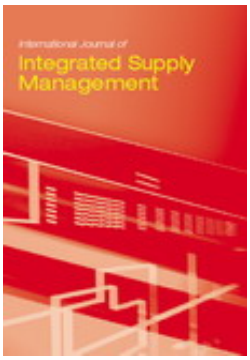

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Supply chain resilience: a tertiary study

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Supply chain resilience: a tertiary study

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Abstract: This tertiary study systematically analyses 65 literature reviews on supply chain resilience (SCR) published in academic journals or conference proceedings. Our focus is on the vulnerabilities and capabilities of a supply chain that need to be balanced to achieve resilience. We explore the interdependencies of these two categories of SCR by developing an innovative framework to realise capabilities after identifying the SCR vulnerabilities. First, we propose a framework that systematises the vulnerabilities and capabilities identified in the literature. Then, we discuss the identified SCR characteristics based on the framework and quantitatively evaluate the literature reviews' focus on the two SCR categories. A synthesis of the research results shows the SCR characteristics addressed in the literature and reveals deficits for specific vulnerabilities. Finally, we outline future research opportunities based on these findings by mapping SCR capabilities and vulnerabilities in light of Industry 4.0 and digital supply chain developments. Then, we derive research gaps and recommended actions for practitioners in the context of SCR and Industry 4.0.

Keywords: resilience; supply chain risk management; sustainability; Industry 4.0; systematic literature review; review of reviews.

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1 Introduction

Supply chains have always been exposed to the risk of disruptions, which can result in long-term economic damage, even if they last for a short but unpredictable period (Emenike and Falcone, 2020). For example, the six-day blockade at the Suez Canal by the container ship Ever Given led to the widespread disruption of numerous Eurasian supply chains lasting several weeks. During the blockade, $9.6bn worth of goods could not be moved per day (Harper, 2021) and more than 350 ships piled up at the respective entrances to the Suez Canal (Ziady, 2021). The ensuing ripple effect (Ivanov et al., 2019; Ghadge et al., 2021; Li et al., 2021) of ship shortages in ports has resulted in a threefold increase in freight costs, making some transport routes uneconomical. Another example is the COVID-19 pandemic. The semiconductor industry faced a bottleneck before the pandemic that has since affected numerous downstream industries (Fitch and Koh, 2021). For instance, delivery times for new cars exceed one year, and prices for the latest generation of graphic cards or game consoles have increased significantly owing to a high demand (Hollister, 2021). Moreover, many companies worldwide are concerned that they may be affected by such COVID-19-induced supply chain disruptions (Ivanov, 2021b; Choi, 2021; Hosseini and Ivanov, 2021).

In addition to the risks of supply chain disruptions due to human error or pandemics, other potential causes of disruption need to be considered (El Baz and Ruel, 2020; Singhal et al., 2011; Ho et al., 2015). Supply chain risk management includes all measures to identify risks at an early stage and take preventive measures to avoid or mitigate them (Tang, 2006). Supply chain disruption risks can be caused by internal and external disruptions, depending on the source of the disruption (Stecke and Kumar, 2009). Internal disruptions occur within the supply chain and can be avoided or mitigated

easily through active risk management. These include human failures, financial bottlenecks, and internal accidents, such as fires or breakdowns in central production facilities. Conversely, external disruptions are caused by the environment surrounding the supply chain and can therefore be avoided or mitigated less easily, such as pandemics, natural disasters, economic setbacks, and deliberate threats including terrorist attacks (Park et al., 2013; Sheffi, 2001).

The variety of possible causes of disruptions illustrates the complexity of risk management in global supply chains. As risk management becomes increasingly challenging with the growing number of risks, scientific research in recent decades focuses on complementary forms of dealing with supply chain risks. Supply chain resilience (SCR) is an important topic in supply chain management research (Ali and Gölgeci, 2019; Fiksel, 2006; Hohenstein et al., 2015; Jüttner and Maklan, 2011; Ponis and Koronis, 2012; Ponomarov and Holcomb, 2009; Tukamuhabwa et al., 2015; Alkalha et al., 2021). The word resilience is originally derived from the Latin 'resiliere', which means 'to bounce back' (Hosseini et al., 2016). This concept has since evolved in many ways and has been used in ecology and psychology (Ponis and Koronis, 2012). The most frequently cited definitions of SCR are those by Christopher and Peck (2004) and Ponomarov and Holcomb (2009). Christopher and Peck (2004, p.4) define SCR as "the ability of a system to return to its original state or move to a new, more desirable state after being disturbed". Ponomarov and Holcomb (2009, p.131) explain SCR as "the adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining [the] continuity of operations at the desired level of connectedness [,] and control over structure and function". In summary, resilience in the context of supply chain risk management can be described as the supply chain's ability to withstand or mitigate the effects of disruption and subsequently return to its normal or better state. Therefore, resilience differs from risk management as it may already be a part of a supply chain and does not have to be actively pursued. Rather, resilience is established through the construction of the supply chain itself (Gunasekaran et al., 2015), for example, by considering low security needs in the design of a supply chain (Ivanov and Dolgui, 2019) or by using resilient assets (Ivanov, 2021a).

The resilience of a supply chain is determined by the *vulnerabilities* it can withstand and by its resilience-building capabilities (or contributors) to return to the normal state after being disrupted (Pettit et al., 2013). Notably, resilience-building capabilities have recently received increased attention in scientific research (Agarwal et al., 2020; Hosseini et al., 2019a; Kochan and Nowicki, 2018; Naimi et al., 2021; Negri et al., 2021; Vishnu et al., 2020). Thus, an increasing diversity of capabilities and vulnerabilities are being addressed, including capabilities related to the recovery aspect of a supply chain after a disruption and aspects of anticipation or adaptability before a disruption occurs.

Furthermore, the number of literature reviews on SCR is increasing. However, despite the large number of published literature reviews on this subject, the number and designation of capabilities vary significantly. Moreover, compared with resilience-based capabilities, the vulnerabilities addressed by resilience tend to be explored in less detail. As resilience is assumed to complement risk management, the identification of vulnerabilities covered by resilience capabilities is of crucial importance. As such, a synthesis of published review articles can be beneficial. Therefore, this study aims to determine how contemporary literature addresses the vulnerabilities and capabilities of resilience and whether a balance between the two can be identified. Although capabilities are an important pillar of SCR, they have been treated superficially in the literature till

date (e.g., Pettit et al., 2013). Therefore, we provide a condensed overview of the capabilities and vulnerabilities addressed in the literature, introduce a new framework that allows quantification of the balance of supply chain vulnerabilities and capabilities, and identify recommendations for future SCR research.

For this purpose, we conduct a tertiary study (i.e., a systematic review of the literature). This approach is particularly recommended because of the large amount of secondary literature that has been published on SCR. Moreover, it enables an aggregated compilation of the current state of research. This allows us to derive conclusions based on a condensed state of information that is significant due to the underlying top-down-view. First, based on a systematic methodology, existing literature reviews on SCR are identified and analysed according to our conceptual framework. Relevant literature reviews are examined and their content is systematically classified and evaluated (see Hochrein et al. (2015) for a similar approach). This enables downstream analysis of popular topics and helps identify promising research gaps. A tertiary study also combines the results of different methodological approaches into a single contribution, thereby minimising the influence of subjective limitations of individual articles. To the best of our knowledge, only one preliminary tertiary analysis of SCR is available in the literature. Simbizi et al. (2021) examine the development of SCR definitions. In their conference paper, they analyse the content of 17 literature reviews and identified common aspects in the definition of SCR. However, a detailed differentiation of the capabilities and vulnerabilities of SCR is lacking. Similarly, the sample size is limited. Thus, a new in-depth investigation is warranted.

