Supply chain resilience: A review, conceptual framework and future research

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Abstract

Purpose – The study identifies nine important research areas and critically maps the structural relationships among supply chain resilience (SCRES) dimensions, namely, vulnerabilities, capabilities, strategies and performance metrics. The analysis also revealed various influential authors, journals, institutions and trending articles, across SCRES literature.

Design/methodology/approach – This study performs a bibliometric analysis of 771 articles published over the 32 years from 1988 to 2020, and network analysis in combination with content analysis of 90 most cited articles published in research fronts of SCRES.

Findings – The results demonstrate the underlying research areas within the SCRES, which are clustered into nine research themes: (1) conceptual development of SCRES, (2) recent developments of designing resilient supply chain (SC) networks, (3) focus on identifying drivers of SC vulnerability and risks, (4) impact of risks on network resilience, (5) risk assessment to avoid breakdowns/disruptions, (6) measuring resilience approaches/drivers to improve SC performance, (7) building resilient capabilities by integrating other SC dimensions, (8) quantification of SC network and (9) emphasis on developing robustness in SC networks.

Practical implications – This research offers implications for classifying the works in literature based on bibliometric information and network analysis techniques. This can help researchers and practitioners to understand the prominent areas in SCRES and provide guidelines for future research in this area.

Originality/value – This study provides an overview of the evolution of SCRES over time in the domain of supply chain management and also outlines a future research agenda claimed by the trending articles to encourage further investigations in the field of SCRES.

Keywords Supply chain resilience, Bibliometrics, Literature review, Network analysis, Supply chain risk
Paper type Research paper

1. Introduction

Sustainability and resilience are the present keywords of interest to managers and supply chain (SC) practitioners of this decade. As achieving sustainable competitive advantages being a primary focus, resilience assumes significance in SCs. Supply chain resilience (SCRES), a property defined as the capability of SCs to bounce back to their original conditions or improved settings, once disruption occurs (Christopher and Peck, 2004) is

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gaining importance in the present context. The instability in today's world of seamless boundaries and global interconnectivity can influence SC operations, which in turn makes them vulnerable to several disruptions (Pettit *et al.*, 2010). SC risks are inevitable, and hence, risk management responses assume significance. But, most of these risk management responses are reactive than proactive. This enables us to understand the need for a proactive system to avoid the hazardous effects of SC risks and disruption. SC risks are broadly categorized into operational risks and disruption risks (Choi *et al.*, 2019).

Disruptive risks are those events that have low probability but high impact, are rare and hard to predict, widely vary in scale and nature and may have long-term and short-term negative effects (Dolgui *et al.*, 2018). And, operational risks are related to frequent SC business risks, which include lead-time delays and demand fluctuations (Hosseini *et al.*, 2019). Recent years were marked with highly publicized events resulting either from natural disasters or anthropogenic catastrophes. To name a few, transportation disruptions due to the fuel protests in the year 2000, terrorist attacks of 9/11 in 2001, Asian tsunamis in 2004, hurricanes that occurred in Central and North America in 2005, the global financial crisis of 2008, earthquakes in Japan 2011, Beijing's maritime port explosion in 2015 and the 2016 floods in Australia (Pettit *et al.*, 2010; Jüttner and Maklan, 2011).

As a result, these events caused massive shortages for materials and delays in delivery, which further propagated downstream in the SC, resulting in ripple effects and depreciating performances and value ultimately leading to reduced productivity (Dolgui *et al.*, 2019). Tousignant (2017) reported that natural disasters alone cost over USD 306 billion in 2017, which was found to be double the amount – USD 189 billion – lost in 2016. All of these disruptions warn us about the need for SC and system resilience for the future.

Recently, global public health is becoming more vulnerable to emerging pandemics caused by novel pathogens (i.e. recent outbreaks of COVID-19, Zika, Ebola). Therefore, critical response planning activities are vital for dealing with such unpredictable events and in designing resilient global SCs (Speier *et al.*, 2011). These circumstances not only impact industries but also entire economies (Halkos *et al.*, 2018); hence, more attention is being paid to SCRES by academicians and practitioners (Christopher and Peck, 2004; Sheffi, 2005; Tang, 2006). Studies are now required to predict and mitigate risks and vulnerabilities (Choi and Lambert, 2017), support humanitarian SC operations (Ataseven *et al.*, 2018), enhance the resilience of SC operations (Choi *et al.*, 2018) and SC networks (Ivanov, 2020). Recent SC disruptions (e.g. shortage of supplies, highly volatile demand) due to the COVID-19 outbreak spurred SCRES research to enable SCs to withstand disruptions and recover disruptions (operational or environmental) rapidly and cost effectively (Carmeli *et al.*, 2020; Yang and Hsu, 2018). Thus, the complex global SCs demand a paradigm shift from traditional risk management thinking to cope with extreme vulnerabilities, uncertainties and unforeseen disruptions (Pettit *et al.*, 2013).

Ever since the concept of resilience emerged in early 2000 through Hamel and Valikangas (2003), Rice and Caniato (2003), Christopher and Peck (2004) and Sheffi and Rice (2005), SCRES research has developed its roots and later developed into a branch of SC management with indispensable effects. Considering the recent developments in this direction, Tukamuhabwa *et al.* (2015) formulated a theoretical lens to observe definitions and reviewed conceptual factors that could improve the SCRES. A systematic literature review conducted by Kamalahmadi and Parast (2016) explained the principles of SCRES, analyzed definitions and proposed strategies for SCRES. Ali *et al.* (2017) improved the conceptual clarity by establishing the relationship between SCRES and its constructs in an integrated and systematic way. Kochan and Nowicki (2018) examined the SC capabilities and their relationship to SCRES outcomes using the CIMO framework. Recently, Hosseini *et al.* (2019) proposed a new definition of SCRES based on resilience capacity and classified quantitative analysis approaches (mathematical modeling) to formulate and quantify SCRES problems.

To further synthesize the SCRES research and pave the way for future development, in this study, we address the following research questions:

RQ1. Which are the key journals, widely discussed articles in SCRES research?

To address this research question, we count on bibliometric citation analysis. Bibliometrics is a structured method in library and information sciences for ascertaining the progress and development of information in a particular field of knowledge by making use of data such as publication trends, author activities, country and institution collaborations (Sharma *et al.*, 2020). A bibliometric analysis effectively contributes to organizing and classifying publication data assets that are important considering the purview of data management (Firdaus *et al.*, 2019; Wu *et al.*, 2015). The next step is to carry out a network analysis for the selected studies. Network analysis is a useful tool for the identification of trending and established research areas considering a field of research. Further, network analysis helps to identify the clusters about the development of theory, past and present research trends and helps to find influential researchers based on author and institutional characteristics.

RQ2. How the studies in SCRES have evolved, and which are the principal themes in SCRES research?

The citation mapping technique was used in this research along with content analysis. Using meticulous bibliometric tools, an exhaustive network analysis was carried out, resulting in nine significant research groups. The identification of these research groups can set the tone for classification and clustering of the models published and can further investigate the development of these research groups over the years. The results help in generating more insights into the research interests of the present and future.

RQ3. How the SCRES strategies and measures of performances can be aligned in a single framework and what are the learning outcomes?

RQ3 presents the relationships among SCRES drivers, their focus, associated strategies and the performance measures in an all-inclusive conceptual framework. Furthermore, these learning are summarized for further research investigations, based on the widely discussed and most cited articles.

