues in academic and professional circles. The literature reviewed includes 14 key digital tools, each the subject of at least one article (see Table 2). These tools are changing the supply chain to better anticipate and respond in real time to stakeholder demands.

Table.2. Digital technologies

Technologies	Authors	*Description/definition*
Digital twins	(Hosseini et al., 2019 ; Ivanov and Dolgui, 2021 ; Cavalcante et al., 2019)	A DIGITAL TWIN is used for real-time control and decision-making. It strengthens the physical supply chain and provides end-to-end data visibility (Hosseini et al., 2019).

Blockchain	(Cole et al., 2019 ; Cavalcante et al., 2019 ; Garay-Rondero et al., 2019 ; Queiroz et al., 2019 ; Müßigmann et al., 2020 ; Gupta et al., 2020 ; Zouari et al., 2020 ; Zekhnini et al.,2020 ; Krykavskyy et al., 2019 ; Annosi et al., 2021)	Blockchain is a data structure that links data records, called blocks, into a single chain. It is essentially a distributed database system that stores transactional data or other information, secured by encryption (Cole et al., 2019).
Machine learning (ML)	(Cavalcante et al., 2019 ; Zouari et al., 2020)	This is a sub-domain of artificial intelligence. Machine learning (ML) enables computers to learn without explicit programming. In other words, it studies how computers can learn directly from data and solve problems (Zouari et al., 2020).
Cloud computing (CC)	(Cavalcante et al., 2019 ; Li et al., 2020 ; Ghadge et al., 2020 Garay-Rondero et al., 2019 ; Queiroz et al., 2019 ; Agrawal et al., 2019 ; Zouari et al., 2020 ; Zekhnini et al.,2020 ; Krykavskyy et al., 2019 ; Haddud et al., 2020)	It is a concept that enables networked access to a shared pool of reconfigurable computing resources anywhere, anytime and on demand (Zouari et al., 2020).
Internet of things (IoT)	(Cavalcante et al., 2019 ; Li et al., 2020 ; Ghadge et al., 2020 ; Majeed and Rupasinghe 2017 ; Garay-Rondero et al., 2019 ; Queiroz et al., 2019 ; Bechtsis et al., 2018 ; Agrawal et al., 2019 ; Gupta et al., 2020 ; Zouari et al., 2020 ; Zekhnini et al.,2020 ; Yang et al., 2022 ; Krykavskyy et al., 2019 ; Haddud et al., 2020)	The term "Internet of Things" refers to an information technology infrastructure that makes physical elements interconnected and enables data to be collected and sent between devices (Li et al., 2020).
Big Data	(Cavalcante et al., 2019 ; Li et al., 2020 ; Queiroz et al., 2019 ; Agrawal et al., 2019 ; Zouari et al., 2020 ; Zekhnini et al.,2020 ; Cheng et al., 2021 ; Yang et al., 2022 ; Krykavskyy et al., 2019 ; Haddud et al., 2020 ; Annosi et al., 2021)	Researchers characterize megadata in terms of the "7 Vs", standing for "volume", "velocity", "veracity", "variability", "variety", "volatility" and " volume" (e.g., Belhadi et al., 2020). Big data enables the use of sophisticated IT tools and structures to collect, store, extract and analyze huge volumes of data as part of decision-making processes (Wamba et al., 2015; cited in Edwin Cheng et al., 2021).

