WHAT IS A STATE-OF-THE-ART DEFINITION OF SUPPLY CHAIN RESILIENCE IN 2024 – WITH A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

In light of escalating disruptions to global supply chains catalysed by events such as the COVID-19 pandemic and the Russo-Ukrainian war, the imperative of enhancing supply chain resilience (SCR) has become increasingly pronounced. The existence of varying definitions of SCR complicates efforts to quantitatively measure and assess resilience. To elucidate the essence of supply chain resilience, we conducted a meticulous systematic literature review (SLR) aimed at crystallizing a scientifically rigorous definition of SCR. Our SLR methodology involved comprehensive preparation and judicious paper selection, followed by a thorough analysis of supply chain resilience definitions. This analysis was conducted via the dimensions of three typical characteristics—preparedness, reaction, and recovery—and four foundational pillars—focus event, performance level, speed, and adaptive response. As a result, a robust definition of SCR is proposed, synthesizing insights from the three typical characteristics theory and the four pillars theory, supplemented with meaningful additions. The research contributes to developing frameworks for supply chain resilience measurement.

KEYWORDS

Supply Chain Resilience, Definition, Systematic Literature Review, Disruption

1. INTRODUCTION

Global supply chains have been threatened due to more disruptions coming from all the directions (Christopher and Peck [1]; Jüttner and Maklan [2]; Wieland and Durach [3]). A single disruption derived from one country or area may ripple around the world making unprepared companies suffer from many difficulties [4]. The Russo-Ukrainian war and the COVID-19 pandemic are appropriate examples. Their emergences have led an additional uncertainty to supply chains, provoking panic reactions and internal border restrictions for the transport of people and products [5]. The number of risks and disruptions is ramping up, drastically influences the prosperous SCs [6]. What makes the situation worse is that it is very hard for companies in the SC to predict disruptions and plan for next steps due to the uniqueness of elements and timing for diverse disruptions. Material shortage leads to lower productivity and tardy delivery, natural disasters may destroy the pre-set supply network, strikes reduce the productivity and on-time delivery, trade wars compel manufacturers to remake a decision on supplier selection, and cyber-attacks affects the normal run of companies' information management systems.

Though it's hard for companies to thrive because of facing difficulty in supporting flexibility and adaptivity, supply chain resilience (SCR) can be a viable avenue to take into account [7]. It helps companies to react to dangerous disruptions and risks and recover from them quicklier and better.

Datta et al. [8] state that the concept "resilience" is multidimensional and multidisciplinary, with roots in psychology and ecosystems and being applied to other sectors such as supply chain management. The term "resilience" derives from the Latin word "resiliere", meaning to bounce back [9]. Though SCR catches more attention, there are still a small number of publications concentrating on the literature review on "supply chain resilience definition", and many of the studies have not answered the question: "what is supply chain resilience?". Among the literature review articles, two stand out with significant citations, offering well-structured content and rigorous logic. Kamalahmadi and Parast [10] examine the definitions of SCR using a SCR definitions list and put forward the direction of future research. Ribeiro and Barbosa-Povoa [11] propose the sound definition of supply chain resilience based on the designed literature review. But till now, there is no standardized definition of "supply chain resilience" and different researchers use different characteristics to describe SCR (Kamalahmadi and Parast [10]; Ribeiro and Barbosa-Povoa [11]; Mishra and Singh [12]).

Understanding how to define SCR is crucial, as without clarity on its definition there is no way for us to assess SCR level quantitatively or qualitatively, let alone figure out effective management and improvement strategies. Consequently, more and more researchers are putting much effort to this endeavor, striving to generate innovative concepts. Therefore, to continue the advancement of the knowledge in this area, and also to make contribution to future research on SCR measurement and improvement, this article will answer the following research questions:

RQ 1: How do researchers define supply chain resilience?

RQ 2: What is a state-of-the-art definition of supply chain resilience in 2024?

The remainder of the article is structured as follows. Section 2 describes the research design process, Section 3 analyzes the selected papers in different dimensions to obtain the results, Section 4 proposes a state-of-the-art supply chain resilience definition in 2024, and Section 5 draws the conclusion.

2. RESEARCH DESIGN

To answer the research questions mentioned in Section 1, we opt for a systematic literature review (SLR) approach that ensures the comprehensiveness, rigor and replicability [12]. We follow the three key phases for designing a SLR with the following research design processes (Sawyerr & Harrison [13]).