The remainder of this paper is organised as follows. Section 2 provides an overview of the proposed methodology followed by a discussion of the conceptual design of the framework, which uses a point scale to quantitatively weigh and analyse the aspects of SCR. Section 3 presents the results of the tertiary analysis. Section 4 discusses the findings through the lens of the developed framework, addressing capabilities and vulnerabilities of SCR and their interactions. In Section 5, we present a new classification framework that maps the vulnerabilities and capabilities of SCR using Industry 4.0 technologies. Research gaps have been identified based on this framework. Finally, Section 6 summarises the findings of our study and discusses the implications and limitations in our research.

2 Methodology

2.1 Literature search and selection strategy

Tertiary studies require a comprehensive and reliable literature sample to ensure that readers can evaluate and comprehend research findings (Abedinnia et al., 2017). The main objective of a literature review is to structure the existing literature on a topic to analyse the current state of research and identify existing research gaps (Hochrein et al., 2015). Literature reviews are commonly differentiated into narrative reviews, scoping reviews, systematic reviews, and meta-analyses based on their approach to deriving a literature sample (Hochrein and Glock, 2013). Narrative reviews do not describe how the literature sample was developed, and do not systematically document the literature search process. Therefore, it is often difficult or impossible for readers to reproduce the findings, particularly when the research results are based on the selection of articles reviewed from

a research field (Glock et al., 2017). Depending on their designation and in contrast to narrative reviews, scoping reviews aim to identify and map the available evidence on a topic to clarify the key concepts and definitions in the corresponding literature (Munn et al., 2018). Scoping reviews examine how research is conducted on a certain topic or field and attempt to identify and analyse existing knowledge gaps. Owing to their exploratory nature, scoping reviews often tend to be a precursor to a systematic literature review, which uses a systematic methodology to generate a literature sample. The objective of a systematic literature review is to present the research results as transparently, objectively, and reproducibly as possible (Durach et al., 2017; Glock and Grosse, 2021). For this reason, systematic literature reviews represent the most unbiased form of literature review. Often the data from systematic reviews are extracted and used as a starting point for a subsequent meta-analysis. Finally, meta-analyses evaluate an existing literature sample using statistical techniques to gain insights and, therefore, are primarily quantitative (Hochrein and Glock, 2013). The aim of our methodology is to systematically identify the capabilities and vulnerabilities of SCR. We conduct a systematic literature search following the methods of Tranfield et al. (2003) and Denyer and Tranfield (2009) to identify relevant literature review articles. As shown in Figure 1, the literature sample has been derived in five successive steps.

1 *Formulation of research questions:* the first step is to ensure that the research questions are consistent with the objective of identifying the capabilities and vulnerabilities of SCR. The following research questions are formulated.

   RQ1 What types of literature reviews address the topic of SCR or supply chain risk management and resilience?

   RQ2 What capabilities and vulnerabilities are mentioned in the context of SCR in these reviews? How can they be classified and systematised?

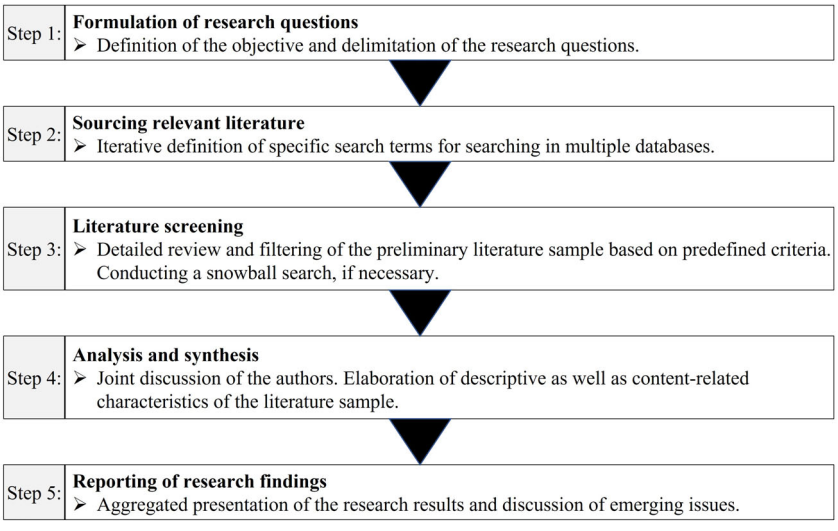
   RQ3 Which SCR topics are addressed in literature reviews and what are the specific research gaps that emerge?

2 *Sourcing relevant literature:* the aim is to define topic-related search criteria that can be used to identify relevant literature. Literature reviews that cover SCR are classified as relevant if they mention at least one SCR capability or vulnerability. It is also important to vary the search terms used to identify studies with different wordings. In addition, the methodology used in each review article is also considered. Table 1 provides an overview of search terms. The scholarly databases, including Google Scholar, Ebsco Host, Wiley Online, Emerald, Elsevier, Springer Link, and Web of Science, are searched in January 2022 and include all publications that appeared by the end of 2021. The search terms are limited to the title, abstract, and keywords of the articles and are combined using the Boolean connectors ‘AND’ between groups and ‘OR’ within a group to narrow down the search results.

3 *Literature screening:* relevant literature reviews are identified using the search. The suitability of the literature is determined using the PRISMA approach, as shown in Figure 2. A two-step process is used. The abstract of an article is first read to determine its suitability in terms of content and methodology for the research questions. If a final conclusion cannot be reached based on the abstract, the entire article is read in the second step. If an article is still not considered relevant because, for example, it only addresses a minor aspect of SCR or is conducted without using

the methodology of a literature review, it is removed from the sample. Conversely, additional literature reviews are added to the sample after the snowball search. After filtering 126 articles from the initial search, 65 articles remain. Certain review articles have been excluded because they focus on supply chain sustainability (e.g., Brandenburg et al., 2014; Fahimnia et al., 2015) or supply chain management in general and not SCR (Spina et al., 2013; Pournader et al., 2020). We also exclude articles that thematically addressed SCR but not in the form of a literature review.

Figure 1 Literature search and review methodology

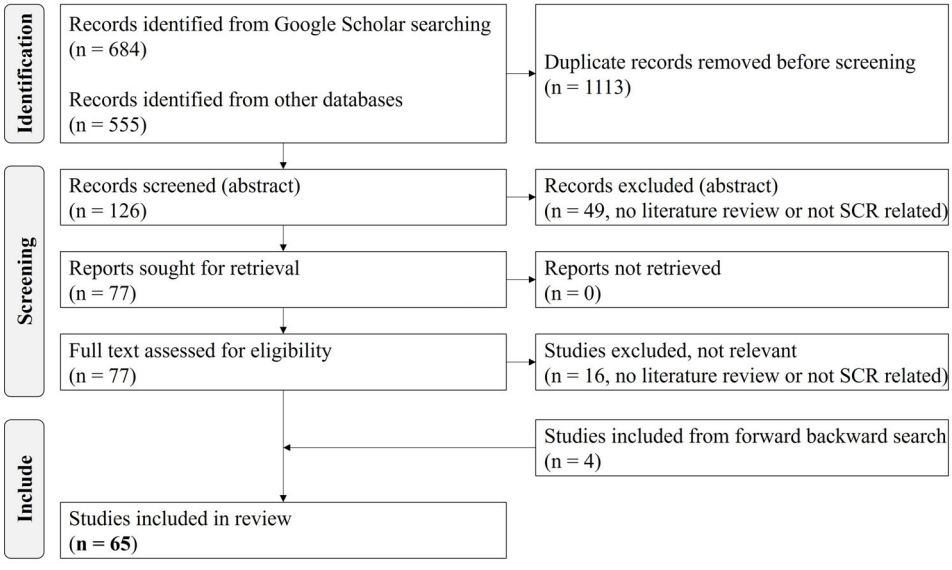


Source: Adapted from Denyer and Tranfield (2009) and Stone and Rahimifard (2018)