After a manual review, we found that only eight studies are directly related to SCRES, others were concerning topics about SC without a dedicated focus on SCRES. In comparison to those eight studies, this study contributes in the following ways. First, five of the SCRES review studies were published before 2020 (Ali *et al.*, 2017; Ali and Gölgeci, 2019; Karl *et al.*, 2018; Kochan and Nowicki, 2018; Tukamuhabwa *et al.*, 2015). Their literature search was as latest as 2018. The SCRES research has gained increased attention since the COVID-19 pandemic hit. Hence, this study included studies published until the earlier half of 2020 and provides new insights. Second, the majority of the previous SCRES review studies are systematic literature reviews (SLR). SLRs often focus on a smaller number of studies with a narrower focus. Only two studies utilized bibliometric methods and tools, which are Ali and Gölgeci (2019) and Ekanayake *et al.* (2021). In contrast to these two, our literature search is comprehensive resulting in a larger sample. Finally, our study contributes by revealing nine underlying clusters within SCRES research, exploring them in detail, synthesizing future research directions and proposing a conceptual framework for SCRES.

As we see, many recent review articles can be seen in the literature of SCRES; say, e.g. Negri *et al.* (2021) reviewed on the articles discussing on sustainability and resilience together as the core themes in SCs. Also, in the recent review conducted by Shekarian and Mellat Parast (2021), the impact of strategies such as flexibility, agility, redundancy and collaboration in mitigating different types SC disruptions are noted. In a parallel study, conducted by Rha (2020), the trends in SCRES research were analyzed using network

analysis technique. Although many review articles are seen in the literature on SCRES, this study is motivated from the idea that any early researcher in SCRES need to have an understanding of overview of the literature in this area, which mainly includes the key journals that are publishing articles in the area of SCRES and also some of the widely discussed and cited articles in this area or domain. This can aid them to comprehend the major works in this direction and discern the key findings.

Apart from that, a classification of the major themes in SCRES research is needed to understand the emerging themes and the well-developed clusters in this domain. This can aid researchers in SCRES to throw light in the area of developed and developing clusters of research and they can plan future research accordingly. Although, these are the primary motivations of this study, this study also add to the literature by analyzing resilience in various other contexts such as engineering, psychological, social, economic, environmental, family, system, ecological and biological perspectives to discuss the main themes under each. Also, a conceptual framework is proposed in this study for the researchers in SCRES to understand the SCRES drivers, SC focus, SC resilience strategies and SC performance measures. Hence, this study as a whole can benefit a researcher in understanding the past, present and future of research in SCRES domain.

The remainder of this paper is organized as follows: Section 2 highlights the review of the literature followed by review methodology which is exposed in section 3. Section 4 depicts the results of bibliometric analysis. Based upon the review findings, a network analysis of the selected papers is shown in section 5. This study concludes by highlighting implications, directions for future research and limitations in section 6.

2. Literature review

2.1 Resilience

The Latin word *resiliere* is the base of the word resilience, which means *bounce back,* and the core concept of resilience is the notion that the system can regain back to its original conditions, once disruption occurs (Christopher and Peck, 2004). Resilience can be attributed as a multidisciplinary and multidimensional phenomenon that spans from physical sciences to management theory. Weick and Sutcliffe (2001) report resilience is not an outcome but rather a process to anticipate and respond, to external threats continuously. Resilience is a notion defined across the literature in various domains. The commonality in the concept of resilience in all disciplines is that it helps to manage or cope with any changes or disruptions happening to a system. Engineering resilience is defined as the capability of a system to bounce back to its original conditions, once a disruptive event occurs, whereas, in the concept of ecological resilience, resilience is referred to as the capability of the eco-system to adapt and move forward. Hence, the concepts of bouncing back and bounce forth assume significance. SCRES defined by Christopher and Peck (2004) adopts the definitions of engineering resilience and mentions resilience as a capability of SC systems to regain their original states after a disruption occurs. Later, this is redefined by Sheffi (2005) and by Ponomarov and Holcomb (2009) that SCRES is the capability of SC systems to regain their original state or even better state, once disruption occurs. This is more related to the concepts of adaptability and the definitions of ecological resilience. A pictorial display of the concepts of resilience discussed across disciplines and the works done are shown in Figure 1.

Resilience cannot be seen as the opposite of vulnerability but is a discrete category, which can be considered as a process and is often more than just "bouncing back" (Matyas and Pelling, 2015). Pettit *et al.* (2010) highlighted that SCRES can upsurge when there is an increase in SC capabilities and a decrease in SC vulnerabilities. In the SC domain, Melnyk *et al.* (2014) indicated that SCRES is the central idea behind the present SC management thinking for reducing vulnerabilities. There exist various theoretical underpinnings applied that act as

Note(s): References in the figure are provided in the extended list of references

Figure 1.
Resilience concepts discussed across literature

a medium to achieve specific outcomes in the SCRES research as shown in Table 1. Previous literature has highlighted that there is a need for addressing more theoretical frameworks,

Theory	Authors
Dynamic capabilities	Ponomarov and Holcomb (2009), Golgeci and Ponomarov (2013), Mandal *et al.* (2016), Chowdhury and Quaddus (2017), Li *et al.* (2017a, b)
Resource-based view	Ponomarov and Holcomb (2009), Blackhurst *et al.* (2011), Brandon-Jones *et al.* (2014), Yang and Hsu (2018)
Systems theory	Blackhurst *et al.* (2011), Raj *et al.* (2015), Munoz and Dunbar (2015)
Control theory	Ivanov *et al.* (2012), Ivanov and Sokolov (2013), Ivanov *et al.* (2014a, b), Levalle and Nof (2017)
Complex adaptive systems	Day (2014), Tukamuhabwa *et al.* (2015)
Complexity	Gunasekaran *et al.* (2015), Papadopoulos *et al.* (2017)
Grey systems theory	Rajesh *et al.* (2021), Rajesh (2021)
Social capital	Johnson *et al.* (2013)
Information processing	DuHadway *et al.* (2019), Mandal (2017)
Relational view	Wieland and Wallenburg (2013), Chowdhury and Quaddus (2017), Yang and Hsu (2018)
Graph theory	Kim *et al.* (2015), Li *et al.* (2017a, b)
Contingent theory	Boone *et al.* (2013), Brandon-Jones *et al.* (2014), Arani *et al.* (2016)
Network theory	Soldi *et al.* (2015), Ruiz-Martin *et al.* (2015)

Note(s): *References in the table are provided in the extended list of references

Table 1.
Different theories and relevant literature

which capture and investigate the dynamic nature and relational capabilities (such as collaboration, trust, cooperation, communication and integration) on SCRES. These theories enhance our ability to comprehend a phenomenon, ascertaining the relationship among variables, and enable us to apply those outcomes in diverse contexts. For instance, the resource-based view (RBV) serves as a base point to identify the relationship among key resources, capabilities and performance.

As RBV is criticized for being static other theories have been developed to complement RBV. Most of the theories have similar shortcomings such as resource dependence theory, dynamic capabilities and contingency theories, which emphasized only on firm's capabilities and resources while ignoring their synergies and were not able to explain the systemic nature of SCRES. As a result of rapid globalization, the locus of control of SCs has now expanded beyond the firm level thus making them complex. Systems theory helps in capturing the systemic nature to deal with nonlinear dynamic interactions among components. We find RBV, dynamic capabilities and systems theory are widely used theoretical lenses to explore SCRES.