2.1. Identification of Studies

There have been literature reviews on SCR definition published between 2005 and 2014, thus our focus in this literature review will be papers published from 2015 until now in 2024. SCOPUS will be the primary scientific database for our research process. We require all relevant papers to be written in English and to be final versions, so articles in press will be excluded. Though SCR is a multidisciplinary concept applied in diverse sectors, in light of our research purpose and target, we limit the subject areas to: (1) engineering; (2) business, management, accounting; (3) social sciences; and (4) decision sciences. We select articles and journals as document and source types because we consider journals to be the premier avenues for acquiring pertinent discoveries.

2.2. Selection and Evaluation of Papers

According to the two research questions, we set the keywords and the following initial search parameters:

TITLE-ABS-KEY (“supply” AND “chain” AND “resilien*” AND “defin*”)
With this advanced query, there were 413 documents found. Filtering out the publications before 2015 resulted in 369 publications. After narrowing down the subject areas and language we obtained 282 papers. Further restricting the document type to articles and source type to journals, and ensuring that only finalized papers were included, led us to a final count of 150 papers.

At last, the search parameters became the following ones:

TITLE-ABS-KEY (“supply” AND “chain” AND “resilien*” AND “defin*”) AND PUBYEAR > 2014 AND PUBYEAR < 2025 AND (LIMIT-TO (SUBJAREA, “ENGI”) OR LIMIT-TO (SUBJAREA, “BUSI”) OR LIMIT-TO (SUBJAREA, “DECI”) OR LIMIT-TO (SUBJAREA, “SOCI”)) AND (LIMIT-TO (LANGUAGE, “English”)) AND (LIMIT-TO (PUBSTAGE, “final”)) AND (LIMIT-TO (SRCTYPE, “j”)) AND (LIMIT-TO (DOCTYPE, “ar”))

2.3. Final Result and Descriptive Analysis

After reviewing the titles and abstracts, we deleted the papers not related to supply chain resilience and selected totally 56 from the initial pool of 150 to peruse. Then, each article was in-depth examined by analysing the content with regard to the research focus. The final number of the papers to be analysed is 21. What is noteworthy is that most of the articles proposing SCR measurement models were excluded finally as they did not provide explicit definition of SCR. The entire process of the systematic literature review is shown as follows in Figure 1.

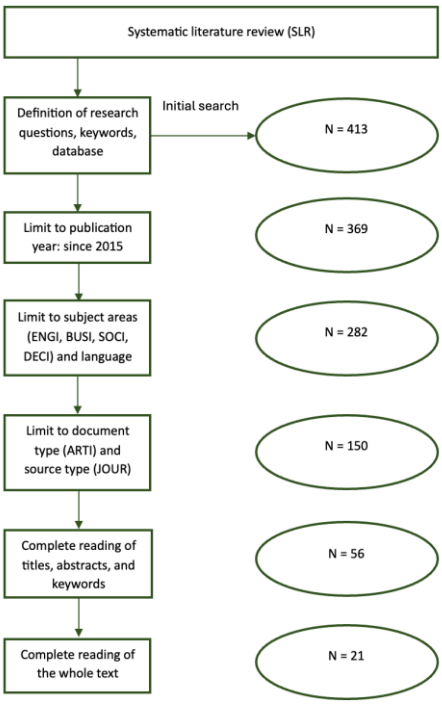

Figure 1. The SLR procedure conducted on supply chain resilience definition

Figure 2 illustrates the chronological trends in the number of articles concentrating on supply chain resilience (SCR) definition published between 2015 and 2024. The results diverge from those of Han et al. [14] in the SLR on supply chain resilience. Han et al. [14] conclude that the research on SCR has been thriving driven by the COVID-19 pandemic. But in our SLR, the result does not show that trend. There are 6 papers published in 2020 relating to SCR definition. 2015, 2016 and 2021 see 3 papers published, respectively.

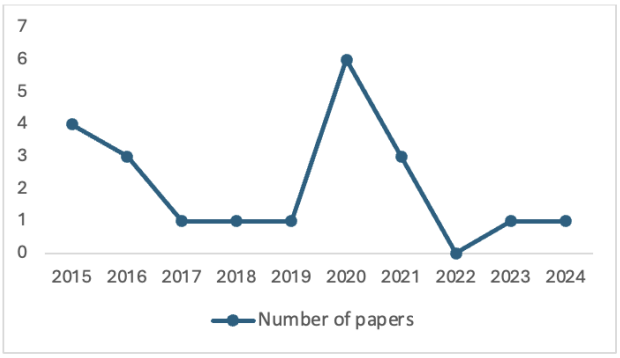

Figure 2. Number of papers on SCR definition, 2015-2024

A total of 21 papers includes contributions from different sectors. Table 1 lists the application areas of all the papers used in SLR. More than a half of papers propose the definition of supply chain resilience for generic SCs, not specifying the application areas. Apart from the generic sector, there are few articles from the sector of manufacturing, logistics, food, economics, business etc.