Table 1 Keywords used in the database search

Group A: Search strings related to resilience (topic)	*Group B: Search strings related to literature reviews (methodology)*
'Resilience'	'Review'
'Supply chain'	'Literature review'
'Supply chain resilience'	'Literature analysis'
'Supply chain risk'	'Literature'
'Supply chain disruption'	'Analysis'
'Disrupt/ion'	'Meta analysis'
'Supply chain vulnerability'	'Systematic'
'Supply chain capability'	'Systematic literature review'
'Vulnerable/bility'	'Narrative'
'Capa/ble/bility'	'Narrative literature review'
'Supply network'	'Bibliometric'
	'Scoping'
	'Scoping literature review'

Figure 2 Process of literature selection based on the PRISMA approach



4 *Analysis and synthesis:* finally, all authors have read the literature to establish a common level of knowledge. To avoid subjective impressions, codes are critically discussed and important aspects of the articles are extracted. This includes the capabilities and vulnerabilities mentioned in the corresponding review articles, SCR definitions, and methodological approaches. Based on this, a framework is developed to create a platform and analyse relevant information. The development of this framework follows a mixed approach: first, existing frameworks are deductively compared considering the number of capabilities and vulnerabilities identified. Then, the framework with the highest level of agreement is selected as the starting point (Pettit et al., 2013) and continuously expanded inductively to include missing attributes. In addition to content-related aspects, we analyse the descriptive characteristics of the sample.

5 *Reporting the research findings:* the final step is to apply the developed framework. The associated categories are systematically filled and then designed in a visually appealing manner to ensure that the research results can be presented as comprehensibly and inductively as possible. For this, the characteristics of a supply chain are tabulated as vulnerabilities or capabilities to easily compare the ratio between the two aspects and individual characteristics. A detailed illustration of the framework table is provided in Appendices A–D.

2.2 Framework

The starting point for the development of our framework follows the concept of SCR outlined by Ponomarov and Holcomb (2009), Pettit et al. (2010) and Ponis and Koronis (2012). Although SCR has no unique definition, the resistance and recovery capabilities of the supply chain have been addressed in many definitions (Hosseini and Ivanov, 2019). The definitions of SCR are summarised in Table 2.

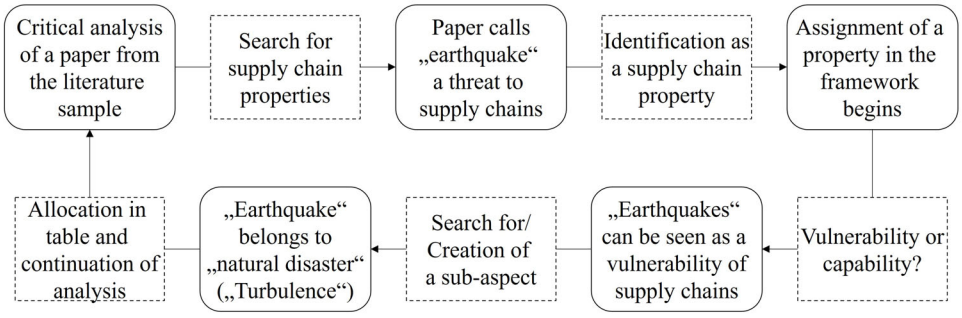
Table 2 Supply chain resilience definitions

Authors/year	*Definition of SCR*
Christopher and Peck (2004, p.2)	"The ability of a system to return to its original state or move to a new, more desirable state after being disturbed."
Ponomarov and Holcomb (2009, p.131)	"The adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function."
Pettit et al. (2010, p.1)	"The capacity for an enterprise to survive, adapt, and grow in the face of turbulent change."
Jüttner and Maklan (2011, p.247)	"Supply chain resilience addresses the supply chain's ability to cope with the consequences of unavoidable risk events in order to return to its original operations or move to a new, more desirable state after being disturbed."
Ponis and Koronis (2012, p.925)	"The ability to proactively plan and design the supply chain network for anticipating unexpected disruptive (negative) events, respond adaptively to disruptions while maintaining control over structure and function, and transcending to a post-event robust state of operations, if possible, more favorable than the one prior to the event, thus gaining competitive advantage."
Melnyk et al. (2014, p.36)	"The ability of a supply chain to both resist disruptions and recover operational capability after disruptions occur."
Brandon-Jones et al. (2014, p.58)	"The ability of a supply chain to return to normal operating performance, within an acceptable period, after being disturbed."
Hohenstein et al. (2015, p.108)	"Supply chain's ability to be prepared for unexpected risk events, responding and recovering quickly to potential disruptions to return to its original situation, or grow by moving to a new, more desirable state in order to increase customer service, market share, and financial performance."
Kim et al. (2015, p.50)	"We define supply network resilience as a network-level attribute to withstand disruptions that may be triggered at the node or arc level."
Tukamuhabwa et al. (2015, p.5599)	"The adaptive capability of a supply chain to prepare for and/or respond to disruptions, to make a timely and cost-effective recovery, and therefore, progress to a post-disruption state of operations-ideally, a better state than prior to the disruption."
Elleuch et al. (2016, p.1449)	"Resilience is defined as the ability of a system to return to its original state or a more favourable condition, after being disturbed."
Hosseini and Barker (2016, p.71)	"The ability to withstand, adapt to, and recover from a disruption is generally referred to as resilience"
Kamalahmadi and Parast (2016, p.121)	"The adaptive capability of a supply chain to reduce the probability of facing sudden disturbances, resist the spread of disturbances by maintaining control over structures and functions, and recover and respond by immediate and effective reactive plans to transcend the disturbance and restore the supply chain to a robust state of operations."
Hosseini et al. (2020, p.1)	"Supply chain resilience is defined as the ability to absorb negative external disturbances and restore normal operations."
Wieland and Durach (2021, p.316)	"Supply chain resilience is the capacity of a supply chain to persist, adapt, or transform in the face of change."

Table 3 Categories of vulnerabilities and capabilities used in the framework

Vulnerability category	*Definition*	*Examples of sub-aspects*	*Capability category*	*Definition*	*Examples of sub-aspects*
Turbulence	Environment characterised by frequent changes in external factors beyond your control	Pandemic; natural disaster; economic settlement	Flexibility in sourcing	Ability to quickly change inputs or the mode of receiving inputs	Backup suppliers; contract flexibility; multiple uses
			Flexibility in order fulfilment	Ability to quickly change outputs or the mode of delivering outputs	Additive manufacturing; flexible production; distribution channels
Deliberate threats	Intentional attacks aimed at disrupting operations or causing human or financial harm	Terrorist attacks; theft; espionage	Capacity	Availability of assets to enable sustained production levels	Redundancy; robustness; resistance capacity
			Efficiency	Capability to produce outputs with minimum resource requirements	Sustainability; resource productivity; failure prevention
External pressures	Influences, not specifically targeting the firm, that create business constraints or barriers	Closed borders; political instability; forced closure	Visibility	Knowledge of the status of operating assets and the environment	Data analytics; industry 4.0; transparency
			Adaptability	Ability to modify operations in response to challenges/opportunities	Process integration; velocity; reengineering
Resource limits	Constraints on output based on the availability of the factors of production	Financial weakness; human resources; production and distribution capacity	Anticipation	Ability to discern potential future events or situations	Risk management culture; agility; preparedness
			Recovery	Ability to return to normal operational state rapidly	Restoration capacity; contingency strategies; crisis management
Sensitivity	Importance of carefully controlled conditions for product and process integrity	Complexity; process risk; resource scarcity	Dispersion	Broad distribution or decentralisation of assets	Diversity; risk sharing; delocalising facilities
			Collaboration	Ability to work effectively with other entities for mutual benefit	Collaborative planning; trust; integration
Connectivity	Degree of interdependence and reliance on outside entities	Control risk; scale of the network; degree of outsourcing	Organisation	Human resource structures, policies, skills, and culture	Top management support; innovation; knowledge management
			Market position	Status of a company or its products in specific markets	Alignment; public private partnerships; market share
Supplier/customer disruptions	Susceptibility of suppliers and customers to external forces or disruptions	Supplier reliability; customer disruptions	Security	Defence against deliberate intrusion or attack	Blockchain technology; layered defences; access restrictions
			Financial strength	Capacity to absorb fluctuations in cash flow	Insurance; portfolio diversification; price margin

