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Is there a theory of supply chain resilience? A bibliometric analysis of the literature

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Abstract

Purpose – This study aims to identify the past, present and future lines of research in the supply chain resilience (SCRES) literature and to answer the question of whether resilience is "just another" supply chain (SC) concept or if it constitutes its own theory.

Design/methodology/approach – This study involves a bibliometric analysis of 1,596 research articles published in the Web of Science Core Collection™ database between 2004 and 2021, with a focus on: publications and citations per year, co-citations of articles and authors, co-occurrences of the keywords used and thematic development. Seven SCRES experts have also analysed and discussed the research results.

Findings – The results show how resilience has become one of the main thematic blocks of SC research in the aftermath of the COVID-19 pandemic, with a 62.04% increase in academic publications. Despite the abundant literature, there is still no overarching theory of SCRES. One possible hindrance to the creation of such a theory is the variety of existing definitions and models of SCRES. This research identifies this as a shortcoming that future studies should address. As the results show, the combination of SCRES with other fields, such as engineering and ecology, can help in constructing a global theory of SCRES.

Originality/value – Bibliometric analysis is used to confirm the SCRES literature gap in the development of an overarching theory, although resilience constitutes one of the main thematic blocks of the SC literature.

Keywords Supply chain resilience, COVID-19, Bibliometric analysis, Co-occurrences of keywords, Engineering, Ecology

Paper type Research paper

1. Introduction

Over the last few years, the supply chain (SC) literature has strengthened its focus on supply chain resilience (SCRES) to understand how SCs have been managed in the context of one of the largest, most unprecedented shocks ever experienced: the COVID-19 pandemic (Cohen, 2020). The coronavirus affected all global activities in different economic sectors and industries, mostly due to the disruption caused by government lockdowns imposed to stop the spread of the virus among the population. The transportation and logistics sector was partially paralysed by the lockdown measures (Castillo *et al.*, 2022) and SC activities, which often depend on this sector, were the first to be affected. This had a negative impact on future business operations in different markets around the world (Handfield *et al.*, 2020; Knight *et al.*, 2022). Because SCs have never been exempt from disruptions, which jeopardise their efficiency, the literature has explored their ability to withstand these disruptions and recover functional capacity after such occurrences (Min *et al.*, 2019). Interest in the SCRES concept has increased exponentially since the COVID-19 pandemic, as shown by the large number of recent academic publications on this topic (e.g. Azadegan and Dooley, 2021; Gunessee and Subramanian, 2020; van Hoek, 2020).

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Given this increase in SCRES academic publications and to lay the foundation for future research in this context in the post-COVID era, the objective of this research is to conduct a bibliometric survey of the literature on the development of SCRES to understand its past, present and future lines of research and thereby answer this research question: *Is resilience just another concept in SCs, or does it have its own theory?* This is an especially relevant topic because despite the development of SCRES and discussions about it, existing studies do not provide a comprehensive picture of the state of resilience, so there is a gap in encompassing it as a concept within SC research or as a theory of its own. In contrast to existing systematic literature reviews, this research allows not only for identifying the state of the literature but also knowing all the thematic streams used in SCRES in combination with other fields. A global picture of the SCRES context allows future research to establish the basis for filling the literature gap: the development of a SCRES theory. To meet this objective and answer the research question, a bibliometric analysis was performed. This choice was based on the consideration that bibliometric analysis allows for a global analytical approach to the SCRES literature by identifying the key terms contained in studies in the field, thereby helping establish the main thematic clusters and recognise both its development over time (Denyer and Tranfield, 2009) and its relationships with other fields (Ivanov *et al.*, 2019; Moore and Manring, 2009). This allows for an examination of the development of SCRES to determine its status – whether it is a concept or a theory.

In total, 1,596 articles published in the Web of Science (WoS) database between 2004 and 2021 were analysed, which constituted 86.79% of the total number of published articles about SCRES. The articles were analysed through Bibliometrix, which can be run as a package of the free R software. This allows for obtaining an overall picture of the state of the SCRES literature and observing its development over the years to determine whether it is just a concept or a theory in its own right. To this effect, the scope of this research comprises only publications in the WoS database covering the period 2004–2021 and excludes some articles published in other databases, such as Scopus or Google Scholar. The reason for this is that bibliometric analysis programmes do not currently allow for working with data extracted from different bibliographic databases.

The results of this research were discussed with seven recognised academic experts in SCRES, which allowed their experiences to be incorporated in the analysis and for the conclusions to be discussed with them. First, the results show that resilience has become one of the main thematic blocks of SCs over the last two years. Over the 17-year period covered by the study, almost half of all the SCRES articles were published during the COVID-19 pandemic. Second, despite the extensive literature on SCRES and all its definitions, no solid overarching theory exists. This is one of the most important findings of this research because it identifies a crucial gap that future research will need to address to further advance the development of SCRES. Third and related to the second point, perhaps one of the most significant steps for the development of its own theory is to combine the SCRES literature with insights from other fields, such as engineering and ecology, taking the ways that they have developed their own theories as examples.

The research findings identify resilience as one of the main thematic blocks of SCs, generating a multitude of related academic articles that propose various definitions of the concept and different models explaining its framework for action. It is precisely this lack of consensus on the definition of SCRES that may explain why a global theory for SCRES has not yet been proposed. However, it is also important to bear in mind that as in any other mature research area, there are always different schools of thought, so this division is to be expected in this continuously developing field.

This article is divided into five sections. Section 1 covers the introduction. Section 2 details the literature review. Section 3 explains the methodology used to conduct the research. Section 4 presents the results, with the analysis and discussion. The article ends with Section 5, which includes the main conclusions, limitations and suggestions for future research.

2. Literature review

The interest in SCRES-related research has grown in recent years, especially due to the disruptions resulting from globalisation and affecting SCs (Sheffi, 2015). This interest has shown companies and researchers that unforeseen disruptions facing global SCs are now more complex than they were previously, requiring new strategies to deal with them (Fiksel *et al.*, 2015; Pettit *et al.*, 2013). As SCs experience new disruptions, as has recently been the case with the COVID-19 pandemic, there is a need for novel approaches and reflections on SCs to insulate them from these disruptions and make them more resilient (Christopher and Holweg, 2011). The SCRES literature has been built on over time, according to the disruptions that have occurred throughout the history of SCs and have adversely affected them – including diseases, natural disasters, economic downturns and other unforeseen situations – prompting research on their resilience (Annarelli and Nonino, 2016). The following subsection provides a brief review of the development of SCRES in the literature, its relations with other fields and future research projections in the post-pandemic context.