RFID	(Cavalcante et al., 2019 ; Li et al., 2020 ; Ghadge et al., 2020 ; Majeed and Rupasinghe 2017 ; Zouari et al., 2020, Krykavskyy et al., 2019)	Radio frequency identification is a technology that increases visibility throughout the supply chain by capturing and providing up-to-date information in real time (Majeed and Rupasinghe, 2017).
AI	(Ghadge et al., 2020 ; Garay-Rondero et al., 2019 ; Queiroz et al., 2019 ; Zouari et al., 2020 ; Yang et al., 2021 ; Krykavskyy et al., 2019 ; Annosi et al., 2021)	Artificial intelligence (AI) is the term used to describe programs or devices that resemble the human intellect to perform tasks and can iteratively improve based on the data they receive (Zouari et al., 2020).
Autonomous robot	(Ghadge et al., 2020 ; Garay-Rondero et al., 2019 ; Queiroz et al., 2019 ; Gupta et al., 2020 ; Zouari et al., 2020 ; Krykavskyy et al., 2019)	It is a predefined software instance that uses business rules and an established activity choreography to complete the autonomous execution of several processes, activities, transactions, and tasks in one or more independent software systems to deliver a product or service (Zouari et al., 2020).
Additive manufacturing/3D printing	(Ghadge et al., 2020 ; Garay-Rondero et al., 2019 ; Gupta et al., 2020 ; Zouari et al., 2020 ; Zekhnini et al.,2020 ; Krykavskyy et al., 2019 ; Haddud et al., 2020)	3D printing or additive manufacturing is used to create 3D objects layer by layer (Ghadge et al., 2020). In other words, it's a process that creates three-dimensional solid objects from a digital file (Zouari et al., 2020).
Simulation	(Ghadge et al., 2020 ; Gupta et al., 2020)	Simulation is frequently used in business models to exploit already accessible real-time data and to reproduce the real world of work in a virtual environment. (PwC, 2016 ; cited in Ghadge et al., 2020).
Business intelligence (BI)	(Ghadge et al., 2020)	Are technological platforms used to collect, analyze, store and present enterprise data from a wide range of sources (Mulcahy, 2007).

Augmetend reality (AR)	(Garay-Rondero et al., 2019 ; Gupta et al., 2020 ; Zouari et al., 2020 ; Zekhnini et al.,2020)	Using computer-generated perceptual data, augmented reality is an interactive experience that enhances the real world. Simply put, it's the addition of audio, visual or other inputs to a real environment to modify it (Ghadge et al, 2020).
Virtual reality (VR)	(Zouari et al., 2020)	A computer-generated environment known as virtual reality (VR) contains images and objects that appear authentic, giving the user the impression of being surrounded by the environment. In other words, virtual reality is the process of superimposing computer simulation models onto the real, physical architecture of the world (Zouari et al., 2020).

Source: Authors

Traditional supply chains are being impacted by digital technologies, accelerating the transition to digital supply chains. As Table 9 shows, publications cover a wide range of technologies, indicating that supply chain managers can adopt several digital technologies at once.

These technologies enable companies to better understand customer preferences, create real-time visibility of their operations and build a more agile and flexible supply chain (Choudhury et al., 2021). The result will be greater product efficiency and availability, reduced costs, and delivery times and, above all, sustainable growth (Calatayud et al., 2019; cited in Agrawal et al., 2019).

4.4 Relationship between DSC and supply chain resilience

We were not surprised by this theme, covered by several articles, given that supply chain resilience has received particular attention over the last two years due to the pandemic context.

Indeed, disruptive incidents affect supply chain operations not only directly, but also indirectly. The ripple effect caused by such events can spread throughout the supply chain (Ivanov and Dolgui, 2020). For this reason, authors have characterized supply chain resilience as a dynamic supply chain capability, necessary to operate in an unpredictable environment (Zouari et al., 2020).

Furthermore, resilience is defined by consensus among authors. For example, (Zouari et al., 2020) define it as a company's ability to endure, adapt and grow in the face of disruptive change. The notion of resilience applied to supply chains is particularly interesting for examining the adaptive capacity of coupled physical and informational processes constantly exposed to risk.

In addition, the authors examine the link between digital tools and resilience, arguing that it is complex to determine how digitization affects supply chain resilience. They draw attention to the value of descriptive and

predictive data analysis in improving the visibility and accuracy of forecasts and the activation of contingency plans (Zouari et al., 2020).