Figure 3 Model for allocating a supply chain property in the framework



Thus, a variety of aspects can be subsumed under SCR. Consequently, the comprehensive framework needs to be as specific as possible and sufficiently detailed to allow meaningful mapping of the multitude of vulnerabilities and capabilities of SCR into appropriate superordinate terms. Therefore, we developed a framework based on Pettit et al. (2013) that first aims to capture and systematise any number of possible SCR capabilities and vulnerabilities. Systematisation is carried out hierarchically and consists of three levels. The top level defines whether an identified aspect is a capability or vulnerability. At the middle level, an aspect is assigned to one of the several superordinate terms. These superordinate terms are based on Pettit et al.'s (2013) study and represent a central aspect of SCR in a condensed form. The newly identified individual sub-aspects are appropriately assigned to the superordinate terms at the lowest hierarchy level. The assignment of an aspect within the framework is not subjective but is part of a collective decision-making process. Consequently, an identified aspect is first classified as a capability or vulnerability in the framework, assigned to a corresponding superordinate term, and finally recorded as a sub-aspect at the lowest level of hierarchy. We are guided by the existing sub-aspects of the respective superordinate terms. If no corresponding sub-aspect is found for an identified capability or vulnerability in Pettit et al. (2013), the identified capability or vulnerability is added to the framework as a new sub-aspect and assigned a suitable superordinate term.

Finally, our framework extends Pettit et al.'s (2013) framework by considering additional sub-aspects along with the same superordinate terms. To make the identified sub-aspects comprehensible, reproducible, and transparent, they are categorised verbatim in the framework so that they could be retrieved later from the original source. Therefore, a comprehensive and verbatim overview of all underlying categorised sub-aspects is not provided, as it still refers to the same sub-aspects and there is little difference due to the contextual notation in some cases. The source-related spellings of all identified and categorised sub-aspects and the associated superordinate term assignment can be found in Appendix B–C. Figure 3 shows an example of the procedure for assigning a supply chain property to an existing sub-aspect in the framework.

Table 3 shows the generic terms and definitions used according to Pettit et al. (2013), examples of associated sub-aspects, and vulnerabilities and capabilities categories. Assigning the capability of flexibility is difficult. In the review articles, this is often mentioned in a generalised manner without specifically addressing whether flexibility in sourcing or flexibility in order fulfilment is beneficial for SCR, as both aspects can be seen as superordinate terms according to Pettit et al. (2013). Therefore, for the

generalised mention of flexibility as a capability of SCR, we assign this sub-aspect to both superordinate terms. Once all identified aspects are mapped within the framework, the capabilities and vulnerabilities mentioned in the review articles are examined for cross-linkages. The individual SCR aspects should not be viewed in isolation, as they influence each other (Wieland, 2021); therefore, the framework has been expanded to include a quantitative scale, following the approach of Abedinnia et al. (2017). A review article receives one point for each aspect mentioned, regardless of whether it is a capability or vulnerability. The general mention of flexibility as an SCR capability is excluded from this rule, which can lead to one point for each of the two superordinate terms, 'flexibility in sourcing' and 'flexibility in order fulfilment'. However, because the diversity of capabilities and vulnerabilities is of particular importance in SCR, as shown in Table 3, the maximum number of points that can be achieved per superordinate term is capped at three. This ensures that articles that address aspects of multiple superordinate terms tend to score higher than those that address only one aspect of SCR, in an isolated manner.

Furthermore, to include the aspect of balancing capabilities and vulnerabilities of SCR in the scoring, the sums of the points of the two categories, that is, the sums of the points of the respective head terms of the two categories 'capabilities' and 'vulnerabilities', are finally added for one another. Ideally, the vulnerability score should correspond to the capability score. Thus, this article has a score that pays equal attention to both aspects of SCR. According to Pettit et al. (2013), there are 7 and 14 superordinate terms for vulnerabilities and capabilities, respectively. Accordingly, the potential achievable score for the aforementioned capabilities can be twice as high as that for the aforementioned vulnerabilities. To compensate for this, the sum of the points for the 'vulnerabilities' category is doubled to equalise the maximum achievable number of points, 42, for both categories. For example, if an article mentions seven sub-aspects of vulnerabilities and ten sub-aspects of capabilities, it will score 14 points for vulnerabilities but only ten points for capabilities. A high score for an article in a category does not represent the quality of its content, rather the number of different aspects of the vulnerabilities and capabilities of SCR identified. The ratio of the scores of vulnerabilities and capabilities is an indicator of the extent to which an article provides equal weightage. Thus, it can be an important indicator of the current state of research and the need for future research. The framework allows us to answer several questions simultaneously: Which aspects of superordinate terms are identified in the literature? Which superordinate terms are addressed less often? Is more attention paid to vulnerabilities or capabilities? Consequently, how do the aspects of the two categories relate to each other?