2.1 Definition of SCRES in the literature: development and relations with other fields

Resilience first appeared in the literature in the field of engineering, especially referring to the resistance of the materials used (e.g. Guillet and Bernard, 1913). One of the best-known works for its subsequent implications for other fields is Holling's (1973) article, wherein the concept of resilience was introduced in the context of ecology and the survival experience of living beings in nature, some as prey and others as predators in the life cycle. Thus, resilience was identified as the ability to prevail in a system and adapt to change in order to continue to survive. Based on this initial premise, subsequent studies broadened the scope of resilience from wildlife to social relationships among humans, thus forming socio-ecological scenarios. The concept of resilience in the SC context was first used in research conducted between 1998 and 2003, but there was no clear definition of the SCRES concept (e.g. Gokhale, 1998; Rice and Caniato, 2003). It was not until 2004 when the first definition was established in the literature as the ability of a system (SC) to return to its original state or move to a new desirable state following a disturbance (Christopher and Peck, 2004). This definition was expanded some years later to include not only the ability to return to the initial state or adapt to change but also the requirement for the acquired new state to be better than the initial one (Ponomarov and Holcomb, 2009). The first definitions of SCRES were based on previous research on resilience in the field of engineering, forming the fundamental basis for its subsequent implementation in SCs (e.g. Sheffi and Rice, 2005). To this effect, resilience can be considered a multidisciplinary and multidimensional phenomenon that can range from physical research to management theory. As mentioned above, resilience has been defined and used in different fields and disciplines in the literature (Shishodia *et al.*, 2021), all of which use the same common concept for its definition: resilience helps in managing or coping with any change or disruption to a system so that it can later return to its original condition or adapt to the new situation. Moreover, the literature shows that it is precisely in the SCRES context that the fields that have been used most are those related to engineering and ecology.

Regarding the interpretations of resilience in the literature, one of the most prominent and widely used is that of Holling (1996). The author, an ecologist, distinguished between engineering resilience and ecological resilience. The first is related to the fail-safe design necessary to protect an engineered system. The second involves the design to protect an organism, so it can persevere and adapt to the environment. However, the SC literature has been based on the engineering interpretation of resilience, considering that the SC system, after a perturbation, should return to its previous state (Sheffi and Rice, 2005). Thus, it has been implicitly assumed that SCs behave as engineered systems. This explains the paucity in the literature that addresses SCs as ecological systems. The difficulty in reinterpreting an SC

from the perspective of ecology is that it is insufficient to replace an engineered system with an ecological one, since all the involved parties that contribute to the disruption, as well as its resolution, must be taken into account. Wieland (2021) proposes an interpretation of an SC as a socio-ecological system. Although it is true that it does not identify with the ecological interpretation, it takes into account the actors involved in SCRES and maintains the idea that after a disruption, the SC system does not necessarily have to return to its previous state or to a stable equilibrium. Specifically, it is the function of the social actors involved to guide the SC system towards its transformation after disruptions (Walker, 2020).

As for the engineering resilience perspective, it is based on efficiency and has a control-oriented approach or capabilities, in addition to contingency planning, in other words, a continuity plan to respond to unforeseen events through communication and information technology (Adobor and McMullen, 2018). Engineering resilience therefore focuses on the robustness of a system close to equilibrium and the ability to restore it to that state (Wieland, 2021). From this perspective, the resistance to equilibrium disturbance and the speed of return to normality are the measures of resilience (Davoudi *et al.*, 2013). SCRES engineering focuses on the planning, operation and design processes of SCs, dealing with areas such as the distribution of goods and pricing. The method of sourcing labour, raw materials and other resources is highly dependent on the resilience of SCs. SCRES engineering and related concepts are consistent with the notion of resilience and the SC system's ability to maintain a critical structure after a shock. SCRES engineers strive to augment, analyse and carry out the various activities required to meet their companies' needs and business requirements. These include reviews of SC operations, proper records management and the facilitation of the distribution of goods, which all help build strong vendor relationships (Campanella, 2006). Without an engineering approach, it would not have been possible to resume production operations in SCs during the COVID-19 pandemic (Modgil *et al.*, 2021).

The ecological resilience perspective arises from the failure of the engineering resilience approach in some life situations, where it is not always possible to accurately measure the speed of recovery and the stability of the situation in the face of a perturbation (Holling, 1986; Wieland, 2021). Thus, the ecological resilience perspective measures the number of unforeseen and critical situations that a system can withstand before reaching its limit (Simmie and Martin, 2010). To this effect, ecological resilience consists of adapting to changing environments by using different strategies, applying diversity and distribution of resources in different areas or locations to avoid system collapse (Adobor and McMullen, 2018). As far as SCs are concerned, they do not usually behave as engineered systems and although it cannot be stated that they function as ecological systems, they do match the latter's adaptive cycle in the face of a disruptive event (Wieland, 2021). For this reason, the interpretation of socio-ecological resilience seems to fit better with the SC system, since SCs depend not only on themselves but also on their social environment, which can either be the propellant of disruptions or the solution provider (Walker, 2020). The social actors that relate to the SC system have the task of guiding its transformation towards a desirable state (Davoudi *et al.*, 2013). Thus, from this socio-ecological resilience perspective, the SC system's degree of resilience is defined as the magnitude of the disturbance that can be absorbed before structural changes occur in the system (Wieland and Durach, 2021).

The impact of disruptions in the SC system has been one of the focal points of much SCRES research conducted in recent years. In terms of ecosystem disruption, the most beneficial effect is that ecosystems do not revert to their original forms but adapt to new configurations (Novak *et al.*, 2021). In this sense, the COVID-19 pandemic has taught the world about the importance of awareness and structural preparedness, as well as the adoption of ethical responsibilities to improve SCRES in order to cope with disturbances. The stresses created in socio-ecological systems will require a systemic approach to ecological sustainability and resilience for effective improvements of global

social, human and ecological health (Zabaniotou, 2020). Although this thematic comparison of the SCRES literature over time is discussed in more detail in the next two subsections, the existing literature shows a shift in the focus on SC resilience following the outbreak of the COVID-19 pandemic (Ivanov and Dolgui, 2020; Paul *et al.*, 2021). The following two subsections review the main topics of studies on SCRES before and after the pandemic to establish the theoretical basis for this research.

2.2 Pre-pandemic literature: what was the focus of SCRES research?

The outbreak of the COVID-19 pandemic in 2020 marked a turning point in societies worldwide and in all areas of research in the academic world (e.g. Sohrabi *et al.*, 2021). As shown in Subsection 2.3, in the SCRES context, the research has focused on the pandemic's impacts on SCs by examining the topic from different perspectives, such as engineering – with the use of technology in the SCRES field (Hussain *et al.*, 2021) – or from an environmental standpoint, taking advantage of the disruptive circumstances of the pandemic to convert SC models into more sustainable systems (Klymenko and Halse, 2021). Hence, the SCRES literature published since the COVID-19 pandemic has mainly focused on how it has affected SCs and what transformation SCs need to undergo as a result. Therefore, the literature presumes that change is occurring and that post-pandemic SCRES will be different from its previous state. Nonetheless, what was the focus of SCRES studies prior to the pandemic?