2.2 Contribution of strategies in enhancing resilience

Resilience within organizations is necessary for turbulent environments for dealing with operational and disruptive risks. For example, how resilient are the SCs in sustaining a disruption? What would be the recovery time for an SC from an epidemic/pandemic outbreak? Which SC operating policies would be most resilient to overcoming disruptions with different severity? When to act, react or use a contingency pandemic plan by keeping their short- and long-term impacts during and after the epidemic? Are decision-support frameworks needed for predicting outbreaks of epidemics and their impact on the SCs? Based on the literature, there are several strategies as shown in Table 2, which can be used as a trade-off among

Author(s)	Strategies
Lee (2009)	Quality, flexibility, delivery, technology, supply and demand constraint, buyer–supplier constraint, suppliers' and stakeholders' profile, relationship building, cost of the product, cost of relationship
Lengnick-Hall *et al.* (2011)	Policies, practices (techniques), organizational resilience (shared capabilities), organizational capacity (common characteristics), ways of human resource management
Sawik (2013)	Cost of prepositioning of emergency inventory
Yilmaz-Börekçi (2014)	Structural reliance, organizational capability, process continuity
Aditya *et al.* (2014)	Strategic stock, optimal use of assets, multiple sourcing, demand aggregation, teamwork, lead time reduction, flexible transportation
Haldar *et al.* (2012)	Quality of product, reliability of the product, customer satisfaction, functionality of the product, product cost
Chen *et al.* (2014)	Safety, quality, delivery, cash flow, risks, cost, people, environment
Torabi *et al.* (2015)	Business continuity plans for partners, contract with backup suppliers, fortification of partners
Hosseini and Barker (2016)	Absorptive capacity, restorative capacity, adaptive capacity
Kamalahmadi and Parast (2016)	Flexibility, inventory gap, risk-sharing rate
Lücker and Seifert (2017)	Stock-out time and demand served during the disruption
Parkouhi and Ghadikolaei (2017)	Benefits, (delivery, flexibility, quality, culture), opportunities (joint growth, supplier's technology, relationship building), risks (buyer–supplier constraint, partners' profile), and costs (cost of product, cost of relationship, supply constraint)
Shishodia *et al.* (2019)	Geographic location, the technical capability of suppliers, flexibility, variability in the cost of supplies, quality parameters and lead time

Table 2.
Resilience strategies

Note(s): *References in the table are provided in the extended list of references

themselves before disruptions, during disruptions, and post-disruptions for minimizing the associated financial and non-financial losses. Hence resilience could be built in by managing SC design characteristics and adoption of practices (multiple sourcing, rapid configuration, strategic inventory) (Carvalho *et al.*, 2012a, b).

According to Parsons (2020), a resilient SC must be capable of detecting any early warning indicators of disruption because if the disruption lasts longer, many manufacturers, and maybe even retailers, suspend their operations for weeks, due to delays or unavailability of required key input supplies. As reported by Wisniewski (2020), the scale of the recent COVID19 outbreak is an invisible and unfamiliar threat just like it "*hits all the hot buttons that lead to heightened risk perception*" (Fisher, 2020). The latest report of WHO (2020) has highlighted how severe the impact of COVID-19 was and further, reports by Deloitte (2020) and McKinsey (Craven *et al.*, 2020), have highlighted that for weeks, manufacturing and other businesses were entirely locked down in China, the European Union and other major countries.

Many factories stopped production cities appear vacant, as COVID-19 turned into a pandemic. This situation appears as a sign of a fragile global system [1], where individuals or organizations did not fully anticipate or plan for it. It is natural to anticipate a drastic reduction of operative performance (EBIT), shortage of materials and fluctuations in prices during any such pandemic outbursts. Say, for instance, German Post has announced an earnings before interest and taxes (EBIT) lessening in the range of €60m and €70m; apart from that, retail prices have increased in February 2020 in China by 21.9% on an average (Bild, 2020). Apple publicized in early February 2020 that their quarterly earnings shall be dropped by a large margin as there is a stoppage of manufacturing operations (Apple, 2020). Considering the late February 2020, the COVID-19 pandemic outbreak has impacted the reduction of container shipping fleets by 9% and there was a sudden dropping of the manufacturing indices in China ever since the great recession due to the immediate shutdown of all manufacturing facilities (Unglesbee *et al.*, 2020).

Wisniewski (2020) also highlights that even the best risk-management strategy with the most diversified suppliers cannot be efficient for handling roughly any outbreaks such as COVID-19, considering a short span. Organizations should focus on building their internal capabilities, preparedness, trust and local infrastructure for strengthening local SCs. Such strategic measures can induce agility for overcoming the impact of situations such as COVID-19. Figure 2 highlights some of the strategies that can be adopted by enterprises to overcome the impact of disruptive events.

3. Research methodology

A literature review provides essential insights for investigating research in an emergent field of study and reveals future research directions (Sharma *et al.*, 2018). This study adhered to the guidelines provided in established literature review studies (Thomé *et al.*, 2016; Kitchenham and Charters, 2007) for devising robust and replicable bibliometric analysis. The efficacy of a review is achieved through deploying an iterative cycle through identifying search terms (keywords), examining pertinent literature and carrying out the exploration at the end.

For this study, appropriate sources of publications were recognized in the area of SCRES. Articles were collected from the database of Scopus that accounts for the largest collection of peer-reviewed articles. The approach used for literature search for this study is comparable to an approach adopted by Maditati *et al.* (2018) and is explained in Figure 3.

3.1 Selection of database

The majority of the existing studies on review of literature have used Web of Science (WoS), Scopus and EBSCO databases, while some even used Google Scholar. For a topic in

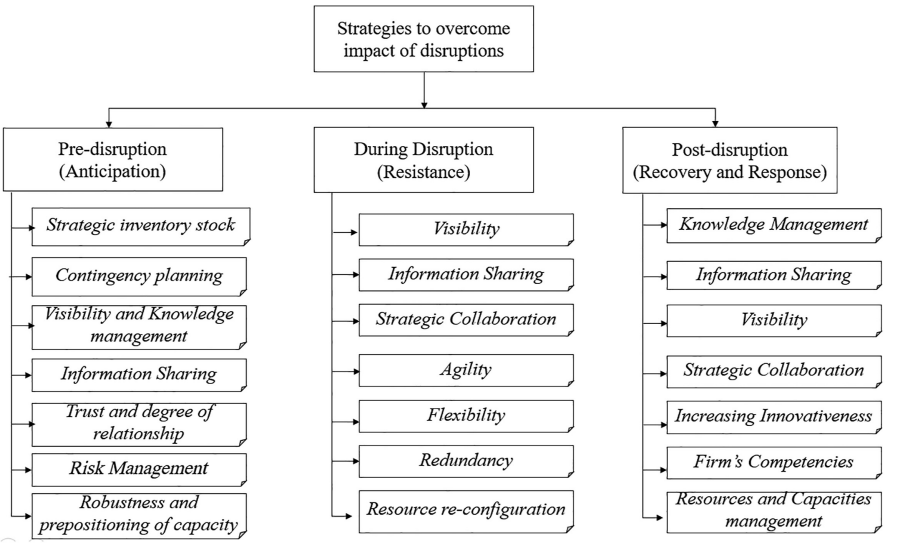

Figure 2.
Strategies for overcoming the impact of disruptions

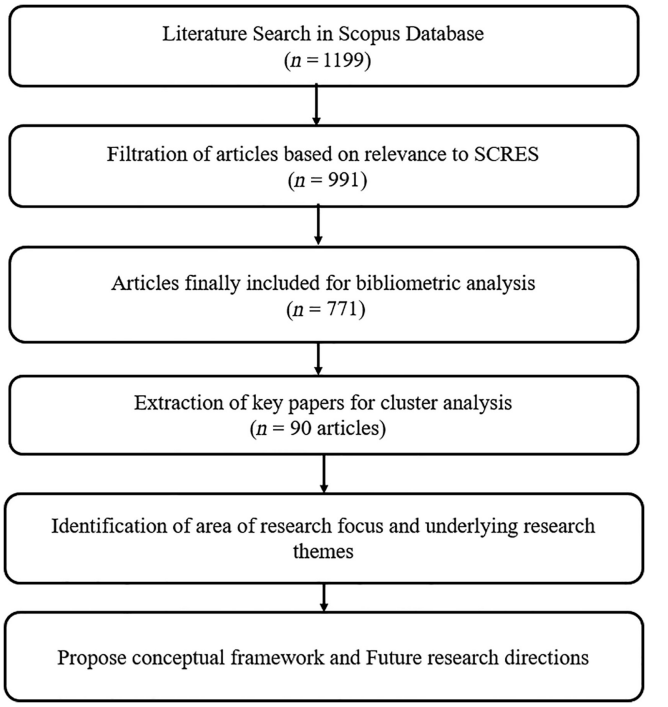

Figure 3.
Research methodology

management science such as SCRES, WoS and Scopus are most relevant. We choose the database of Scopus, as it has a wider collection of journals and article titles in the field of management, social sciences, technology and medicine (Mongeon and Paul-Hus, 2016). In

addition, from an indexing error perspective, Scopus is more accurate than WoS (Franceschini *et al.*, 2016).