3 Results

3.1 Descriptive results

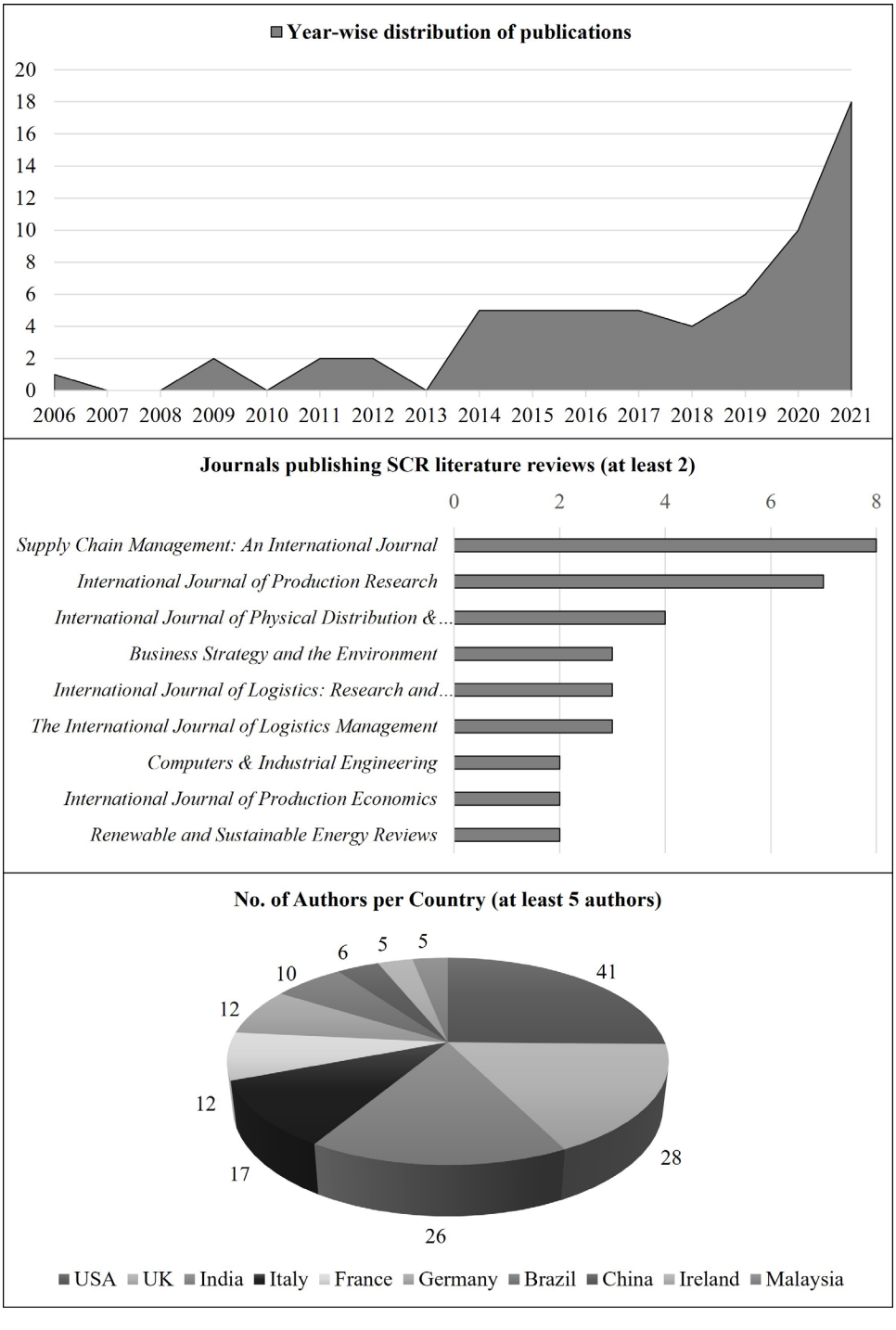
The literature sample consists of 65 review articles on SCR from 2006–2021. Figure 4 shows the year-wise distribution of publications, journals in which most articles were published, and the most common countries of origin of the authors. The high proportion of published review articles on this subject in the last five years is striking. This may be due to recent supply chain disruptions with significant economic implications and reflects increasing research interest in SCR. Therefore, this study reinforces the need to

synthesise and systematise the extant secondary literature. Numerous journals have contributed to the publication of articles in the literature sample, with *Supply Chain Management: An International Journal*, *International Journal of Production Research* and *International Journal of Physical Distribution and Logistics Management* being the most popular outlets for literature reviews on SCR. This is unsurprising, as SCR is of enormous importance in the logistics sector and the establishment of supply chains. Overall, the diversity of journals in the literature sample is high, with 40 unique journals and an average of 1.625 review articles per journal. Thus, the literature sample can be assumed to have a comprehensive and diversified view of SCR. On an average, approximately 3 (2.95) authors contributed to the publication of a review article. This indicates that cooperative collaboration promotes objectivity by limiting individuals' subjective assessments through collective discussion. In particular, intercultural exchange is considered beneficial, as many reviews show multinational collaboration. Authors from 27 countries contributed to the development of the 65 reviewed articles. Most authors were from the USA, followed by the UK, India, and Italy.

A closer comparison of the article publication years with the origin of the respective authors reveals that the majority of review articles were published by authors from countries that faced significant supply chain disruptions. For example, the Euro crisis of 2014 (e.g., Durach et al., 2015; Hohenstein et al., 2015; Scholten et al., 2014) and the COVID-19 pandemic in 2020 (e.g., Katsaliaki et al., 2021; Sajjad, 2021; Spieske and Birkel, 2021). Thus, the publication behaviour on SCR and significant supply chain disruptions appear to be related. Regarding the literature review methodology, our sample consists of 18 scoping, five narrative, and 35 systematic reviews and five meta-analyses. Meta-analyses and narrative literature reviews are least common. This can be attributed to the downstream role of meta-analyses, which require an appropriate database. In the case of narrative literature reviews, the low proportion may be due to progress in research, as narrative reviews are primarily used to investigate unexplored topics. Thus, the most common methods in the literature are systematic and scoping reviews. More than 80% of the articles used either method, with systematic literature reviews being the most common. Appendix A provides a detailed methodological categorisation of individual review articles. The high share of scoping and systematic literature reviews are advantageous, as it provides multilevel comprehensibility of the research results due to the high level of transparency. For example, an underlying literature sample can be easily understood and compared, particularly in these reviews. Thus, the average size of the literature sample analysed in this study is 134. The largest literature sample consists of 867 articles, while the smallest has nine articles. To determine these values, we exclude all review articles that do not provide precise information about the derivation of their literature samples. Appendix A provides descriptive quantities of the literature samples.

Furthermore, special attention should be paid to the review articles that are most frequently cited. These are usually articles that are either published early or of high importance. We identify these articles using the number of citations from Google Scholar and citations in the bibliographies of articles in the literature sample. The most cited articles (as of January 2022) are those by Ponomarov and Holcomb (2009), Bhamra et al. (2011), Hosseini et al. (2016) and Fiksel (2006). Most of the high number of citations can be attributed to early publication dates. However, as this is not the exclusive reason, the high presence may be due to substantive findings in individual articles, which means that these articles are assumed to be highly relevant for research on SCR.

Figure 4 Descriptive characteristics of the literature sample



3.2 Tertiary analysis

The description of the content in the sampled review articles is based on the vulnerabilities and capabilities of SCR mentioned therein. Table 4 shows the mean value, standard deviation, and maximum value of the points scored by the sub-aspects per superordinate term across all review articles in the sample, which is differentiated by the capabilities and vulnerabilities of SCR. All values are unbiased; that is, the identified sub-aspects per superordinate term have not yet been restricted to three points per category.

Table 4 Distribution of the point scores of the vulnerabilities and capabilities in the literature sample

Vulnerabilities		*Turbulence*	*Deliberate threats*	*External pressures*	*Resource limits*	*Sensitivity*	*Connectivity*	*Supplier/ customer disruptions*
	Mean	1.585	0.554	0.646	0.246	0.538	0.277	0.369
	St. dev.	1.117	0.685	0.856	0.469	0.885	0.65	0.651
	Max.	5	2	3	2	4	3	2
Capabilities		*Flexibility in sourcing*	*Flexibility in order fulfilment*	*Capacity*	*Efficiency*	*Visibility*	*Adaptability*	*Anticipation*
	Mean	1.092	0.938	2.831	1.031	1.215	1.938	2.169
	St. dev.	0.824	0.808	1.516	0.749	1.082	1.285	1.387
	Max.	4	4	7	3	5	5	6
		Recovery	*Dispersion*	*Collaboration*	*Organisation*	*Market position*	*Security*	*Financial strength*
	Mean	1.031	0.323	2.277	0.985	0.323	0.385	0.154
	St. dev.	0.612	0.64	2.019	1.218	0.731	0.578	0.364
	Max.	3	3	8	4	3	2	1

The absolute frequencies of the *vulnerabilities* show a strong uneven distribution. Vulnerabilities from the turbulence category are mentioned most frequently, whereas those in the other categories are relatively infrequent. Review articles with the highest absolute number of vulnerabilities mentioned include Naimi et al. (2021), Bayramova et al. (2021) and Agrawal and Jain (2021). While the three articles are published with a short time difference between each, they differ in the aspects of SCR considered. While Naimi et al. (2021) examine the historical development of research on SCR, Bayramova et al. (2021) examine the potential of blockchain technology to mitigate the vulnerability of supply chains to cyber-attacks, and Agrawal and Jain (2021) investigate possible enablers of SCR.