Table 1. The application areas of the papers selected for SLR

Application areas	**Number of papers**
Generic	12
Manufacturing	3
Logistics	2
Economics	1
Food	2
Business and management	1

Here, we delve into the utilization of these definitions by SCs to manage SCR across the 21 papers. The analytical findings are presented in Table 2 below.

Table 2. How are SCR definitions used by SCs to manage the SCR?

What do the studies do with the SCR definition	**Number of papers**
For SCR measurement	12
For SCR improvement	4
For SCR principles	1
For supplier selection	1
Not mentioned	3

Table 2 reveals that over ten papers of the 21 studies leverage their definitions of SCR for modeling SCR level calculation, with 4 papers exploring strategies of enhancing SCR level and several others serving various purposes. This underscores the significant contribution of a comprehensive SCR definition to the measurement and improvement of supply chain resilience.

3. ANALYSIS OF PAPERS

This section will present and analyze how researchers define SCR in previous studies. In light of that these 21 papers picked only stands for the SCR definition trend in the last 10 years, we will borrow the SCR definitions list used in Kamalahmadi & Parast [10] to analyze the trend of SCR definitions from 2003 to 2014, which is as follows in Table 3. Table 4 lists the definitions of SCR from 2015 to 2024.

Table 3. Definitions of SCR from 2003 to 2014 (referring to Kamalahmadi and Parast [10])

Author/year	**Supply Chain Resilience definition**
Rice et al. (2003)	The ability to react to unexpected disruptions and restore normal supply network operations
Christopher and Peck (2004)	The ability of a system to return to its original state or move to a new, more desirable state after being disturbed
Gaonkar and Viswanadham (2007)	The ability to maintain, resume, and restore operations after a disruption
Datta et al. (2007)	Not only the ability to maintain control over performance variability in the face of disturbance, but also a property of being adaptive and capable of sustained response to sudden and significant shifts in the environment in the form of uncertain demands
Falasca et al. (2008)	The ability of a supply chain system to reduce the probabilities of a disruption, to reduce the consequences of those disruptions, and to reduce the time to recover normal performance
Ponomarov and Holcomb (2009)	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
Barroso et al. (2011)	The supply chain's ability to react to the negative effects caused by disturbances that occur at a given moment in order to maintain the supply chain's objectives
Juettner and Maklan (2011)	The apparent ability of some supply chains to recover from inevitable risk events more effectively than others
Ponis and Koronis (2012)	The ability to proactively plan and design a 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
Carvalho et al. (2012)	The ability of supply chains to cope with unexpected disturbances
Melnyk et al. (2014)	The ability of a supply chain to both resist disruptions and recover operational capability after disruptions occur
Barandon-Jones et al. (2014)	The ability of a supply chain to return to normal operating performance, within an acceptable period of time, after being disturbed
Pereira et al. (2014)	The capability of supply chains to respond quickly to unexpected events so as to restore operations to the previous performance level or even to a new and better one