In the early days of SCRES research, the concept was mainly used to measure organisational efficiency within the thematic block of management (Barker and Santos, 2010). In other words, it was an indicator used mainly to assess the state of organisations once the disruptions had passed. Over the years, the literature began to attach more importance to SCs and to analyse their levels of resilience during disruptions to improve SCs in situations of uncertainty and change. To this effect, the studies focused on strategies to achieve SCRES not only in a reactive way, adapting the SCs once the changes have already occurred, but also from a proactive stance, contemplating robust SCs capable of adapting to changes before disturbances occur (Durach *et al.*, 2015). At that time, SCRES began to relate the concept to the risk of SC disruptions and in particular, to the ways to avoid them (e.g. Cantor *et al.*, 2014; Chang *et al.*, 2015). This vulnerability of SCs to disruption can be measured mathematically in terms of "risk", which integrates the likelihood of an incident and its associated consequences (Pettit *et al.*, 2010). Thus, the SCs' resilience capacity significantly mediates the influence of risk (Um and Han, 2020). This development prompted a proliferation of SCRES and risk management research, given that more awareness and education were needed in this context to ensure that companies used the theory as part of their risk management (Colicchia and Strozzi, 2012). However, the extant literature showed a low level of awareness of SC risks in many countries and the inevitability of SC disruptions, despite the existence of research on the subject (Gunessee *et al.*, 2018). SCRES depends on organisations that are able to control disruptions to their SCs (de Sá *et al.*, 2019). The growth of SCRES studies increased interest in how to avoid risk and uncertainty, largely due to the globalisation of the economy, the emergence of new technologies in industry and organisations' search for more efficient SC systems (Ali *et al.*, 2017). However, the literature showed a lack of both empirical knowledge on SCRES and responses to the uncertainties generated for SCs by the current challenges they face (Ali and Gölgeci, 2019).

As a general summary of the pre-pandemic SCRES literature, up to nine underlying research areas in SCRES can be identified, which all researchers should consider when approaching a SCRES study. These nine areas are fully identified in the research by Shishodia *et al.* (2021): (1) conceptual development of SCRES, (2) SCRES network design development, (3) identification of SC vulnerability drivers and SC risks, (4) impact of risks on network resilience, (5) risk assessment to avoid disruptions, (6) measurement of resilience

approaches/drivers to improve SC performance, (7) resilience capacity building by integrating other SC dimensions, (8) SC network quantification and (9) resilience building in SC networks. All these topics have evolved and expanded in the literature for many years. With each new major disruption in SCs, an update on the state of the art is required and each of these research areas must undergo modifications. A major disruption such as the COVID-19 pandemic becomes a turning point in the SCRES literature and refocuses interest in SCRES.

2.3 The future of SCRES: the post-pandemic era

The COVID-19 pandemic demonstrated the lack of preparedness for a global pandemic, leading to gaps in protracted responses and the need for greater SCRES (van Hoek, 2020). The pandemic's underlying consequences, such as shortages of resources and materials and delivery delays, have affected the gross domestic product (GDP) of the world's major countries by 5.4–9.7% (World Bank, 2020). This situation has highlighted the need for further development of the SCRES literature and a new post-pandemic turning point for SC studies is occurring, focused on how to avoid a future recurrence of such an impact (Nikookar and Yanadori, 2021). In addition to reminding managers and researchers of the importance of building SCRES from different perspectives to make it successful (Sarkis *et al.*, 2019), the literature shows that this goal can indeed be achieved if SCRES is observed in combination with theories and methods from other fields (Schultz and Lundholm, 2013), for example, the improvement of SCRES through focused decision making in human resource management (de Vries *et al.*, 2022). Furthermore, the risk management approach to SCRES previously developed in the literature is relatively difficult to apply in the new pandemic and post-pandemic contexts, given such events' unpredictable nature (Dohale *et al.*, 2021). The rationale is that the COVID-19 pandemic situation has undermined the way that organisations identify and respond to SC risks, considering the extent of sudden shocks on a global scale that are exceedingly difficult to predict (El Baz and Ruel, 2021). To this effect, SCRES responses to the pandemic are unlike any previously undertaken and have not had similar effects, leading to unknown long-term impacts that require further research (Sarkis *et al.*, 2019).

The COVID-19 pandemic has posed several challenges for the future in the SCRES context, as the most recent literature shows (Hussain *et al.*, 2021). However, since SCRES research is at a very early stage, the studies conducted have mainly focused on theoretical attempts to explain and understand the situation and the consequences of the pandemic for SCs. The literature is striving to learn from COVID-19 to identify the challenges ahead for SCs. For example, recent studies (Wang *et al.*, 2018) indicate that to reduce their overhead costs and ensure greater efficiency, the vast majority of companies opt for a *just-in-time* approach to their SCs. This is an ideal approach in stable and predictable environments, but it puts the SC system on the spot in the context of disruption such as the COVID-19 pandemic (Kovács and Falagara Sigala, 2021). The post-pandemic scenario therefore creates the need to look for novel approaches and poses the challenge of increasing flexibility throughout SCs to make them more resilient in the future, irrespective of the type of crisis (Ivanov, 2020a). Other challenges posed by the COVID-19 pandemic include companies' ability to implement innovation, collaboration and standardisation of operations in the future as measures to mitigate SC disruptions (Butt, 2021). Lastly, the transition from global to local sourcing strategies is an example of the challenges being faced at this new stage of the literature (Choi *et al.*, 2021), with new inventory management strategies also required to withstand unforeseen events (Sodhi *et al.*, 2021).

In brief, the turning point identified by the literature in the post-pandemic era requires studies such as the present one to establish the knowledge base for future research by

performing bibliometric analysis to easily identify SCRES-oriented academic streams (Denyer and Tranfield, 2009). These extensions of the SCRES literature are necessary, not only for future researchers, but also for companies to help improve the competitiveness of their SCs and reduce the likelihood of uncertainty and adverse situations (Kochan and Nowicki, 2018). Despite great progress in studying SCRES in this context, future research should contribute to the literature on this topic and unify a single concept of SCRES to facilitate research work in the field (Ali and Gölgeci, 2019). This study contributes to the latter as it not only provides the theoretical basis for future research on SCRES, but it also goes a step further to answer the question of whether SCRES is just another SC concept or has its own theory. This question can be answered by conducting a bibliometric analysis of the literature and examining the development of SCRES throughout the history of SCs. This starting point will facilitate the development of future research.

3. Research methods

The use of bibliometrics in academic research has increased exponentially in recent years because it allows various characteristics of the literature to be identified objectively and systematically (Donthu *et al.*, 2020). For example, it performs an in-depth analysis of the relations between keywords and citations in the examined articles and provides researchers with clear information about the research (Feng *et al.*, 2017). Bibliometrics is therefore an interdisciplinary approach that integrates mathematics, statistics, philology and quantitative analysis of the literature (Raghuram *et al.*, 2010).