Furthermore, their approaches differ by methodology. Naimi et al. (2021) undertake systematic mapping and categorisation, while Bayramova et al. (2021) use grounded theory analysis and meta-analysis. Agrawal and Jain (2021) employ a point model based on the ALDEP framework. Commonalities can be found in the multitude of vulnerabilities mentioned. All three articles mentioned all seven superordinate terms in our framework, which shows their multifaceted consideration of the vulnerabilities of SCR. The comparatively high balance of the sub-aspect mentions is also notable. In

addition to the vulnerabilities to turbulence, Bayramova et al. (2021) also mention the most sensitivity-related sub-aspects, such as malfunctions, power failures, and lack of reliable information technology systems. All three vulnerabilities can have fatal consequences for a supply chain when disruption occurs, especially in a global supply chain network. While Bayramova et al. (2021) show that blockchain technology can contribute to the cybersecurity of a supply chain, Agrawal and Jain (2021) highlight certain enablers of SCR, including the capabilities underlying our framework. Naimi et al. (2021) show the main components required to reconfigure a supply chain, which is an important aspect related to the adaptability of a supply chain. They then relate these to the vulnerabilities of the supply chain under the superordinate term of turbulence, such as pandemics, natural disasters, or fire accidents. In all cases, these events usually occur unexpectedly, making it essential for supply chains to adapt quickly.

One example of making adjustments as rapidly as possible is decentralising the logistics centers of a supply chain. If a fire or earthquake occurs at one location, causing failure, the supply chain can be quickly relocated to another location. Furthermore, the locations should be as international as possible to prevent vulnerabilities to external pressure. Emenike and Falcone (2020), Hohenstein et al. (2015) and Kochan and Nowicki (2018) have dealt with the vulnerabilities to external pressures by noting sub-aspects such as wars, political instability, or economic shocks. If necessary, these factors can be mitigated by selecting forward-looking locations and adequate risk management.

However, vulnerabilities related to connectivity are unlikely to be mitigated. These include multifaceted networks of trade partners, outsourcing, and offshoring, which are sub-aspects that Gurtu and Johny (2021) consider in their article on supply chain risk management. They conclude that maintaining in-house inventories is important for SCR, and more attention should be paid to risks. Processes, such as outsourcing or offshoring, may have advantages in terms of risk-sharing within the supply chain but they also bring vulnerabilities in the form of interconnectedness with suppliers. If suppliers or customers disrupt supply chains, this connectivity can also be detrimental.

One way to prevent supply chain disruptions is to integrate various *capabilities* into the supply chain. As with the number of superordinate terms, numerous sub-aspects can be considered as capabilities for building resilience in a supply chain. Ali and Gölgeci (2019), Ali et al. (2017) and Stone and Rahimifard (2018) mention most of these. These authors use different types of frameworks to derive future research approaches to SCR. In line with the total number of mentions in the literature sample in Table 4, they increasingly state the capabilities of anticipation and collaboration. On the one hand, they mention various topics as sub-aspects, such as risk management, agility, velocity, and predefined decision plans. On the other hand, they find important interpersonal skills such as cooperation, coordination, communication, and trust. Therefore, when designing a supply chain, it is important to ensure that all parties involved first define a common goal for how the supply chain should be operated and then work together in a cooperative and coordinated manner to achieve this goal. For example, for the Suez Canal, if the goal is smooth operation, the canal managers should cooperate and communicate with passing ships based on trust. If a supply chain is disrupted, it is important to anticipate this event by having a predefined crisis plan that addresses the case of canal blockage. If the canal is blocked, to resume the supply chain operation, the disruption needs to be restored as quickly as possible, according to the crisis plan. The swiftness of implementing a crisis plan is also reflected in a supply chain's ability to adapt and be efficient. Hosseini and

Ivanov (2020) investigate capabilities of SCR using Bayesian networks and conclude that measuring the effects of SCR capabilities on one another can be instrumental for future research. However, no sampled article outlines a precise procedure for measuring these effects. The focus of this study is on the relationship between these capabilities and the vulnerabilities of SCR and not on a one-sided approach. Hence, we refrain from taking a closer look at the outstanding capabilities at this point. The exact characteristics of all sub-aspects of the literature sample are presented in Appendices B and C. We build a bridge between the vulnerabilities and capabilities of SCR in the following section using our interconnected metric score to understand whether the literature has a balanced focus on capabilities and vulnerabilities.

4 Discussion of the tertiary study results

A comparative analysis of the capabilities and vulnerabilities of SCR is based on capping the achievable points by a maximum of three per superordinate term to remove one-sided emphasis in the sampled articles. This approach is justified by the diversity of SCR aspects. However, SCR is underpinned by various capabilities and vulnerabilities. Consequently, articles with a broader focus using this scoring scheme tend to achieve a higher overall score. To keep the capping of points comprehensible, the corresponding cells in Appendices B and C are highlighted if the number of points reaches the set cap of three.

The scores of the individual superordinate terms of vulnerabilities and capabilities are added separately, considering the cap, and the score of the vulnerabilities is then doubled. Table 5 shows all analysed review articles, for which the relative deviation of the summed scores of capabilities and doubled vulnerabilities did not exceed 20%. This limitation has been highlighted for clarity. The relative deviation of the scores is obtained by first calculating the absolute deviation of the two summed scores and, if necessary, doubling the scores and then dividing this by the higher of the two scores. If several sampled articles have the same relative deviation, they are sorted according to their total score as a second-order criterion. To make the scoring transparent, the intermediate results for the scores of the first and second halves of the superordinate terms of capabilities are shown separately. The various superordinate terms of SCR capabilities are divided into two halves, similar to the order shown in Table 4, according to the order originally listed by Pettit et al. (2013). At first glance, a deviation of 20% may seem high. However, because of the double scoring of vulnerabilities used in our scoring scheme, a single point can quickly lead to a significant increase or decrease in the relative deviation. Therefore, even higher deviations may not be immediately attributable to an unbalanced thematisation of vulnerabilities and capabilities of SCR, particularly the absolute deviation seems low. The relative deviations of all articles in the literature sample and the total scores achieved by both capabilities and vulnerabilities are shown in Appendix D.

Overall, in most reviewed articles, the total score of capabilities is higher than that of vulnerabilities. In 48 articles, capabilities are mentioned more than vulnerabilities; the opposite case occurs only 14 times. This may be due to the large number of capabilities in the context of SCR, and the interconnectivity of individual capabilities can also play a role. During our research, we note that different authors assigned certain SCR characteristics to different capabilities. Depending on the interpretation of a

characteristic, assignment to certain capabilities is not always clear-cut, which shows how fluid the boundaries are between the SCR capabilities. For example, the aforementioned assignment of the flexibility characteristics and the classification of sustainability. Certain authors see sustainability as a part of efficiency, as it describes the ability to use resources that are necessary or can be replenished within the shortest possible time (Ahmadi et al., 2021; Jain et al., 2017). Others see sustainability as a sub-aspect of a capability's anticipation or adaptability, that is, sustainability is based on a long-term oriented planning capability (Sajjad, 2021). Meanwhile, a third group sees sustainability as a separate construct from SCR that exists independently and does not represent a capability per se (Negri et al., 2021). Sustainability, as part of SCR and as a separate construct, appears to affect a supply chain's resilience and, thus, its ability to withstand disruptions. The extent to which a supply chain can be sustainable varies depending on its underlying definition. However, in most cases sampled, the authors allude to the conscious use of resources within a supply chain.