Table 4. Definitions of SCR from 2015 to 2024

Author/year	Supply Chain Resilience definition
Hohenstein et al. (2015)	The 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
Kim et al. (2015)	Supply network resilience is a network-level attribute to withstand disruptions that may be triggered at the node or arc level
Tedeschi et al. (2015)	The ability of a system to recover and reestablish a dynamic equilibrium after it has been perturbed
Hoy (2015)	The capacity of a system to adapt, reorganize, and maintain key functions in the face of turbulent and unpredictable change in its environment
Vargas and González (2016)	The ability of a company/community/environment/people to recover after it has been exposed to an important disturbing event
Dixit et al. (2016)	The ability of a network to regain its original state post-disaster
Sahu et al. (2016)	The capability of successful survival (of the firm's SC) against those adverse events/happenings
Li et al. (2017)	The ability of the system to withstand disruption and return to a normal state quickly
Ali et al. (2018)	An ability of firms in a SC to reconfigure tangible and intangible resources into operational capabilities and to anticipate, resist and cope with contingencies, thereby maintaining continuity of operations to the end consumers
Zavala et al. (2019)	The ability to restore the system to its full operational capability within a quick time span time span
Cruickshank (2020)	The ability to function during a shock and then return to normal function
Ahmadian et al. (2020)	The ability of the supply chain to neutralize the functionality loss after nodes in the supply network have been disrupted
Behzadi et al. (2020)	The ability to recover quickly and effectively from a disruption
Fattahi et al. (2020)	The supply chain's ability to return quickly and effectively to its initial condition or even a more desirable state after a disruption
Hosseini et al. (2020)	The ability to absorb negative external disturbances and restore normal operations
Greene (2020)	The ability to anticipate, absorb, adapt to, and recover from major disruptions, and to rapidly restore service
Wieland and Durach (2021)	Does not just relate to the ability of a system to "bounce back" after an impeding event, but also to the capacity to adapt and transform
Meng et al. (2021)	The intrinsic property of a complex dynamic system including a supply chain system, reflecting the system's ability to overcome the changes caused by one or more disturbing events and to recover to its initial state or normal operations
Sahebi et al. (2021)	The capacity to withstand risks that are more significant, rapid recovery after risks, and reduced degradation by virtue of a certain number of hazards
Karan et al. (2023)	The ability of a system to adapt in the presence of a disruptive event
Sadeghi and Abadi (2023)	A supply chain's ability to avoid an unexpected disruption or quickly return to a normal situation

3.1. Three Typical Characteristics of SCR Definition

From Table 3 we can know, there are three typical characteristics of supply chain resilience when researchers define SCR: (1) preparedness; (2) reaction; (3) recovery (Kamalahmadi and Parast [10]). Rice et al. [15] mention "reaction" and "recovery", Christopher and Peck [1] use "return" whose meaning is similar to "recovery", Gaonkar and Viswanadham [16] focus on "recovery"

also. Ponomarov and Holcomb [17] are the very first authors that combine “prepare” with “react” and “recover” to describe SCR. Since 2010, more scholars have been adding some new characteristics and capabilities. Juettner & Maklan [2] mention “more effectively than others” when the authors define SCR, considering more than a single company in the SC, instead it focuses on the efficiency of the “resilience”. Carvalho et al. [18] use a simpler version of SCR definition. Ponis & Koronis [19] and Pereira et al. [20] take into account gathering comparative advantage from the react-to-be-resilient process, having the argument similar to “restoring to a better state than that prior to the disruptive events”. Melnyk et al. [21] mention “after disruptions occur” apart from using “resist” and “recover”. Barandon-Jones et al. [22] emphasize the significance of recovery time using “within an acceptable period of time”, while also employing "after being disturbed" to characterize SCR, which is similar to that of Melnyk et al. [21].

Notably, in most of definitions in Table 3, there is an event that makes the SC or the supply network turbulent, the researchers using “disruption”, “disturbance”, “risk” and even “shock” (Rice et al. [15]; Gaonkar and Viswanadham [16]; Falasca et al. [23]; Ponomarov and Holcomb [17]; Barroso et al. [24]; Ponis and Koronis [19]; Carvalho et al. [18]; Melnyk et al. [21]). In contrast, in other studies, the authors use phrases like “being disrupted”, “being disturbed”, etc. or they refrain from mentioning the specific event, using “unexpected event” or “disruptive event” instead (Christopher and Peck [1]; Barandon-Jones et al. [22]; Pereira et al. [20]). It can also be found in Table 4 that “the disruptive event” is a crucial term when defining SCR.

Adana et al. [25] address that there are two different viewpoints when defining SCR. One view considers SCR as the ability to recover from unforeseen disruptions and to return to the normal state of operation, and the other looks beyond recovery to involve additional capabilities and an improved ability to utilize new opportunities. Table 4 shows the SCR definition in the last decade. Hohenstein et al. [26] use the three characteristics, and the authors add “grow by moving to a new, more desirable state” to the SCR definition. This accords with Adana’s theory. Kim et al. [27] and Ahmadian et al. [28] based on network theory give their definition on SCR, using “arc” and “node” to describe “supply, demand, and transportation processes” and “each company in the SC” respectively. “To recover and reestablish a dynamic equilibrium” addressed by Tedeschi et al. [29] is similar to “restore and grow by mobbing to a new, more desirable state” of Hohenstein et al. [26], considering “recovery” and “the disruptive event”. The similar case can be found in Vargas and González [30], Dixit et al. [31], Sahu et al. [32], Li et al. [9], Cruickshank [33], Hosseini et al. [34]. Hoy [35] uses “adapt”, “reorganize” and “maintain” instead of “restore” or “recovery”, the three terms are inclined to “reaction” rather than “recovery” regarding the three characteristics. Li et al. [9] emphasize the importance of “time” – the SC must return to the normal state “quickly”. Similarly, terms like “quickly” also exist in Zavala et al. [36], Behzadi et al. [37], Fattahi et al. [38], Sahebi et al. [39], Sadeghi and Abadi [40]. In Table 3, Falasca et al. [23], Barandon-Jones et al. [22], and Pereira et al. [20] are also examples where the speed of SCs’ response is mentioned.