To meet the objectives of this research, a rigorous study of the relevant literature was conducted through a bibliometric analysis, following these four-step methodological guidelines proposed by Donthu *et al.* (2021): (1) Define the objectives and scope of the bibliometric study. (2) Choose the most appropriate technique for the bibliometric analysis. (3) Collect the data for the bibliometric analysis. (4) Execute the bibliometric analysis and report the results. Recent recommendations on conducting systematic literature reviews were also considered, such as those proposed by Durach *et al.* (2017), who outlined the following six steps: (1) Define the research question. (2) Determine the characteristics required for primary studies. (3) Retrieve a sample of potentially relevant literature. (4) Select the pertinent literature. (5) Synthesise the literature. (6) Report the results.

Finally, to validate the research findings, the author obtained the opinions of seven renowned academics (with publications on SCRES), who assessed this study's results and shared their views on them. An analysis of the experts' assessments is detailed in Section 4.

3.1 Objectives and scope of the bibliometric study

The definition of the research objective and scope is a fundamental first step in the design of the bibliometric analysis. If these two aspects are unclear, it will not be possible to obtain satisfactory results and draw conclusions. The objective of this research is to conduct a bibliometric study of the development of the SCRES literature in order to identify its past, present and future lines of research and to answer the question of whether resilience is just another SCs concept or has its own theory. Consequently, the scope of this research covers the publications included in the leading database (WoS) of academic articles.

3.2 Techniques for bibliometric analysis

The important points to consider about the techniques used for the bibliometric analysis in this research are described in Subsection 3.2.1 and 3.2.2.

3.2.1 Software selection for bibliometric analysis. This study used the open-source software called Bibliometrix, available as an R package and developed by Aria and Cuccurullo (2017).

This software was selected because apart from its capacity to be integrated quickly with other *R* statistical packages, it contains the broadest and most appropriate set of techniques for professionals who want to carry out a bibliometric analysis of the literature (Moral-Muñoz *et al.*, 2020).

3.2.2 Techniques of bibliometric analysis. The recommendations for the selection of bibliometric analysis techniques (Donthu *et al.*, 2021) were followed. Therefore, the co-citation analysis was combined with the analysis of the total sample of articles and citations to measure productivity and influence (Broadus, 1987). Using co-citations to account for the linkage structures of cited papers and map the main research streams by identifying the main key clusters related to the SCRES concept (Baker *et al.*, 2020; Broadus, 1987), bibliographic coupling was then carried out with the one performed previously, in addition to the keyword co-occurrence analysis, which measures the most frequent keywords appearing below the abstracts of the selected articles by tracing the network of co-occurrences between them (Baker *et al.*, 2020).

3.3 Data collection for bibliometric analysis

The selection of articles for analysis and review to meet the objectives of this research followed a two-step approach. The first step involved the selection of the database in which to search for articles. This research focused on academic publications from WoS because it is a commonly accepted database of high-quality abstracts and references and high-impact academic articles (Gil *et al.*, 2020; Shukla *et al.*, 2019). The second step consisted of deciding on the specific search criteria to determine the inclusion of articles in the sample in order to carry out the bibliometric analysis. Table 1 shows both the criteria used to search the WoS database and the results regarding the articles included in the sample. In total, 1,596 results were obtained from WoS, representing 86.79% of the total number of articles on SCRES published in journals. Next, 243 articles that were indexed only in the Scopus database were excluded from the sample. This approach enabled observing trends in SCRES over time, as found in WoS and drawing the conclusions from this study.

The selection of keywords was based on a preliminary literature review to identify the development of SCRES over time and its interaction with other fields.

4. Executing the bibliometric analysis: results, analysis and discussion

This section shows the results obtained using the bibliometric analysis techniques explained in the research methods section. These bibliometric results on SCRES allow analysing and discussing the existing literature to achieve the research objective.

Criteria used to search WoS	Total number of articles
Keywords: "supply chain" AND "resilience" OR "SCRES" OR "SC resilience" OR "resilient" OR "resilien*"	1,596
Field tags that contain the keywords: topic and abstract	
Language: English; *Document types*: only articles	
Restrictions: Exclude early access with final publication in 2022	
Timespan: All years (1900–2021); *First data downloaded:* 2021-12-28 *Last data downloaded:* 2022-05-18	

Table 1. Criteria used to search Web of Science (WoS) to obtain the study sample

4.1 Publications and citation structure

The first definition of SCRES was published in 2004; since then and especially in recent years, the number of published articles on this topic has increased considerably. However, the peak of academic publications on SCRES occurred with the outbreak of the COVID-19 pandemic at the global level (see Figure 1).

It was not until 2013 that the total number of SCRES articles published yearly exceeded 20, followed by an exponential growth, with 2017 standing out as a particular turning point. Likewise, annual citations per article increased considerably from 2013 onwards, with significant research interest in SCRES becoming apparent over the period of the COVID-19 pandemic. These results are to be expected, considering that the SC disruptions caused by the pandemic constituted both one of the largest, most unprecedented supply crises of the 21st century and one of the most published and researched crises in recent years (Donthu and Gustafsson, 2020). This research confirms that the academic output on SCRES has increased exponentially in the wake of the COVID-19 pandemic (e.g. Golan *et al.*, 2020; Harland *et al.*, 2021) and has been a turning point for research in this field (Nikookar and Yanadori, 2021), as shown in Table 2. The total number of SCRES articles published in the literature before 2019 (emergence of COVID-19 in China) was 540, whereas from 2019 to 2021 alone, 875 articles were published (a 62.04% increase in academic output). These findings show that despite the already growing interest in SCRES in SC research, the real turning point was triggered by the COVID-19 pandemic.

Until the disruptions caused by COVID-19, in the globalisation context, studies on SCRES focused on increasing the efficiency of SCs with more complex structures that would allow maximum benefits under normal circumstances (Ribeiro and Barbosa-Póvoa, 2018), as well as on managing the risks of SC disruptions that clearly did not have the same impacts as those of the pandemic (Bevilacqua *et al.*, 2019). Table 3 shows this academic production on SCRES in recent years, with the ten most cited articles in the field. It can be observed that the most cited articles in the SCRES context over the analysed period are generally those that address risk management to mitigate the consequences of disruptions in SCs and the studies that focus on the conceptualisation of SCRES.