Regarding the general understanding of SCR capabilities, conceptualisations are highly heterogeneous. Some authors refer to capabilities (e.g., Pettit et al., 2013), while others refer to them as contributors or enablers (e.g., Agarwal et al., 2020), elements (e.g., Hosseini et al., 2019b), strategies (e.g., Bayramova et al., 2021), or antecedents (Spieske and Birkel, 2021). All terms denote the other functions of capabilities. However, given the intention in this context and the partly identical wording of the corresponding sub-aspects, it can be assumed that similar issues are being targeted: strengthening the supply chain against disruptions by acquiring selected capabilities and establishing resilience. By contrast, vulnerabilities are often presented in isolation. This may be because disturbances arising from vulnerabilities do not necessarily occur together. For example, there may be raw-material bottlenecks owing to national border closures. However, the occurrence of terrorist attacks due to a global pandemic seems unlikely. Therefore, these two vulnerabilities are often not mentioned in the same context. In addition, articles tend to refer to vulnerabilities that have historically led to significant disruptions in supply chains. For example, the COVID-19 pandemic or the events following the 9/11 terrorist attack. While there are fewer mentions of more general vulnerabilities, such as complexity or espionage. Whether the increased mention of certain vulnerabilities in the literature and supply chain disruptions is a coincidence or a link should be investigated. In any case, the increased mention of SCR vulnerabilities at the beginning of the articles is striking. Consequently, these tend to be used more as topic hooks in the corresponding articles and subsequently focus more on the capabilities of SCR.

The review articles by Fertier et al. (2021), Ivanov et al. (2017) and Tukamuhabwa et al. (2015) stand out for their balanced mention of vulnerabilities and capabilities. Fertier et al. (2021) do not mentions many SCR-related vulnerabilities and capabilities, as shown by their low score; however, the remaining articles have many more mentions, with a score of at least 12 or even 28 per category. Notably, all four articles mention turbulence as a vulnerability. The predominant capabilities are efficiency, adaptability, and risk management as a form of anticipation, and recovery as capabilities of SCR.

Table 5 Most balanced review articles in terms of vulnerabilities and capabilities

Reference	*Vulnerabilities*	*Vulnerabilities x2*	*Capabilities (1)*	*Capabilities (2)*	*Capabilities Sum.*	*Total score*	*Absolute deviation*	*Relative deviation*
Fertier et al. (2021)	2	4	4	0	4	8	0	0
Ivanov et al. (2017)	3	6	5	1	6	12	0	0
Tukamuhabwa et al. (2015)	7	14	11	3	14	28	0	0
Naimi et al. (2021)	13	26	15	10	25	51	1	0.04
Agarwal et al. (2020)	11	22	13	8	21	43	1	0.05
Datta (2017)	10	20	14	7	21	41	1	0.05
Golan et al. (2020)	6	12	8	3	11	23	1	0.08
Pereira et al. (2014)	8	16	12	6	18	34	2	0.11
Bayramova et al. (2021)	12	24	15	12	27	51	3	0.11
Kochan and Nowicki (2018)	10	20	13	10	23	43	3	0.13
Emenike and Falcone (2020)	5	10	8	4	12	22	2	0.17
Shekarian and Parast (2021)	5	10	9	3	12	22	2	0.17
Briano et al. (2009)	9	18	12	3	15	33	3	0.17
Chin and Min (2021)	5	10	6	2	8	18	2	0.2
Colicchia and Strozzi (2012)	5	10	6	2	8	18	2	0.2
Aldrighetti et al. (2021)	6	12	10	5	15	27	3	0.2

Regarding the example of COVID-19-induced supply chain disruptions, a pandemic must be identified beforehand as a potential supply chain vulnerability (Moosavi and Hosseini, 2021). Then, the capabilities to deal with this vulnerability can include increasing efficiency by, for example, identifying and redesigning redundant activities or delegating them. By managing risk, we can anticipate the occurrence of a pandemic to respond, if necessary, by rescheduling transport routes or activities. This adaptability is essential to mitigate the effects of supply chain disruption and ensure the continuation of goods movements. In the aftermath of a disruption, the supply chain should be restored to its original state as quickly as possible to ensure competitiveness. The speed with which a company returns to its original state is described by its efficiency. However, the exact efficiency achieved in the context of SCR has not yet been addressed in the literature; thus, further research is required.

Regarding the remaining capabilities, the low number of mentions of market position, security, and financial strength in the literature sample is particularly striking. In the case of market position and financial strength, this may be due to the difficulty in generalisation, as both capabilities are highly company specific and depend on numerous factors. However, in the case of security, the low level of topic coverage is surprising because related topics, such as whistleblowing, data leaks, and cyber-attacks, are becoming increasingly important because of growing international networking. In this respect, the number of articles on security capability has increased over the last few years. In particular, blockchain technology is increasingly mentioned (e.g., Ali and Gölgeci, 2019; Etemadi et al., 2021); which can represent a gain for SCR. However, other digital technologies, such as big data, are also sporadically discussed and can prove potentially valuable for supply chain design.

Meanwhile, regarding the lack of security capabilities, among all vulnerabilities, sensitivity or connectivity have the fewest mentions. This is because issues such as complexity or networking with partners may be seen as advantages rather than vulnerabilities for some companies. Furthermore, no significant disruption of supply chain networks can be clearly attributed to these vulnerabilities. Nevertheless, this neglect may be one of the reasons for the ongoing search for SCR. A closer look at the methodology of the articles with the lowest absolute deviation in Table 5 confirms this observation. Notably, most studies use a systematic analytical solution with the aid of a framework (e.g., Fertier et al., 2021; Ivanov et al., 2017; Naimi et al., 2021; Agarwal et al., 2020; Golan et al., 2020). However, these approaches are highly heterogeneous. For example, Fertier et al. (2021) use the Akaike information criterion (AIC) framework, Agarwal et al. (2020) use ALDEP and Tukamuhabwa et al. (2015) use CAS.

5 Open research questions and future directions

The results of our tertiary analysis reveal increasing scientific interest in Industry 4.0 and SCR (see also Pires et al., 2021). We develop a matrix, as shown in Table 6, which indicates how SCR capabilities and selected Industry 4.0 technologies are suitable for eliminating SCR vulnerabilities. Industry 4.0, which is taken from Ivanov et al. (2021) and Ivanov (2021c), represents a multi-disciplinary approach for identifying open research questions. The matrix shows a comparison of the vulnerabilities of SCR with those of Industry 4.0. SCR capabilities obtained from the sampled literature reviews are input in the cells to address the vulnerabilities that are mentioned in the rows, while the

respective Industry 4.0 technologies are shown in the columns. Thus, the matrix can be understood as a guideline for achieving SCR that is enabled by the implementation of Industry 4.0 technologies. For example, if a company or supply chain is vulnerable to turbulence, IoT infrastructure is recommended to achieve SCR, or how innovations in engineering technology can help prevent vulnerabilities owing to resource limits. This can ensure the capability of flexibility in order fulfilment, which is important component of SCR when it comes to adapting supply chains at short notice.