3.2 Keyword selection

The keywords used in article search are the backbone of a literature review. The keywords should be comprehensive enough to cover the major studies on the topic of interest at the same time unbiased and ensure reproducibility of the sample articles. Hence, the concept of SCRES was defined through its various synonyms in the keywords for making this research as comprehensive as possible (Farooque *et al.*, 2019). A Boolean search was conducted in the Scopus database to search articles in the area of SCRES using the combined keyword search "resilience" OR ("supply chain" and "resilience") AND ("supply chain" OR "disruptions"); narrowed to the topic, article title, abstract of the study and keywords.

3.3 Collection of articles

The keyword search returned 1,199 articles on SCRES published during 1988–2020 (earlier half of 2020). The initial search returned 1,199 articles. Similar to other literature review studies (Lamba and Singh, 2017), to ensure the high scientific quality of assessed articles for review, we excluded chapters in books, theses for masters and doctoral studies and editorial notes from the selected sample. This process led to 991 articles for further consideration.

3.4 Filtering (inclusion/exclusion of articles)

To have an effective selection of the articles, these 991 articles were refined further. The researchers excluded articles with incomplete bibliographic data, and we chose articles that belonged to Q1 and Q2 in Scopus which reduced the sample to 771 articles. Finally, these 771 articles were selected for bibliometric analysis.

3.5 Overview of the articles in the sample

The trend in the number of articles published year-wise is depicted in Figure 4. The number of publications has been increasing at a year-to-year growth rate of 20.9%. Descriptive data highlights that about 25% of the total sample is covered by the top ten contributing journals, that is, 191 articles. Table 3 reports the top 10 journals (as per the number of articles published per year). IJPR, SCM and IJPE top the list.

3.6 Data analysis

We analyzed the sample of 771 articles using bibliometric analysis tools and techniques, see sections 4 and 5. The bibliometrics package (Aria and Cuccurullo, 2017) using the *R* software was used for bibliometric citation analysis. For the bibliometric network analysis (i.e. co-

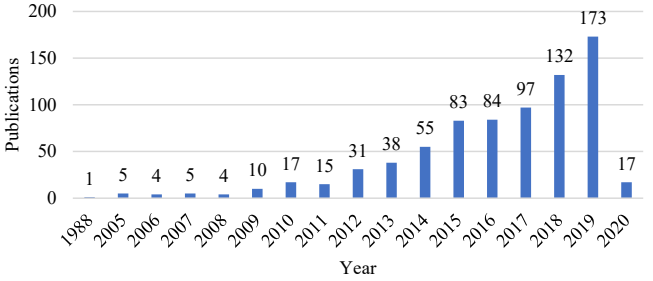

Figure 4.
Trends in publishing in the area of SCRES

Source	Publication year 2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
IJPR	0	0	2	0	0	2	4	1	6	10	18	2	45
SCM	0	0	1	2	5	3	2	3	4	3	6	1	30
IJPE	0	0	1	1	0	1	1	4	4	2	6	1	21
JCP	1	0	0	0	2	0	1	1	3	3	6	2	19
Sus.	0	0	0	0	0	1	0	3	9	3	3	0	19
CIE	0	0	0	1	0	1	2	1	0	3	4	0	12
IJOPM	0	0	0	0	1	0	1	2	0	3	5	0	12
TPE	0	0	0	0	0	0	3	3	0	3	1	1	11
IJPDLM	0	0	0	0	2	0	2	0	1	3	3	0	11
JESS	0	0	0	0	0	0	11	0	0	0	0	0	11
Total	1	0	4	4	10	8	27	18	27	33	52	7	191

Note(s): Where, IJPR = International Journal of Production Research; SCM = Supply Chain Management: an International Journal; IJPE = International Journal of Production Economics; JCP = Journal of Cleaner Production; Sus. = Sustainability (Switzerland); CIE = Computers and Industrial Engineering; IJOPM = International Journal of Operations and Production Management; TPE = Transportation Research Part E: Logistics and Transportation Review; IJPDLM = International Journal of Physical Distribution and Logistics Management; JESS = Journal of Environmental Studies and Sciences

Table 3.
Top ten journals publishing articles related to SCRES

citation), we used the VOSviewer software developed by Van Eck and Waltman (2010). The software used is both open source and can provide a wide range of bibliometric and scientometric analytics tools.

4. Bibliometric analysis

Many past studies (Sharma *et al.*, 2020; Maditati *et al.*, 2018; Fahimnia *et al.*, 2015) have employed typical software with diverse capabilities and limitations for conducting bibliometric analysis. For example, BibExcel is flexible for carrying out data analysis but fails to generate network diagrams; Gephi has excellent capabilities in drawing network diagrams but fails on the citation analysis part. Thus, we use the bibliometrics tool in *R* for citation analysis and VOSviewer for network analysis. Bibliometric analysis in this study reveals the most impactful studies on SCRES considering total citations and the trending articles based on the citation count received per article during the last five years. We observe the recent articles published for a 10-year window period from 2011 onwards in the domain of SCRES, considering the Scopus database and conduct some analysis on the publishing trends in this area. We use the keywords "supply chain" AND "resilience" for the search and limit our focus to journal articles and review papers only.

We analyzed the keywords that are appearing mostly with the terms "supply chain" and "resilience" and limit to a minimum appearance of the keyword 15 times. We remove some of the keywords based on the interpretive logic of the authors and the following results show the five keywords mostly appearing about "supply chain" and "resilience". These keywords are *risk management* (no of occurrences: 110 times), *risk assessment* (no of occurrences: 73 times), *sustainability* (no of occurrences: 69 times), *climate change* (no of occurrences: 51 times) and *decision making* (no of occurrences: 50 times). These keywords help to understand the recent and future trends in this area and assist researchers to understand the trends in SCRES research. A visualization of the major keywords and density analysis of the same is envisioned in Figure 5.

On a detailed analysis of the keyword clusters, we could perceive that there are four clusters of keywords, where the first cluster includes the connections showing "SCs, resilience, sustainability and ecosystems. The second cluster depicts the connections among

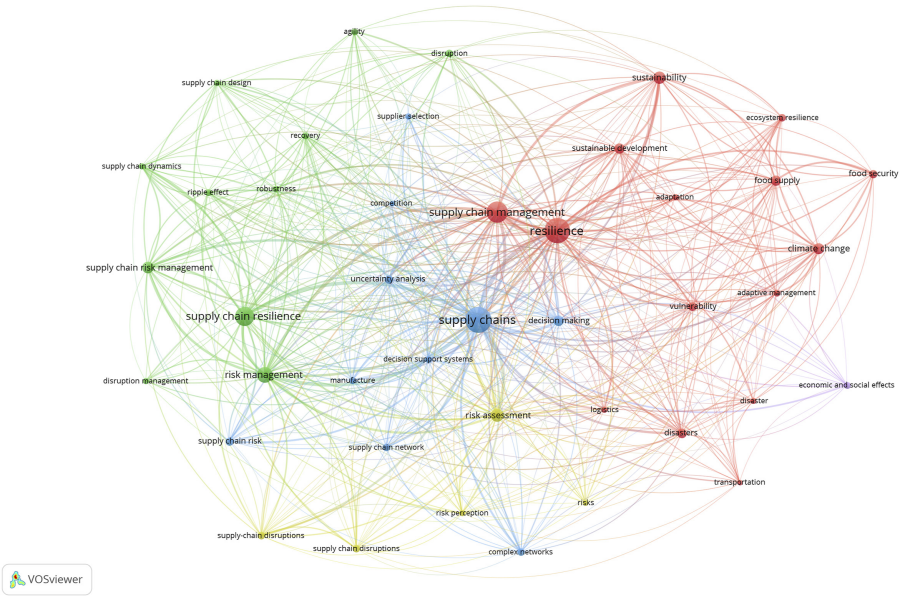

Figure 5.
Keyword analyses of the co-occurring terms of supply chain resilience

SCs, risk assessment, risk perception and disruptions. The third cluster shows connections between SCs, SC risks, uncertainty analysis and decision-making. The fourth cluster shows the connections between SCRES, ripple effects, robustness and disruption management. Here we can perceive that the first cluster of articles with the indicated keywords discusses resilience in connection with adaptability and sustainability, where the second cluster of articles debates resilience in connection with disruption and risk assessments. The third cluster of articles converses resilience in connection to decision-making and decision support systems, where the fourth cluster of articles discusses connecting resilience with managing ripple effects in SCs.