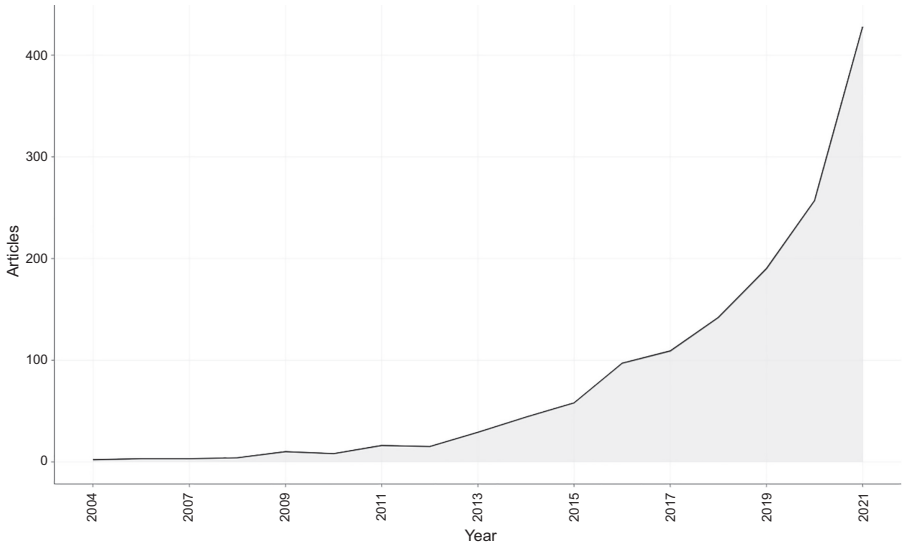

Figure 1.
Annual scientific publications on SCRES included in Web of Science (WoS)

Year	TP	TC
2004	2	1,492
2005	2	1,041
2006	3	151
2007	3	989
2008	4	580
2009	10	1,314
2010	8	934
2011	16	1,913
2012	15	1,490
2013	29	2,773
2014	44	2,447
2015	58	3,165
2016	97	3,111
2017	109	3,604
2018	142	4,152
2019	190	4,794
2020	257	5,633
2021	428	4,721

Note(s): *TP*: total papers; *TC*: total citations

Table 2.
Annual citation structure of SCRES

#	Journal	TC	Title	Author/s	Year	C/Y
1	DS	749	"The severity of supply chain disruptions: design characteristics and mitigation capabilities"	Craighead *et al.*	2007	46.81
2	MIT	731	"A supply chain view of the resilient enterprise"	Sheffi and Rice	2005	40.61
3	IJLM	673	"Understanding the concept of supply chain resilience"	Ponomarov and Holcomb	2009	48.07
4	JCP	643	"A comparative literature analysis of definitions for green and sustainable supply chain management"	Ahi and Searcy	2013	64.30
5	TRLT	455	"Predicting the impacts of epidemic outbreaks on global supply chains: a simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case"	Ivanov	2020b	151.67
6	JBL	442	"Ensuring supply chain resilience: development of a conceptual framework"	Pettit *et al.*	2010	34.00
7	IJPE	422	"The power of flexibility for mitigating supply chain risks"	Tang and Tomlin	2008	28.13
8	SCHIJ	416	"Supply chain resilience in the global financial crisis: an empirical study"	Jüttner and Maklan	2011	34.67
9	IJPR	413	"The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics"	Ivanov *et al.*	2019	103.25
10	IJPR	399	"Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak"	Ivanov and Dolgui	2020	133.00

Note(s): TC: total citations; **C/Y**: citations per year; **DS**: *Journal of the Decisions Sciences Institute*; **MIT**: *MIT Sloan Management Review*; **IJLM**: *International Journal of Logistics Management*; **JCP:** *Journal of Cleaner Production*; **TRLT:** *Transportation Research Part E: Logistics and Transportation Review*; **JBL:** *Journal of Business Logistics*; **IJPE:** *International Journal of Production Economics*; **SCHIJ:** *Supply Chain Management: An International Journal*; **IJPR:** *International Journal of Production Research*

Table 3.
Ten most cited documents on SCRES

It is precisely this continued interest in defining and conceptualising SCRES in the literature that has prompted the interest in an area where the wide variety of definitions suggests a significant lack of consensus (Tukamuhabwa *et al.*, 2015). In this regard, based on this study and its bibliometric analysis of the different articles found, this definition can be established: *SCRES is the ability of SCs to prepare for unexpected events – by proactively planning and designing their networks – or their ability to respond to and recover from disruptions, maintaining continuity of operations at the desired level and over their structure* (e.g. Christopher and Peck, 2004; Ponis and Koronis, 2012; Ponomarov and Holcomb, 2009; Tukamuhabwa *et al.*, 2015; Wieland and Durach, 2021). The results also show the relevance of other fields in terms of the development and definition of SCRES. The concept of resilience has been defined in many fields that are not directly related to SCs, such as ecological and socio-ecological systems, psychology, organisation theory and engineering (Ponomarov and Holcomb, 2009). For example, based on a socio-ecological perspective of SC systems, researchers have shown how social ties between a buyer and a supplier improve system resilience and financial performance (Durach *et al.*, 2020), an important point if SC analysts also consider that supplier response diversity is positively related to SCRES (Kahiluoto *et al.*, 2020). Therefore, the multidisciplinarity of the resilience concept has allowed SCs to adapt it to their contexts, drawing on definitions of resilience from other fields. As discussed in the literature review, two of the fields used to conceptualise SCRES are engineering and ecology (Modgil *et al.*, 2021). To discern their impacts at the academic production level, the analysed sample of 1,596 articles was filtered on the basis of those related to these two important fields in the definition of SCRES. Table 4 shows the academic production on SCRES related to the fields of engineering and ecology. The articles selected through this filter are those that mention the words "engineering" and "ecology" in their abstracts. Table 5 presents the ten most cited articles on engineering and only five articles on ecology in the SCRES context.

Table 5 shows that most of the research related to SCRES and engineering seeks to understand how technology impacts SCs and what strategies can be used to reduce this impact. In the case of ecology, the focus is on how SCRES can adapt as a system to the new environment through the different changes that occur, such as the need for a more sustainable system. The same table also shows that 46.67% of the articles were published over the period 2019–2021, which proportionally demonstrates the recent interest in SCRES in relation to other fields. Based on the literature, two interpretations of SCRES can be offered:

Year	SCRES + engineering		SCRES + ecology	
	TP	TC	TP	TC
2009	0	0	1	216
2010	0	0	0	0
2011	0	0	0	0
2012	1	145	0	0
2013	0	0	0	0
2014	2	55	0	0
2015	0	0	0	0
2016	3	60	1	13
2017	3	61	0	0
2018	6	217	0	0
2019	5	626	1	1
2020	8	92	1	22
2021	5	45	1	2
Total	33	1,301	5	254

Note(s): *TP:* total papers; *TC:* total citations; *SCRES:* supply chain resilience

Table 4.
Annual citation structure of SCRES with other fields: engineering and ecology