Similarly, as data becomes more accessible through blockchain, the Internet of Things and cloud computing, managers can employ intelligent decision-making principles to deal with uncertainty (Cavalcante, et al., 2019).

4.5 Impact of digitalization on the supply chain

The application of new technologies in traditional linear supply chains is shifting SCs from a static to a dynamic succession. In other words, technological advances are focusing on transforming linear SCs into a continuous, dynamically connected digital network, revolutionizing the way companies exchange and share data and resources. Indeed, digital technology helps companies solve diverse problems, develop new opportunities and gain competitive advantage. They offer both versatility and efficiency. The robust, secure and sustainable SCs that businesses need can be built using new instrumentation, interconnection and intelligence technologies (Zekhnini et al., 2020).

Smarter SCs would use intelligent modeling to make sense of the information they actually need. Greater flexibility, higher quality standards, efficiency and productivity are the main benefits (Zekhnini et al., 2020). The long-term goal is primarily focused on improving and developing end-to-end processes between companies, their consumers and suppliers. As a result, digitization can improve productivity and minimize both inventories and time cycles (Cole et al., 2019).

Blockchain promises, for example, to offer extremely secure and irreversible access to supply chain data. Every transaction is traceable and identifiable at all times, and once an entry has been encoded, it is difficult to modify. RFID has also been touted as a means of increasing supply chain transparency and solving problems such as product counterfeiting (Cole et al, 2019). Numerous real-life examples, such as those from Amazon, Dell and Lenovo, show that digital processes are now improving efficiency and collaboration within the supply chain, and creating significant economic benefits by improving cross-border connectivity and integrating different organizational resources and capabilities.

4.6 The role of Industry 4.0

The Germans were the first to introduce Industry 4.0. A wide range of scientists, researchers, consultants and businesspeople from all over the world have come to understand the term and give it a profound meaning. Industry 4.0 today refers to the global digitalization of industrial production (Krykavskyy et al., 2019).

Cutting-edge technologies are linked to the industry 4.0 paradigm. In this respect, a central feature of Industry 4.0 involves intelligent implementations that promote transparent communication. This communication is primarily facilitated by technologies such as the Internet of Things, artificial intelligence and Big Data (Krykavskyy et al., 2019).

From this perspective, it is clear that the components of Industry 4.0 have the ability to act independently and have their own consequences. New connections between people, objects and systems have emerged with the advent of Industry 4.0. These connections have made supply chains much more complex, especially when it comes to rethinking and reorganizing their capabilities to adapt to the digital age (Queiroz et al., 2019).

It's worth noting that during the first industrial revolution, mankind used steam, waterpower and machinery for production. After the second industrial revolution, when mass production began, factories had assembly lines and electricity was essential to their operation. The third industrial revolution saw the development of computerized

automation, which enabled technological automation of part of the production process. Prior to the development and widespread adoption of sophisticated systems, information and communication technologies in the industrial sector were also widely adopted, blurring the distinction between the physical and digital worlds (Majeed and Rupasinghe, 2017).

Consequently, the effects of Industry 4.0 can be seen at different levels of the supply chain as well as in its management; for example, more accurate forecasting and planning through integrated flows and increased traceability of materials and products, improved supplier performance through real-time information sharing, and intelligent systems for vehicle storage and routing (Ghadge et al., 2020).