Ali et al. [41] employ terms such as “reconfigure” “anticipate” and “maintain” to elucidate the processes of “preparedness” and “reaction” while Zavala et al. [36] focus on “recovery” and Cruickshank [33] emphasizes “recovery” and the event. Behzadi et al. [37] use “quickly and effectively”, Fattahi et al. [38] apply “quickly and effectively” also and mention “even a more desirable state after a disruption”. Greene [42] mentions the speed of restoring from major disruptions. Hosseini et al. [34] concentrate on “time”, “reaction” and “recovery” and Wieland and Durach [3] focus on “reaction” using “to adapt and transform”. Meng et al. [43] first time present that SCR is an intrinsic property. The paper also considers “recovery” and “reaction”, so do Sahebi et al. [39]. Karan et al. [44] define SCR in a simplified version only emphasizing “adapt”. Sadeghi and Abadi [40] use the phrase “avoid an unexpected disruption”, yet it is worth noting that many disruptions can indeed be predicted or prevented [4].

It is insufficient to describe SCR utilizing only the three characteristics. The specific event confronting the supply chain is also very important, and almost all the definitions take into account the event when the SCR definitions are given. Furthermore, "preparedness" is not commonly featured when defining SCR, with only few papers considering it (such as Ponomarov and Holcomb [17]; Ponis and Koronis [19]; Hohenstein et al. [26]; Ali et al. [41]). What is more, "time" is also a significant characteristic of SCR definition, with many papers emphasizing terms like "quickly", "rapid", "a quick time span", etc.

3.2. Four Pillars of SCR Definition Proposed by Ribeiro and Barbosa-Povoa (2018)

Based on Kamalahmadi and Parast [10], Ribeiro and Barbosa-Povoa [11] use a new systematic literature review to introduce a framework for SCR definition, which is called "four pillars" of SCR definition. We adopt this framework and assess its applicability to the papers reviewed in our systematic literature review. Figure 3 shows the four pillars of SCR definition.

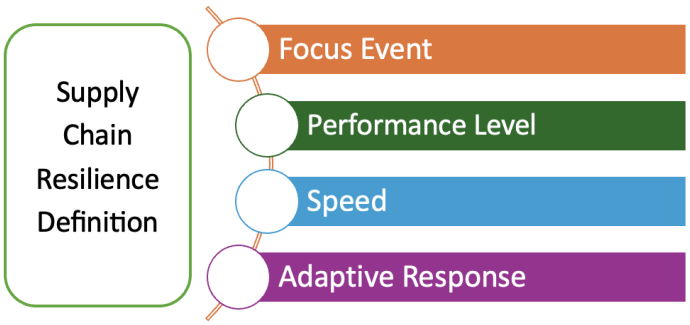

Figure 3. Four pillars of SCR definition (Ribeiro and Barbosa-Povoa, 2018)

Ribeiro and Barbosa-Povoa [11] regard "focus event", "performance level", "speed" and "adaptive response" as the four pillars when we try to give a definition to SCR. Focus event means the event associated with SCR, and "disruption" and "disturbance" are usually used. Performance level is the most important property before SCR level can be measured and it is the target of evaluation or quantification, meaning how much the SCs can recover. Adaptive response, broader than "reaction", means active responses (including prepare, react, maintain, adapt, recover, etc.) when the SCs meet with the focus event. Speed means the time efficiency of the adaptive responses and recovery process. Table 5 examines the papers we reviewed for SLR utilizing the four pillars theory.

From Table 5, it is evident that there are 5 papers among 21 incorporating all the four characteristics when defining SCR, while 15 papers considering at least three characteristics. Regarding the four pillars, the majority of papers take into account adaptive responses and performance level, 2 papers do not include the focus event into consideration, and 7 address the aspect of speed.