Table 6 Interaction between SCR vulnerabilities/capabilities and Industry 4.0

		Research disciplines in the Industry 4.0 context			
		Infrastructure (CPS; IoT)	*Engineering technology (3D printing; AGV; mobile robots; augmented reality)*	*Data technology (BDA; AI; T&T; M2M)*	*Communication technology (cloud services; smart products; blockchain; RFID)*
Vulnerabilities	Turbulence	Capacity, visibility; adaptability; recovery	Recovery	Adaptability; anticipation; recovery; dispersion; collaboration	Capacity; efficiency; visibility; dispersion
	Deliberate threats	Adaptability		Visibility; adaptability; anticipation; recovery	Capacity; security
	External pressures	Flexibility in order fulfilment; efficiency; adaptability; organisation; market position	Adaptability	Anticipation; collaboration; organisation; market position; financial strength	Efficiency; visibility; security; financial strength
	Resource limits	Flexibility in order fulfilment; capacity	Flexibility in order fulfilment; efficiency; adaptability	Visibility; anticipation; organisation	
	Sensitivity	Adaptability; anticipation; recovery	Capacity; adaptability; anticipation	Anticipation; recovery; collaboration	Visibility; dispersion; security
	Connectivity	Visibility; recovery	Efficiency; visibility; adaptability	Anticipation; dispersion; collaboration	Efficiency; dispersion; adaptability
	Supplier/ customer disruptions	Flexibility in order fulfilment; capacity; adaptability	Flexibility in order fulfilment; efficiency; adaptability	Visibility; anticipation; recovery; collaboration	Capacity; adaptability; anticipation

However, Table 6 shows that not every Industry 4.0 technology seems equally suited to achieve every SCR capability. In contrast, some application areas are under-explored. For example, the question whether a smart supply chain implementing Industry 4.0 technologies (e.g., Shao et al., 2021) is resistant to the vulnerability of deliberate threats has not been researched. However, deliberate threats are not explicitly mentioned in any

of the reviews in our literature sample. Therefore, this raises the question whether it is advisable to implement a smart supply chain that is vulnerable to deliberate threats.

Further research is needed to enhance our understanding of how vulnerabilities of a supply chain can be addressed by the design approaches of a digital supply chain (MacCarthy and Ivanov, 2022; Ivanov et al., 2022). Moreover, the matrix indicates that resource limits have not yet been addressed in the context of Industry 4.0 communication technologies. The fact that communication can play an important role in the event of looming resource limits has been demonstrated by the occurrence of ship congestion off the Shanghai port in 2022, when operations were completely shut down due to a lockdown ordered by the government (He, 2022).

While Industry 4.0 communication technologies may not have been able to stop the congestion of ships in the short term, a shift to alternative transport routes would have been feasible in a resilient supply chain with immediate communication. Approaches to communication using technology within supply chains have been proposed in the literature for several years (e.g., Cutting-Decelle et al., 2007). However, there is a literature review in our literature sample that specifically examined Industry 4.0 technologies in the context of resource limits. This and other less-addressed cells of the matrix demonstrate an increased need for research. This matrix only depicts SCR capabilities, for which suitability is expressed in the literature sample. Industry 4.0, technologies that are considered unsuitable, are not included in the context of this study.

Digital supply chain twin and simulation-based analyses of SCR are the next promising future research directions (Burgos and Ivanov, 2021; Ivanov, 2021d, 2022b; Ivanov and Dolgui, 2021b). In addition, 5G and blockchain utilisation in the digital supply chain provide interesting opportunities to increase resilience (Li et al., 2022; Dolgui and Ivanov, 2022). We also note new notions of a viable supply chain, intertwined supply networks, and reconfigurable supply chain as future research directions for SCR research (Dolgui et al., 2020; Ivanov and Dolgui, 2020, 2021a; Ruel et al., 2021). Specifically, ripple effect analysis in the setting of viable, intertwined, and reconfigurable supply chains is a novel research domain where substantial contributions can be made (Dolgui and Ivanov, 2021; Rozhkov et al., 2022).

Underrepresented capabilities, such as the financial strength or market position of SCR, need to be investigated in the future to understand how Industry 4.0 can help accomplish them. Thus, SCR can be achieved despite multiple vulnerabilities. As financial strength and market position are particularly desirable goals from a practical point of view, it can be of interest to companies to know more about the connection between these capabilities and Industry 4.0 technologies. These technologies have been used increasingly in practice for several years. However, success is limited in some cases (e.g., Sanchez, 2019). One reason for this is that companies invest in technologies whose resulting supply chain capabilities have already been realised without implementing the technology. Thus, this technology cannot bring any additional value to the company, at least for the goal of achieving more SCR. In this case, investment in a different technology that can pave the way for an unrealised SCR capability may prove to be more valuable (Ivanov, 2022a). To prevent inefficient technology and investment allocations with the intention of increasing SCR in the future, a comprehensive recommended course of action for the use of Industry 4.0 technologies to achieve resilience is required.

In summary, we suggest the following directions for future research. First, more research is needed on how Industry 4.0 technologies can contribute to building SCR capabilities (e.g., Etemadi et al., 2021). Second, we need approaches that measure the

interactions between SCR capabilities and simultaneously make inferences about associated vulnerabilities (e.g., Aldrighetti et al., 2021). Third, we need a more precise delineation of the individual terms and their meaning for SCR, as shown by the example of sustainability and capabilities (e.g., Bayramova et al., 2021). Fourth, regarding the capabilities, further research is needed on the market position, financial strength, and security of companies within supply chains among others, as can be seen in the 'blank spots' in Appendices B and C. Market position and financial strength are expected to be more challenging for further concretisation of the general operational guidelines of companies because of their company-specific nature. However, the aspects of security gradually gain importance because of increasing internationalisation. Thus, future studies should attempt to fill this gap. The same applies to terminology in SCR, which can provide new insights through condensed literature reviews. In contrast, the research questions require further elaboration of fundamental approaches, which is why these are the primary questions for future primary studies. From a methodological point of view, we encourage future secondary research to employ established literature review methodologies and try to advance theory (see Durach et al., 2021). Compared to previous tertiary analyses of supply chain management research, such as Hochrein and Glock (2013), we see an increased use of systematic review methodologies, which increases the reliability and replicability of the review results. In addition, there is a strong need for future literature reviews to clearly show how they extend previous knowledge.

6 Conclusions

This study is a systematic literature review of review articles to examine whether the existing literature on SCR addresses associated capabilities and vulnerabilities in a balanced manner. The literature focuses on SCR capabilities. Only 16 of the 65 review articles show balanced treatment of capabilities and vulnerabilities. The relative variation in the point scales quantifying capabilities and vulnerabilities is no more than 20% for the 16 aforementioned articles. Notably, seven articles made no specific reference to vulnerabilities. Sensitivity and connectivity are identified as under-researched vulnerabilities, and we explain the reasons for this. Furthermore, a selection of possible future research directions is presented, with a focus on Industry 4.0. In this context, the inseparability of vulnerabilities and capabilities to achieve SCR has been emphasised. In addition to Industry 4.0, future research can address the measurement of SCR and a more precise delineation of concepts. Thus, the results of this tertiary analysis highlight several ideas for future research, particularly literature reviews, and support researchers find starting points to synthesise SCR topics.

The findings of this study can also help companies, particularly global supply chain firms, recognise some vulnerabilities in their supply chains. The multitude of SCR sub-aspects allows managers to target a feasible capability for each vulnerability in the supply chain, thereby balancing vulnerabilities and capabilities. In addition, a compilation of Industry 4.0 technologies is presented, which can be used to target individual SCR vulnerabilities to realise the corresponding SCR capabilities, thus realising path-wise SCR. Our results can also be instructive for supply chain managers for reviewing the resilience of their supply chains in a structured manner, triangulating the analysis across management, technology, and modelling perspectives (Ivanov, 2021f).

In particular, we stress the importance of understanding SCR as an inherent part of strategic, tactical, and operational decisions.

Finally, this study has some limitations, such as how can a vulnerability be identified and the approach to determining the appropriate capability to overcome a particular vulnerability. The framework presented here provides an overview of the possible vulnerabilities and capabilities of SCR identified in the literature. Thus, it does not include any evaluation regarding the suitability of individual sub-aspects for a selected supply chain. Therefore, no general validity of the presented sub-aspects is pronounced. In addition, the methodology of tertiary analysis is a limiting factor, which limits the implications for primary research. Finally, depending on its design, each supply chain has a specific risk of disruption, which should be countered by adequate building capabilities to achieve resilience.

Appendices/Supplementary materials are available on request by emailing the corresponding author or can be obtained under https://doi.org/10.5281/zenodo.7022542.

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