5 Conclusion

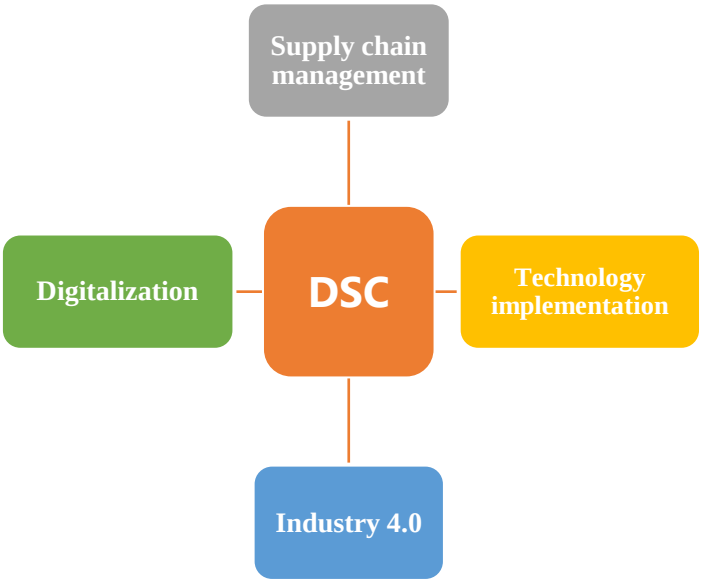
In this concluding section, the most significant results of the research will be highlighted, and some areas for further investigation will also be suggested.

Despite the burgeoning literature in this field, holistic and comprehensive approaches, strategies and frameworks are lacking. This essay has shed a broader light on the digital supply chain and the issues that arise in this field. It proposes a theoretical scheme (fig.8) based on a literature review of the identified articles and their references (for example, Büyüközkan & Göçer, 2018).

Due to the exponential growth of digital technology, business operations, particularly supply chain activities, will continue to be highly digitized. Specialized companies are often under enormous pressure to establish strategies for coordination, cooperation, integration, digitization and use of appropriate technologies in order to respond rapidly to customer demand.

Implementing technologies enables improvements and increases an organization's flexibility, agility and adaptability. The technologies used provide real-time, visible and transparent information that improves forecasting, production planning, order fulfillment and response to disruptions.

Figure. 8 Proposed framework for DSC development



Source: Authors

The beginning of the DSC process is usually marked by the transition to digitalization. To support and accelerate this digital conversion, companies need to draw up their own digitalization plan. This is a fundamental basis,

describing possible business models for future achievements. In other words, digitalization strategies must be focused and based on the exploitation of existing digital capabilities. It's not just a question of supporting the digitalization process, but also of capitalizing on the benefits it brings.

It should be emphasized that technology implementation is distinct from the digitalization process, which is aimed at effective integration. For implementation to be successful, new technologies must be judiciously exploited to improve supply chain efficiency. A comprehensive assessment of these key technologies is essential, as strengthening logistics networks is an ongoing activity (Büyüközkan & Göçer, 2018).

Restructuring a logistics network requires complex decisions over a long period of time. It is essential to master supply chain management in order to make these decisions in line with logistics objectives. Meeting demand, generating customer value, developing responsiveness and building a solid network are all priorities to be taken into account when formulating a successful supply chain management strategy.

The entire supply chain is in a state of flux with the integration of Industry 4.0 into the manufacturing sector. It is essential that suppliers, producers and customers work together to promote transparency throughout the process. It is therefore imperative for DSC to prioritize Industry 4.0-related technologies.

Notwithstanding the importance of these findings, it is imperative to acknowledge several inherent limitations of the research. First and foremost, linguistic limitations may result in the marginalization of significant works written in other languages, which would reduce the range of perspectives. Furthermore, the emphasis on academic articles may omit some types of pertinent information, including industry reports or case studies, which would limit the overall scope of this research. Moreover, the 25-citation threshold may exclude creative but under-cited papers, which would restrict the inclusion of interesting studies in a rapidly developing subject.

Given these limitations, an interesting approach would be to examine trends in greater depth, placing them in a post-2022 perspective and paying particular attention to current technological advances, as well as economic and regulatory changes. At the same time, a comparative sector analysis can provide useful information on the specific characteristics and challenges of many industrial fields. In addition, an in-depth look at practical examples of digitalization solutions implemented in real companies would be useful to document real-world lessons learned, as well as successes and failures.

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