Later, we constrain our analysis to only 771 articles obtained from the database of Scopus and published between 1988 and 2020 (February 2020). The logic for constraining the number of articles to 771 is already discussed in section 3.4 and Table A1 in Appendix depicts the summary of the same. As we infer from Table A2 that the obtained articles were from 379 journal sources. The observed keywords in these articles were 3,358. About 2,056 authors were identified from these articles, with 92 sole author articles and the rest were articles contributed by multiple authors. The coming sections detail the bibliometric analysis.

5. Network analysis of publications

To reveal the underlying themes within the SCRES research, we conducted a bibliometric network analysis on the sample of 90 studies. Clustering is a phenomenon that is most commonly used for carrying out network analysis as it helps in achieving valuable insights into the network structure. As reported by McCain (1990), hierarchical clustering is a clustering technique, which is widely popular. In the context of bibliometric network analysis, each of the articles in the sample is nodes and their citation patterns are inputs for network structure identification. In this study, we use the co-citation technique for network mapping. Two or more articles are called co-cited if a third article cites them together (Small, 1973). Therefore, they are believed to share the same theme.

Based on our bibliometric network analysis, nine major research clusters were identified within the SCRES context. Figure 6 depicts the nine SCRES clusters obtained via VOS Viewer software. These selected 90 articles are highlighted in Table 4. For obtaining the clusters, the authors used a criterion of a minimum of 50 citations in VOS Viewer. The thematic evolution is depicted in Table A2 in Appendix.

5.1 Conceptual development of SCRES

Cluster 1 strengthens the understanding of SCRES emphasizing dealing with vulnerability. Therefore, most of the studies tried to explore the SC vulnerabilities and strategies to overcome them. As an initial attempt, Christopher and Peck (2004) explored the antecedents and consequences of risks through improving SC risk. Later, Tomlin (2006) determined optimal disruption management strategy for the firm considering supply-side tactics, cost, supplier characteristics and firm characteristics. Also, Tang (2006) reviewed quantitative models for managing SC risks. Craighead *et al.* (2007) further enhanced understanding of specific factors that can contribute to or dampen the severity of a SC disruption. As a milestone in resilience research, Ponomarov and Holcomb (2009) formulated a conceptual framework for SCRES, considering the antecedents, and the related consequences. Another framework in future was developed by Pettit *et al.* (2010) to reveal the linkages between SC vulnerabilities and capabilities. In continuation to this, Jüttner and Maklan (2011) investigated the associations among SC resilience, SC vulnerability and SC risk management. Blackhurst *et al.* (2011) explored strategies that can contribute or undermine supply resilience. Keeping their prior research as a conceptual foundation, Pettit *et al.* (2013) later developed a measurement instrument to help managers in improving SCRES. Further, Scholten and Schilder (2015) investigated the influence of collaboration and its underlying mechanism on SCRES. The next subsection highlights the developments in resilience SC networks.

5.2 Developments of designing resilient supply chain (SC) networks

Cluster 2 underlines recent developments in conceptualizing SCRES and emphasized designing resilient chain supply networks. Some initial attempts were made by Klibi and

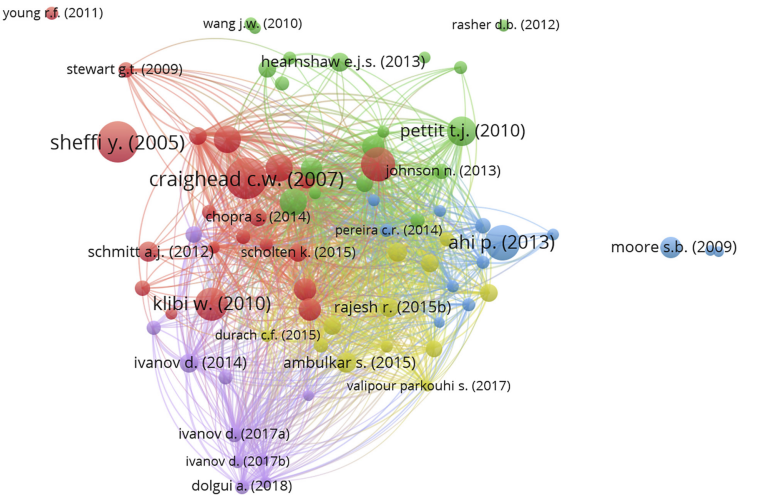

Figure 6.
Network analyses of selected SCRES clusters

Note(s): *References in the figure are provided in the extended list of references

Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V
Tomlin (2006)	Carvalho *et al.* (2012a, b)	Sheffi (2001)	Hamel and Valikangas (2003)	Sheffi (2001)
Tang (2006)	Klibi and Martel (2012)	Peck (2005)	Stevenson and Spring (2007)	Harland *et al.* (2003)
Christopher and Peck (2004)	Ivanov *et al.* (2014a, b)	Tang (2006)	Ratick *et al.* (2008)	Jüttner *et al.* (2003)
Craighead *et al.* (2007)	Chopra and Sodhi (2014)	Knemeyer *et al.* (2009)	Bhamra *et al.* (2011)	Barratt (2004)
Pettit *et al.* (2010)	Ivanov *et al.* (2014a, b)	Zsidisin and Wagner (2010)	Christopher and Holweg (2011)	Christopher and Peck (2004)
Jüttner and Maklan (2011)	Tukamuhabwa *et al.* (2015)	Colicchia *et al.* (2010)	Zhao *et al.* (2011)	Chopra and Sodhi (2004)
Blackhurst *et al.* (2011)	Ho *et al.* (2015)	Schmitt and Singh (2012)	Ishfaq (2012)	Hendricks and Singhal (2005)
Ponomarov and Holcomb (2009)	Sokolov *et al.* (2016)	Wilding *et al.* (2012)	Ghadge *et al.* (2012)	Tang and Tomlin (2008)
Pettit *et al.* (2013)	Ivanov *et al.* (2017)	Johnson *et al.* (2013)	Day (2014)	Hendricks *et al.* (2009)
Scholten and Schilder (2015)	Dolgui *et al.* (2018)	Soni *et al.* (2014)	Ali *et al.* (2017)	Wagner and Neshat (2010)

Cluster VI	Cluster VII	Cluster VIII	Cluster IX
Christopher and Peck (2004)	Francis (2008)	Khmelnitsky *et al.* (1997)	Lee *et al.* (1997)
Kleindorfer and Saad (2005)	Sawik (2013)	Dejonckheere *et al.* (2003)	Jüttner *et al.* (2003)
Jüttner (2005)	Azevedo *et al.* (2013)	Dejonckheere *et al.* (2004)	Blackhurst *et al.* (2005)
Wagner and Bode (2008)	Ambulkar *et al.* (2015)	Klibi *et al.* (2010)	Swafford *et al.* (2008)
Manuj and Mentzer (2008)	Bode and Wagner (2015)	Ouyang and Li (2010)	Ivanov and Sokolov (2013)
Braunscheidel and Suresh (2009)	Kim *et al.* (2015)	Ivanov *et al.* (2010)	Azadeh *et al.* (2014)
Wieland and Wallenburg (2012)	Fahimnia and Jabbarzadeh (2016)	Ivanov and Sokolov (2012)	Munoz and Dunbar (2015)
Carvalho *et al.* (2012a, b)	Mishra *et al.* (2016)	Spiegler *et al.* (2016)	Saenz *et al.* (2015)
Melnyk *et al.* (2014)	Lücker and Seifert (2017)	Ivanov *et al.* (2016)	Kamalahmadi *et al.* (2016)
Brusset and Teller (2017)	Behzadi *et al.* (2017)	Aven (2017)	Hosseini *et al.* (2019)