#	Field	Journal	TC	Title	Author/s	Years	C/Y
1	Engineering	IJPR	413	"The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics"	Ivanov *et al.*	2019	103.25
2	Engineering	IJPR	148	"Scheduling in production, supply chain and Industry 4.0 systems by optimal control: fundamentals, state-of-the-art and applications"	Dolgui *et al.*	2019	37.00
3	Engineering	IJPR	145	"A control engineering approach to the assessment of supply chain resilience"	Spiegler *et al.*	2012	13.18
4	Engineering	TRPP	62	"Supply chain resilience, firm performance and management policies in the liner shipping industry"	Liu *et al.*	2018	12.40
5	Engineering	JLM	52	"Supply chain resilience: a dynamic and multidimensional approach"	Adobor and McMullen	2018	10.40
6	Engineering	IJPR	51	"Scheduling of recovery actions in the supply chain with resilience analysis considerations"	Ivanov *et al.*	2018	10.20
7	Engineering	JMD	47	"Resilience modeling and quantification for engineered systems using Bayesian networks"	Yodo and Wang	2016	6.71
8	Engineering	MPM	45	"An advanced risk analysis approach for container port safety evaluation"	Alyami *et al.*	2014	5.00
9	Engineering	JBL	32	"Two perspectives on supply chain resilience "	Wieland and Durach	2021	16.00
10	Engineering	IJPR	32	"A graph-based model to measure structural redundancy for supply chain resilience"	Tan *et al.*	2019	8.00
1	Ecology	JCP	216	"Strategy development in small and medium-sized enterprises for sustainability and increased value creation"	Moore and Manring	2009	15.43
2	Ecology	JRR	22	"Conceptualising redundancy and flexibility towards supply chain robustness and resilience"	Mackay *et al.*	2020	7.33
3	Ecology	JMM	13	"Supply chain criticality in sustainable and resilient enterprises"	Edgeman and Wu	2016	1.86
4	Ecology	IJPDL	2	"Gamification in freight transportation: extant corpus and future agenda"	Klock *et al.*	2021	1.00
5	Ecology	EB	1	"Effects of disruptive events within the supply chain on perceived logistics performance"	El Abdellaoui and Pache	2019	0.25

Note(s): TC: total citations; **C/Y:** citations per year; **IJPR:** *International Journal of Production Research*; **TRPP:** *Transportation Research Part A: Policy and Practice*; **JLM:** *Journal of Logistics Management*; **JMD:** *Journal of Mechanical Design*; **MPM:** *Maritime Policy and Management*; **JBL:** *Journal of Business Logistics*; **JCP:** *Journal of Cleaner Production*; **JRR:** *Journal of Risk Research*; **JMM:** *Journal of Modelling in Management*; **IJPDL:** *International Journal of Physical Distribution and Logistics*; **EB:** *Economics Bulletin*

Table 5. Ten most cited documents in SCRES with other fields: engineering and ecology

(1) from the engineering perspective, where optimisation and fault-tolerant design are sought and (2) from the socio-ecological perspective, which allows designing SCs adaptive to disruptions, taking into account their social environment (Wieland and Durach, 2021). Especially with regard to design, it is of particular importance that the SC system is able to maintain control over the versatility of responses and performance vis-à-vis adversity, adapting to sudden changes and offering effective alternatives. Thus, if the SC has a flexible system, it will be able to recover its original state and cope with disruptions, adapting and changing its strategy quickly and effectively (Hohenstein *et al.*, 2015), with its performance being moderated by SCRES (Chowdhury *et al.*, 2019).

4.2 Co-citation and collaboration network analysis about SCRES

The previous section has focused on the total number of published articles, as well as the identification of the most cited articles in the SCRES context. However, it is also important to examine the results of co-citation (when one article cites another) and the collaboration network. This will help identify the top journals publishing academic research on SCRES. Figure 2 shows the 20 journals with the most representative co-citation connections.

As shown in Figure 2, the two main journals relating to SCRES and therefore, among those that publish the most-cited articles, are *International Journal of Production Research* (IJPR) and *International Journal of Production Economics* (IJPE). Both are at the centre of all citations of all the other journals in this context and they belong to the same cluster of co-citations. In terms of co-citations among the most cited authors, Figure 3 shows the 20 most representative SCRES co-citations. The co-citation analysis does not consider whether an author is the primary or the secondary author of a published article, so the total number of citations is calculated, regardless of the order in which an author's name appears in a citation. It can be seen how M. Christopher, the most cited among the 20 most representative SCRES authors, stands out in the centre. This author, who chairs the Advisory Board of the Centre for Logistics and Supply Chain Management at Cranfield University, has particularly published articles that address SC risks and how resilience plays a key role in mitigating them.

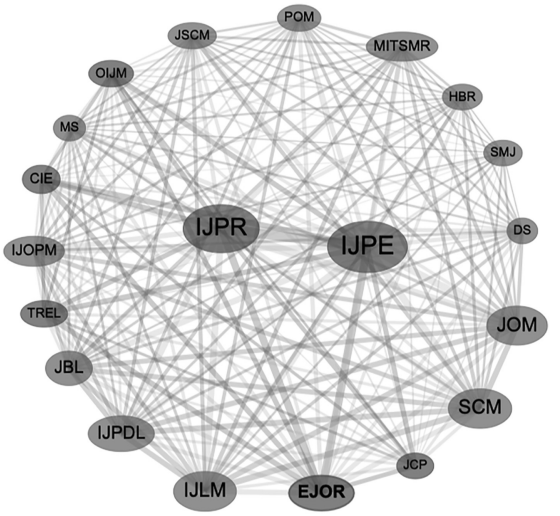

Figure 2.
Co-citation network among journals concerning SCRES

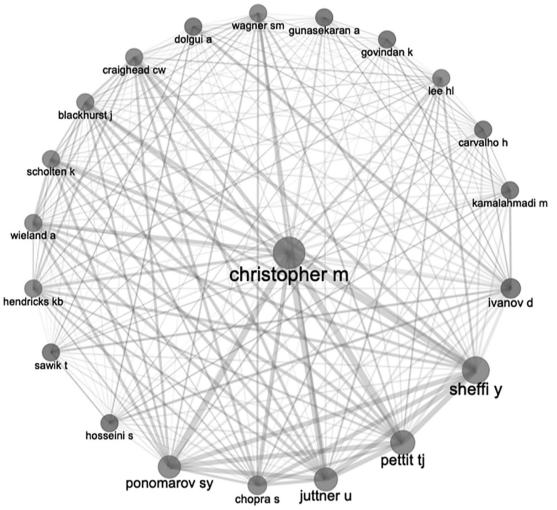

Figure 3.
Co-citation network among authors concerning SCRES

4.3 Keyword co-occurrence network and thematic development concerning SCRES

The bibliometric results presented in the previous sections allow identifying the core topics of the research on SCRES and the main or at least the most cited works on SCRES in other fields such as engineering and ecology. This section identifies the most frequently used keywords and how they relate to one another in the SCRES context over the analysed period, providing an insight into the focus of interest in this field.