Note(s): *References in the table are provided in the extended list of references

Table 4.
Selected studies of SCRES used for cluster analysis

Martel (2012) to explore various stochastic modeling methods for designing effective robust supply networks that are resilient to disruptions. In almost a parallel study, Carvalho *et al.* (2012a, b) redesigned SC using simulation for improving SCRES and understanding the impact of mitigation strategies on SC entity performance. Later in literature, Ivanov *et al.* (2014a, b) formulated a model for solving distribution planning problems for a multi-stage centralized supply network. Also, Ivanov *et al.* (2014a, b) summarized the advances in the area of managing disruptions and analyzed various tools to handle ripple effects in continuity and disruption management of SCs. Considering the use of mathematical models, Chopra and Sodhi (2014) examined SC network for the impact of disruption risk and benefits of containment strategies using simulation and mathematical models. Further, Tukamuhabwa *et al.* (2015) reviewed and synthesized the broad literature on SCRES definitions, strategies

and theories that underpin resilience. And Ho *et al.* (2015) carried out a critical review on research developments in defining, operationalizing and mitigating SC risks. Considering a structural perspective in SCs, Sokolov *et al.* (2016) underlined recent developments in the quantification of ripple effects. Considering literature works, Ivanov *et al.* (2017) reviewed several research streams for analyzing various SC disruptive risks and recovery policies in SCs. Dolgui *et al.* (2018) conducted a quantitative literature review considering the ripple effect in SCs and formulated a control framework for the same. The following sub-section identifies the drivers of SC vulnerability and risks.

5.3 Identifying drivers of SC vulnerability and risks

Cluster 3 highlights the empirical and survey-based studies for finding out the sources and drivers of SC vulnerability, risk elements and SC disruptions. Some of the initial works in this direction can be from Sheffi (2001), who provided suggestions to companies on how should they manage in a new environment. Later, Peck (2005) conducted an empirical study considering the sources and drivers of SC vulnerability. Considering measures to act against vulnerability, Tang (2006) provided cost-effective and time-efficient strategies for mitigating SC disruptions. Knemeyer *et al.* (2009) formulated a method for quantifying different catastrophic risk events on SC locations. Zsidisin and Wagner (2010) investigated the associations among apparent supply-side risks and the occurrence of any supply disruption. Considering mitigation approaches, Colicchia *et al.* (2010) formulated a framework, which is simulation-based for identifying, managing and mitigating risks for enhancing SCRES. These studies were strengthened by Schmitt and Singh (2012), who analyzed various methodologies for inventory placement and backup. Considering a review perspective, Wilding *et al.* (2012) reviewed past studies on SC risk management and analyzed the knowledge creation and development process from a dynamic perspective. For understanding the formative elements of resilience, Johnson *et al.* (2013) examined the linkages between social capital constructs and resilience capabilities. Adding to it, Soni *et al.* (2014) identified interrelationships among SCRES enablers using interpretive structural modeling. The following subsection presents the impacts of risks on SC networks.

5.4 Impact of risks on network resilience

Cluster 4 highlights the effects of risk on SC networks, resilience in SC networks and network adaptability and vulnerability. The role of flexibility in SCs was explored by Stevenson and Spring (2007) through a literature review. Later, Ratick *et al.* (2008) emphasized using emergency backup and storage facilities for improving the SC disaster resilience and reducing potential vulnerabilities. Considering another literature analysis, Bhamra *et al.* (2011) structured the literature on SCRES to uncover several research contributions in that area. In a parallel study conducted by Christopher and Holweg (2011), building of structural flexibility in SC designs was emphasized for improving the management of SCs so as it remain competitive during turbulences. Considering studies on network resilience, Zhao *et al.* (2011) studied the impact of complex topologies of supply networks on the network's resilience against disruptions. A review of literature conducted by Ghadge *et al.* (2012) has focused on SC risk management from a system-thinking perspective. A study by Ishfaq (2012) has highlighted that a flexible logistics strategy can improve the resilience of SC networks in transportation operations. Later, a study conducted by Day (2014) has explored the new perspectives and knowledge regarding organizational participation in improving resilience. The findings of the research by Ali *et al.* (2017) have helped to enhance the conceptual precision by establishing the relationship between SCRES and its constructs through a systematic and integrated approach. The following subsection highlights the risk assessment strategies to avoid breakdowns and disruptions.

5.5 Risk assessment to avoid breakdowns/disruptions

Cluster 5 discusses empirical and modeling-based studies for measuring SC risks, SC vulnerability and SC disruptions. The study by Sheffi (2001) highlighted the strategies for managing SC operations in case of disruptions, such as terrorist attacks. A review analysis by Harland *et al.* (2003) defines risk in supply networks as a potential danger or an undesired consequence that leads to losses in terms of productivity and performance. Also, a review by Jüttner *et al.* (2003) provided insights into SC disruptions and risk management. Considering collaboration and resilience, Barratt (2004) proposed that an SC segmentation approach is the most appropriate context for collaboration. The study by Chopra and Sodhi (2004) highlighted how to effectively manage risks to avoid SC breakdowns. Christopher and Peck (2004) provided a review for creating resilient SCs in current uncertain and turbulent markets. The study by Hendricks and Singhal (2005) highlighted the effects of SC disruptions on equity risks and found that the recovery rate of the firm's post disruptions was very low. Considering a flexibility view, Tang and Tomlin (2008) presented a unified framework and five models to illustrating that an organization can obtain significant strategic value through flexibility. Considering studies on vulnerabilities and disruptions, Hendricks *et al.* (2009) empirically examined several factors such as diversification of business, geographic diversification, operational slack and vertical relatedness that could affect the stock market responses to SC disruptions. Wagner and Neshat (2010) formulated a graph theoretic approach for quantifying and mitigating SC vulnerabilities. The following subsection highlights the resilience approaches and drivers for improving SC performance.

5.6 Measuring resilience approaches and drivers to improve SC performance

Cluster 6 includes studies that have used empirical research for measuring agility, flexibility and responsiveness for creating resilience while focusing on SC performance. Kleindorfer and Saad (2005) presented a combined framework for risk assessments and risk mitigation approaches to various disruptions in SCs. Parallel to this, Jüttner (2005) highlighted business requirements for SC risk management from a practitioner's perspective. The research by Wagner and Bode (2008) operationalized several sources of SC risks using contingency theory and investigate their relationships with SC performance. The conceptual review by Manuj and Mentzer (2008) integrated literature from logistics, SCM, operations management, strategy and international business for developing a model for mitigating global SC risks. Braunscheidel and Suresh (2009) studied the influence of a firm's organizational learning and market orientation with respect to integration in SC, flexibility, disruption, responsiveness and risk mitigation approaches. Considering agility and performances, Carvalho *et al.* (2012a, b) proposed a framework for analyzing relationships among agility and resilience considering various approaches in a SC. Wieland and Wallenburg (2012) investigated the effects of SC risk management on the performance of SC. Subsequently, Brusset and Teller (2017) mapped the relationships among controllable resources, processes and practices for achieving resilience. The following subsection reflects on the studies that incorporated resilient capabilities by integrating other SC dimensions, such as sustainability, supplier selection, organization resilience capabilities and SC decision making.