Figure 4 shows the main or the most used keywords in SCRES and their co-occurrences over the analysed period, which are divided into four clusters. Cluster 1 identifies research related to SCRES and its measurement with regard to SC disruptions, considering the different risks involved (e.g. Revilla and Saenz, 2017; Schmitt and Singh, 2012). Cluster 2 identifies research on SCRES that focuses more on disruption management and its impact on an organisation (e.g. Burnard and Bhamra, 2011; Whiteside and Dani, 2020). Cluster 3 focuses on research on SCRES and the design of new models to mitigate the impact of disruptions, using tools such as simulation to test the SC system (e.g. Ivanov, 2019). Lastly, Cluster 4 also focuses on the definition of the SCRES model – but not as much on mitigating the effects of disruptions as on transforming the model into a new, more sustainable state through decision making (e.g. Bait *et al.*, 2021; Sarkis, 2020). In focusing the analysis on the keywords used, an important detail is that although most of the research output has been produced since the outbreak of the pandemic, the word COVID or pandemic is not among the most used terms. This is because although new research on SCRES uses COVID-19 as the context of disruption, its analysis is conjectural and focuses on building resilience against any disruption, be it COVID-19 or any other future pandemic or disaster. COVID-19 has been the driver of rethinking the state of SCs, but the research goes beyond this circumstance. Of the remaining keywords (inside the larger circles), the most used can be highlighted: (1) management, (2) resilience, (3) performance, (4) model and (5) framework. Notably, "model" and "framework" appear as the most used words, as they mainly refer to the conception and definition of the term SCRES and focus on research that addresses the contextualisation of SCRES by establishing its theoretical framework and model. This is an essential element because (as discussed in the literature review) despite the numerous studies on SCRES, it is a constantly evolving concept that requires further studies (Modgil *et al.*, 2021). With the disruptions

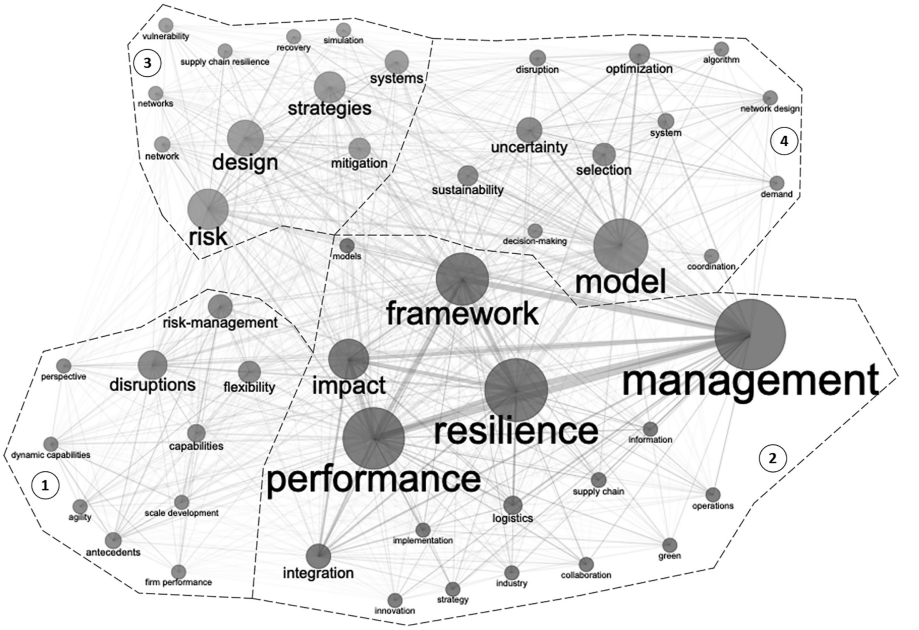

Figure 4.
Keyword co-occurrence network concerning SCRES

caused by COVID-19, studies on SCRES are continuing to expand the literature with new models and theory frameworks (Ivanov, 2020a).

Lastly, one of the most important results that helps answer the research question is the thematic development of SCRES. The aim is to verify whether SCRES is nothing more than a concept within the SC theory or if it does have its own theory and therefore constitutes a thematic block on its own. To this end, the 150 most frequently used keywords over the analysed period were filtered in Bibliometrix to see their thematic development. The results indicate that from 2004 to 2019, three thematic blocks remained intact in SCRES: (1) management, (2) performance and (3) model. In the pandemic context, in the years 2020–2021, the results show a shift in thematic interest from academic articles focusing on performance in the SC context to studies on resilience. To carry out the analysis and develop the discussion on these findings and thus answer the research question, the opinions of seven academic experts in SCRES, who assessed the bibliometric results, were also taken into account.

The analysis of the results reveals that two thematic blocks – "management" and "model" – have remained constant over the years, with no changes, even in the pandemic context. In the case of "management" and in line with expert opinions, this finding is logical because of the close relation between supply chain management (SCM) and SCRES, as reported in the literature. To this effect, SCM is a complex and global management discipline, dealing with research objects that can be completely different within short periods of time in terms of drivers, disruptions, capabilities, geographic locations, economic conditions, among other factors. Therefore, this social and economic scenario, which exists in the management field, encourages its use in the SC field and among the social/economic and other exact sciences. Furthermore, the SC thematic block "model" continues to be of interest as it deals with research that extends its design and contextualises it. This is also likely to be maintained over the years due to the need to continue extending the SCRES theory. The consulted experts consider this interest in the subject of models over the years as coinciding with researchers'

attempt to formulate a single definition of SCRES and with the development of its overall theory. As consensus has not yet been reached, it is logical to assume that future research will continue to focus on the development of models to explain SCRES and will continue to maintain this thematic block as one of the main ones. Among the articles analysed in the bibliometric sample, it should be noted that some studies are related to decision making in the same thematic field of study (i.e. model). This is fundamental to ensuring the flexibility of the SC system and anticipating disturbances, given that success relating to any change depends on this and can help explain the theoretical models of SCRES. Without good decision-making management, it will be difficult to have a robust SC model capable of overcoming any perturbation (e.g. Singh, 2020).

When focusing on the thematic block "performance", it is observed that research on SCRES had remained predominantly focused on this aspect until the beginning of the pandemic. This thematic block mainly contains studies that evaluate performance metrics for the SCM used by firms (e.g. Kleijnen and Smits, 2003; Saleheen *et al.*, 2018). However, with the outbreak of the pandemic, this thematic block has lost momentum, with recent publications focusing more on the thematic block "resilience". This point is important because it effectively demonstrates that over the last two years, SCRES truly has become a topic of interest, generating a high number of related academic articles. However, to answer the research question, the existence of a large body of literature is not equivalent to the existence of a theory.

On analysing the articles in the bibliometric sample, multiple definitions of the SCRES concept over the years are observed, without establishing common criteria. This, as well as the points considered by the consulted experts, may be one of the reasons why there is still no robust theory of SCRES. According to the consulted experts, the literature on SCRES indeed contains many definitions of the concept, some of which follow the dictionary definition of resilience, while others depart from it. The reviewed articles show that the term SCRES is evolving and moving away from terms such as risk management, while gradually being influenced by other fields. Precisely because SCRES is so multifaceted and situation-specific, the experts deem that a single definition and thus the development of a grand theory of SCRES are not straightforward. Recent examples in the literature could represent attempts to find/develop theories to explain SCRES, such as the works of Ivanov (2020b), Pimenta *et al.* (2022) and Wieland and Durach (2021). While they do not comprehensively bring together all existing definitions of SCRES, they can serve as a basis for the development of a theory. As pointed out by the consulted experts, SCRES researchers have different perspectives on SC issues due to their heterogeneous backgrounds and even today, they continue to apply methods and theories from three decades ago to capture 21st-century phenomena. In this regard, drawing on other fields such as social sciences, engineering and ecology could be the key to developing a SCRES theory. The experts believe that these insights can help provide an understanding of how other fields have developed their theories to advance the knowledge on SCRES.