5.7 Building resilient capabilities by integrating other SC dimensions

Cluster 7 presents modeling techniques for capacity building in SC stakeholders, such as resilient supplier selection and evaluation while focusing on SC network design. In view of some of the initial works, Francis (2008) presented definitions on SC visibility for effective SC integration. Considering the supplier part, Sawik (2013) reported conditional value at risk through optimal choice and fortification of part suppliers and order quantity allocation amidst SC disruptions. Attempts for measuring greenness and resilience by Azevedo *et al.* (2013)

purpose to offer an Ecosilient Index for assessing the greenness and resilience of automotive organizations. Considering a disruption management view, Bode and Wagner (2015) proposed a model for predicting the frequency of SC disruptions considering SC complexity in the upstream SCs. In an analogous study, Ambulkar *et al.* (2015) highlighted the factors contributing to the development of an organization's resilience to SC disruptions. Utilizing graph theory, Kim *et al.* (2015) conceptualized SC network disruptions and SC resilience by examining structural relationships among entities in the SC network. In an invigorating work by Fahimnia and Jabbarzadeh (2016), the sustainability–resilience relationship at the SC design level was explored and the ideas for the design of a sustainable–resilient supply network was proposed. Later in literature, Lücker and Seifert (2017) investigated the relationship between risk, operations management and inventory control. In an attempt to proposing strategies for resilience, Behzadi *et al.* (2017) conducted studies in the agribusiness SC and offered robust and resilient strategies for mitigating SC disruptions. The following subsection investigates the studies in the cluster that quantified the SC network for coping up with various risks and uncertainties.

5.8 Quantification of SC network

Cluster 8 discusses on the modeling related to SC dynamics and SC network design under uncertainties. Seeing some initial attempts, Khmelnitsky *et al.* (1997) introduced a continuous-time optimal control strategy to deal with production scheduling problems. As we see, most of the studies in this cluster (Dejonckheere *et al.*, 2003; Ivanov *et al.*, 2010, 2016; Ivanov and Sokolov, 2012; Spiegler *et al.*, 2016) have utilized modeling and structural dynamics analysis for reducing SC uncertainties and enhancing SC adaptivity. For mitigating disruptions, Dejonckheere *et al.* (2003) highlighted the usage of system dynamics and control-theoretic approaches in production smoothing. Adding to it, Dejonckheere *et al.* (2004) highlighted how effective information sharing with the help of replenishment rules can reduce disruptions and uncertainties in multi-echelon SCs. Attempts for the design of supply chain network under uncertainty was made by Klibi *et al.* (2010) and some of the related problems were emphasized. Ouyang and Li (2010) utilized frequency domain analysis for the propagation and amplification of disruptions in SC networks. A framework for adaptive SCs in contemplation of structural dynamics was introduced by Ivanov *et al.* (2010) for planning and operations. Further to this, Ivanov and Sokolov (2012) utilized optimal program control theory and operations research to answer the challenges of SC scheduling under uncertainty. Later in literature, Ivanov *et al.* (2016) presented a dynamic model for scheduling problems in Industry 4.0 manufacturing paradigm that could enable firms to overcome SC disruptions through real-time responsiveness and SC flexibility. Spiegler *et al.* (2016) proposed and tested a methodology utilizing nonlinear control theory for analyzing SCRES dynamically. Seeing works in the intersection of resilience and performances, Aven (2017) highlighted the relationship between risk and resilience by analyzing and defining system resiliency and system performances. The following subsection presents the studies that emphasize developing robustness in the SC networks for mitigating risks.

5.9 Emphasis on developing robustness in SC networks

Cluster 9 emphasizes the importance of robustness in the SC network for enhanced SC performance. Most of the studies in this cluster (Lee *et al.*, 1997; Jüttner *et al.*, 2003; Blackhurst *et al.*, 2005; Swafford *et al.*, 2008; Ivanov and Sokolov, 2013; Azadeh *et al.*, 2014; Munoz and Dunbar, 2015; Kamalahmadi and Parast, 2016; Hosseini *et al.*, 2019) pointed on mitigating sourcing risks that arises due to supplier selection and proposes notions to minimize SC disruptions. A study considering bullwhips by Lee *et al.* (1997) highlighted how effective information flow can minimize distortions and reduce bullwhips in SCs. Jüttner *et al.* (2003)

stressed the risk management strategies (such as avoidance, control, cooperation and flexibility) to mitigate risks in SCs. Considering sourcing risks, Blackhurst *et al.* (2005) explored issues underlying global sourcing and disruptions in SCs, while focusing on SC uncertainty and risk. In an attempt to proposing theory, Saenz *et al.* (2015) provided the groundwork for the emerging theory of SC robustness. A literature study by Kamalahmadi and Parast (2016) focused on enterprises and their SCRES. Several studies also highlighted that factors such as SC planning, agility and flexibility can reduce the ripple effects in the SCs (Swafford *et al.*, 2008; Ivanov and Sokolov, 2013; Hosseini *et al.*, 2019). A gist of the identified themes from the clusters is depicted in Figure 7. The next section highlights the future research directions based on the review conducted and proposes a framework and finally summarizes the study in the conclusion section.

6. Implications, future research directions, limitations and conclusion

6.1 Study implications

This study offers various implications for research and practice. The researchers can make use of the resilience framework for advancing the studies on SC resilience while focusing on the absorptive, adaptive and restorative capacities. They can focus on various SCRES enhancement strategies for enhancing the organizational performance. This study presents a resilience framework that can be used by the practitioners for overcoming disruptions. As it can be inferred from Figure 8, it is anticipated that the practitioners focus on the SCRES