The research question is thereby answered, confirming that in recent years, resilience has become one of the main thematic blocks of the SC literature and has produced a multitude of academic articles. Nonetheless, this academic production has been insufficient to generate a global theory on SCRES – quite the contrary, given the multiple studies that use different definitions and models to explain the same SCRES phenomenon. Some experts agree that a theory of resilience is needed and that in this respect, some recent publications on the panarchy theory (e.g. Bille and Wieland, 2022) offer a key step towards building a SCRES theory. According to the experts consulted, a SCRES theory should be generated by considering that resilience is multidisciplinary and multidimensional and as such, can be applied to different fields such as SC, meaning that future research should rely on other fields to see how they have generated their own theories. Therefore, it can be stated that in the

literature, no overarching theory of SCRES exists to date and it is still used as a concept that depends on the study to which it is applied (sometimes implying different definitions).

5. Conclusions, limitations and future research

The research objective is to conduct a bibliometric study of the literature on the development of SCRES to identify its past, present and future lines of research. To this effect, the research question is whether SCRES is just another SC concept or has a theory of its own. It is concluded that resilience is currently an important thematic block in the SC literature, but in view of the results, it cannot be claimed to have a theory of its own. This assertion is supported by the variety of academic publications that currently continue to define the concept and contribute new theoretical models. The results using bibliometric analysis confirm this positioning of resilience in the development of SC research and demonstrate its consolidation following the COVID-19 pandemic. The disruptions caused by the pandemic have exponentially increased interest in publications on this topic over the last two years. Based on the bibliometric analysis, it is also concluded that the relations between SCRES and other fields such as engineering and ecology are and will be necessary in order to contribute to the development of a theory of resilience in the SC context and specially to build on the definitions and methodologies of these two fields, which can help build a SCRES theory of its own. Thus, at this new post-pandemic stage, future research should rely on the combination of other fields in the SCRES context to advance its theory and thus contribute to the creation of resilient systems capable of withstanding disturbances that may be caused by implementing new technologies in SCs, among others (e.g. Ivanov *et al.*, 2019; Klock *et al.*, 2021). The relations between SCRES and other fields, such as socio-ecological systems, can help make new contributions to the literature, with recent studies showing that resilience improves in SCs, not because of improved operations but due to an organisation's human resources (Polyviou *et al.*, 2019), or even because of the range of interpersonal relationships that affect supplier-initiating risk management behaviours (SIRMBs) in the supply-side resilience of SCs (Fan *et al.*, 2020).

5.1 Theoretical implications

This paper has not only presented a bibliometric analysis of the SCRES literature to provide researchers with knowledge of both the current state of the literature and the main thematic blocks of interest. It has also identified a significant gap in the literature that needs to be addressed to further develop SCRES research. Furthermore, in the analysis and discussion of the results, a single definition of the SCRES concept is proposed for use in future research so that the literature will have a single definition and can work towards the development of a global theory. This is a compilation of all the definitions published so far and there is a need for the literature to establish a single definition unanimously, since over the years, the reviewed studies have defined SCRES in different ways (e.g. Christopher and Peck, 2004; Ponis and Koronis, 2012; Ponomarov and Holcomb, 2009; Tukamuhabwa *et al.*, 2015; Wieland and Durach, 2021). Lastly, the results also show the relations between the SCRES literature and other fields such as engineering and ecology. Despite both fields' contributions to the resilience theory, there is a lack of studies exploring these relations and their impacts on SCs. As can be deduced from the results of this research, understanding how the fields of engineering and ecology have elaborated on their theories of resilience can serve as a basis for the development of a SCRES theory. These relationships between SCRES and other fields, especially the socio-ecological one, so that SCRES can develop its own theory, will allow researchers to leave behind the perception that an SC is based on balance and instead adopt the view that it is a system under the influence of different social actors. It is necessary to adopt a perspective based on the complexity of SCRES (Novak *et al.*, 2021).

5.2 Practical implications

This study is important, not only for academia, but also for business practitioners. When business leaders are unable to understand the vulnerabilities and risks facing their SCs, it is difficult for them to manage decision making in order to build resilience of their SC systems. Thus, this research broadens professionals' knowledge of SCRES and their ability to identify the main research literature on this topic. In addition to summarising the main contributions in this field and identifying the definitions of SCRES used in the literature, this study can serve as an initial basis for these professionals to delve into the academic world of SCRES and to have the theoretical framework necessary to perform their tasks, especially considering the importance of this knowledge transfer across the SCs and among all stakeholders to improve resilience against disruptions (Scholten *et al.*, 2019). Furthermore, the bibliometric results of this study allow practitioners to narrow down the SCRES contributions from other fields in order to clearly identify the publications with the highest impacts and thus put their findings into practice.

5.3 Limitations and directions for future research

This research is one of the most recent that shows the state of the literature on SCRES through a bibliometric analysis. Despite the rigour and relevance of this study, some limitations should be considered. The first is that only SCRES articles published in WoS were used; those published solely in Scopus were not included. Thus, the sample excluded a total of 243 articles because the current bibliometric analysis software, such as Bibliometrix, does not allow two different databases to be combined. To this effect, this study's sample of 1,596 articles constitutes 86.79% of the total number (1,839) of articles found. In this regard, when the bibliometric analysis software evolves, future research could extend this investigation by incorporating studies only published in Scopus. However, in this case, duplications of articles between the two databases will have to be eliminated. Another limitation of this study is that it did not examine the contents of all articles found or their contributions to the literature. Bibliometric data were evaluated by identifying the number of annual publications and the number of citations, among other data, but without identifying the context of each research. However, some of the most relevant contributions to the literature emerging from the bibliometric analysis are highlighted in this paper. Regarding potential future research, it is proposed that the bibliometric analysis be extended to SCs in general, rather than focusing only on the SCRES context. It is also recommended that the relations between SCRES and fields other than engineering and ecology (the ones used in this study) be explored in more detail. For example, the research could be extended to other fields, such as econometric geography (Simmie and Martin, 2010) or psychology (Bonanno, 2004). Finally, in view of the results of this research, the future research agenda should first work on developing a global theory of SCRES based on the contributions of this study. To this end, fields such as engineering or ecology should be considered to understand how they have developed their own theories and to implement them in the SCRES context. In developing this overall theory, future research will possibly identify different schools of thought within SCRES. As in any mature area of research, this difference is common. For this reason, one of the main tasks of future research will be to identify these possible streams of thought.

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