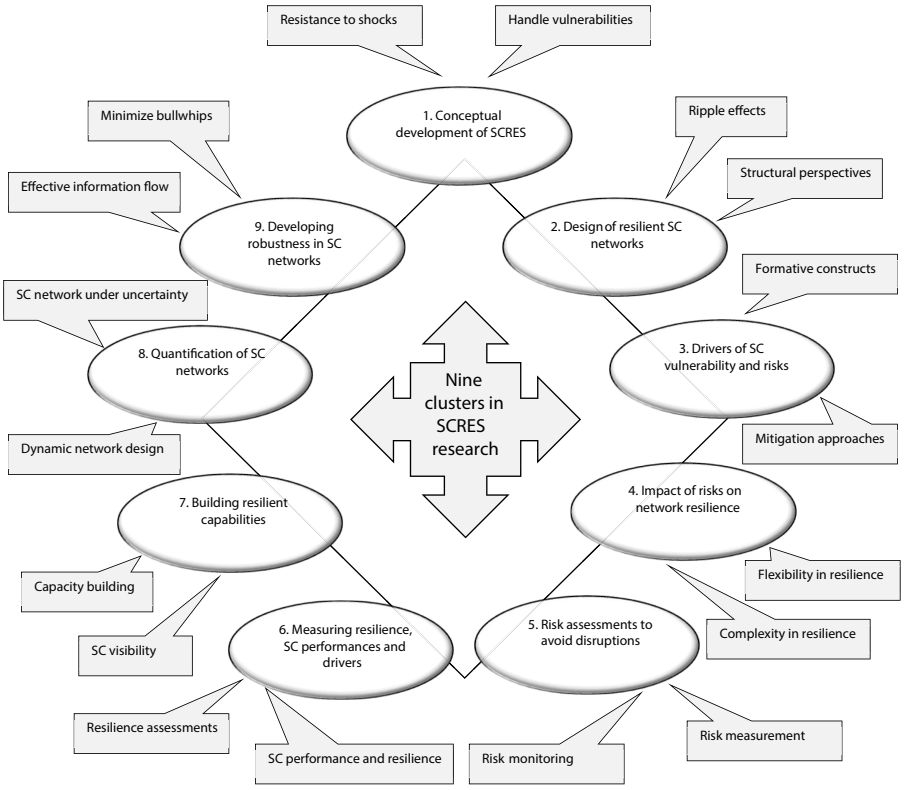

Figure 7.
Resilience clusters and the key constructs in each cluster

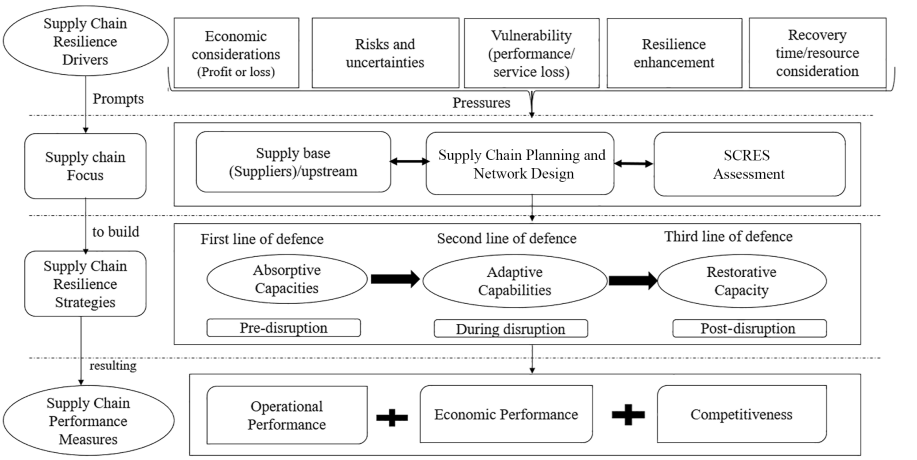

Figure 8.
Proposed conceptual framework

drivers, namely, profit and loss, uncertainties and risks, services/performance loss and resilience enhancement factors such as recovery time considering resource availability. These drivers prompt a focus on the SCs for strengthening the supply bases upstream and downstream. The resilience enhancement factors force swift SC network design, SC planning and allow SCRES assessment. Based on the resilience assessment capabilities in the SC, the practitioners can now build upon the SC resilience strategies, namely absorptive capacities, adaptive capacities and restorative capacities. These predominantly focus on pre-disruption, during disruption and post-disruption. The SC resilience strategies will allow practitioners to measure and assess the SC performance, thereby help in improving the operational efficiency. Therefore, the improved resilience capabilities can then add to the sustainable performance (Awan, 2019a, b).

6.2 Future research directions

Sustainable competitive advantages of firms are directly related to the resilience of their SC systems. Hence, we investigate the articles discussing SCRES and map the important themes. We have analyzed 771 published studies in SCRES from 1988 through 2020. The selected studies were then segregated into themes based on cluster analysis. Further, on basis of the analysis and insights from Figure 7, a conceptual framework is formulated, which is depicted in Figure 8. We observe that the number of studies in journals, which are linking SCRES with sustainability, is found to be less, as depicted from the journal-wise publications. Future studies may benefit by incorporating sustainability frameworks and incorporate the product lifecycle analysis to study SCRES. Furthermore, the studies can empirically test the relationship between SCRES and sustainable SCs. It would be interesting to classify and assess SCRES strategies country-wise, i.e. developed, developing and undeveloped countries to tackle disruptions effectively, as our understanding is limited to what creates SCRES further than top-level generic SC strategies and the interrelationships among these strategies.

This limitation includes, specifically, our understanding on what kinds of capabilities are required for enhancing resilience or can say the best set of indicators for measuring SCRES. It is less obvious to identify when and how much organizations have to invest in resilience, at what level (national, regional and local) and under what circumstances and also, how SCRES strategies can be used to measure the impact of disruption before unexpected events materializes into reality. Some past reviews have outlined how well SCRES can be coupled with

other SC concepts (management practices), but none of these studies called for contrasting and comparing different management strategies. Future studies can categorize the impact of SCRES into different performance parameters including logistics, sustainability, financial and market performance. Practitioners may investigate how SCRES can improve performance while minimizing its impact on risks and cost-efficiency. There is a need of developing a hierarchy of issues or disruptions to study their effect and relative importance for detailed analysis. This is crucial to deal with SC vulnerabilities and these can be addressed through the resilience study at the SC levels. Studies can further empirically investigate the relationship between digitalization (digital technologies) and SCs in terms of nature, impact and performance implications of digitalization on SCRES. With the recent developments in industry 4.0 and SC digitalization, opportunities are abundant, but they also create new challenges for SCRES. Visualizing SCRES is the next step for simulation research as simulation-based models will further enhance the capabilities in SC agility modeling.

6.3 Conclusions and limitations

The data analysis used in this study has explored various influential journals, authors and trending articles across SCRES literature. Furthermore, the clustering technique was used for network analysis of 90 most cited articles. This analysis resulted in the emergence of nine major research clusters highlighting the area of research focus and underlying the following research themes: (a) conceptual development of SCRES (b) recent developments and emphasis on designing resilient SC networks (c) focus on identifying drivers of SC vulnerability and risks (d) impact of risks on network resilience (e) risk assessment to avoid breakdowns/disruptions (f) measuring resilience approaches/drivers to improve SC performance g) building resilient capabilities by integrating other SC dimensions h) quantification of SC network i) emphasized on developing robustness in SC networks. The proposed conceptual framework and future research directions can lead to exploring new areas related to SCRES for offering ground for inspiring future academicians, practitioners and policymakers. The findings from the review are based upon the articles collected from Scopus till February 2020; therefore, we might not have considered any important study beyond that timeline. The review spanned 32 years and we believe it is comprehensive although not exhaustive, as it covers leading academic journals publishing in the area of SCRES.

Note

1. https://www.newyorker.com/news/daily-comment/the-pandemic-isnt-a-black-swan-but-a-portent-of-a-more-fragile-global-system

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Appendix

Description	Results
Documents	771
Sources (Journals)	379
Keywords	3,358
Author's keywords	2,065
Period	1988–2020
Average citations per documents	21.51
Authors	2,056
Author appearances	2,575
Authors of single-authored documents	92
Authors of multi-authored documents	1964
Single-authored documents	113
Documents per author	0.377
Authors per document	2.65
Co-authors per documents	3.32
Collaboration index	2.97
Articles	716
Review	59

Table A1. Bibliometric analysis summary

From	To	Keywords	Occurrences
Supply chains-1988–2014	Complex networks-2015–2016	Complex networks	5
	Supply chain management-2015–2016	Supply chain management; optimization; sustainable development	19
	Supply chains-2015–2016	Risk assessment; supply chains; resilience; uncertainty analysis; commerce; supply chain resilience; risk management; disasters	10
Complex networks-2015–2016	Article-2017–2018	Ecosystem resilience	7
	Supply chains-2017–2018	Transportation	6
Human-2015–2016	Human-2017–2018	Human	8
Supply chain management-2015–2016	Human-2017–2018	Food security; food supply	9
	Optimization-2017–2018	Optimization	6
	Supply chains-2017–2018	Supply chain management; sustainability; vulnerability; climate change; sustainable development	32

(*continued*)

Table A2. Thematic evolution of SCRES

From	To	Keywords	Occurrences
Supply chains-2015–2016	Human-2017–2018	Decision making	8
Supply chains-2015–2016	Supply chains-2017–2018	Supply chains; resilience; risk assessment; design; supply chain resilience; risk management; commerce; uncertainty analysis; disasters; economic and social effects; supply-chain disruptions	63
Human-2017–2018	Article-2019–2019	Human; food supply	9
Human-2017–2018	Supply chains-2019–2019	Decision making	8
Supply chains-2017–2018	Article-2019–2019	Climate change	17
	Supply chains-2019–2019	Supply chains; supply chain resilience; supply chain management; risk assessment; resilience; decision support systems; disasters; risk management; supply chain risk management; recovery; uncertainty analysis; supply-chain disruptions; economic and social effects	76
	Sustainable development-2019–2019	Sustainable development	19
	Supply chain management-2020–2020	Supply chain management	25
	Supply chains-2020–2020	Supply chain resilience; supply chains	24

Table A2.

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