Combining information from Table 4 and Table 5 yields the following observations:

(1) In terms of the "focus event" pillar, 8 papers use "disruption" or "disruptive event", while 3 papers use "disturbance" or "disturbing event", and 2 papers utilize "risk".
(2) Concerning the "performance level" pillar, 8 papers describe the desired performance level as "...to normal state" "...to initial situation" etc. Furthermore, there are 2 papers

mentioning that SCR is the kind of ability to help SCs recover to the normal state and even transit to a more desirable performing state.

(3) Regarding the "speed" pillar, "quick" is used much in the description of the adaptive response process.

(4) As for the "adaptive response" pillar, "recover" and "restore" are mostly used in the definitions. Some researchers emphasize the process of supply chain's efforts with terms like "adapt" and "maintain". Furthermore, some papers stress the importance of reacting rapidly and efficiently to the focus event by using terms like "quickly" and "effectively".

Table 5. Papers examination with the four pillars theory

Author/Year	**Four pillars theory**				**Uniqueness**
	Focus event	**Performance level**	**Speed**	**Adaptive response**	
Hohenstein et al. (2015)	x	x	o	x	"or grow by moving to a new, more desirable state"
Kim et al. (2015)	x	o	o	x	"disruptions that may be triggered at the node or arc level"
Tedeschi et al. (2015)	x	x	o	x	"re-establish a dynamic equilibrium"
Hoy (2015)	x	o	o	x	"adapt"; "turbulent and unpredictable change"
Vargas and González (2016)	x	o	o	x	/
Dixit et al. (2016)	x	x	o	x	"post-disaster"
Sahu et al. (2016)	x	x	o	o	"survival"
Li et al. (2017)	x	x	x	x	/
Ali et al. (2018)	o	x	o	x	"maintaining continuity of operations to the end consumers"
Zavala et al. (2019)	o	x	x	x	"full operational capability"
Cruickshank (2020)	x	x	o	x	"shock"
Ahmadian et al. (2020)	x	x	o	x	"functionality loss"
Behzadi et al. (2020)	x	o	x	x	/
Fattahi et al. (2020)	x	x	x	x	"even a more desirable state"
Hosseini et al. (2020)	x	x	o	x	"absorb negative external…"
Greene (2020)	x	x	x	x	/
Wieland and Durach (2021)	x	x	o	x	"adapt and transform"
Meng et al. (2021)	x	x	o	x	"intrinsic property"
Sahebi et al. (2021)	x	x	x	x	"a certain number of hazards"
Karan et al. (2023)	x	o	o	x	/
Sadeghi and Abadi (2023)	x	x	x	x	"unexpected…"

Note: x means that the authors mentioned this pillar, and o means they did not.

3.3. What is a State-of-the-Art Definition of Supply Chain Resilience in 2024?

The four pillars theory presents a robust framework for defining SCR, as evidenced by our analysis using Table 5. The effectiveness of this theory has been validated through our examination. Notably, the two characteristics (reaction and recovery) of the three characteristics theory proposed by Ponomarov and Holcomb [17] actually align with the pillar of "adaptive response". Although "preparedness" has been omitted in the four pillars theory, it remains crucial to mention when defining SCR. This is because a company equipped with comprehensive preparedness for disruptions stands a better chance of defending itself and recovering from those disruptions.

Back to the RQ 2 of this article and the underlying motivation, before SCR can be measured, it must first be scientifically defined. With this premise, we aim to present the final version of SCR definition. To enhance readability and simplify comprehension, the following criteria will be considered for this definition:

(1) The definition should include all the characteristics of the four pillars theory and the three characteristics theory.
(2) Some unique characteristics from other studies can be included.
(3) The definition should be applied in generic sectors.
(4) The definition should be in a simply-easy-to-understand version.

In this context, we propose the following SCR definition:
Supply chain resilience is the supply chain's intrinsic property reflecting its ability to prepare, react, and recover from disruptions to the normal state or even a better state cost and time efficiently.

This definition is elucidated by several considerations:

(1) In accordance with the Oxford Dictionary, resilience encompasses the capacity to withstand or recover quickly from difficulties. We replace "difficulties" with "disruptions" and use the three characteristics (prepare, react, recover) to describe the concept of withstanding or recovering.
(2) Supply chain resilience is regarded as an intrinsic property of a supply chain, which can be readily comprehended compared to the resilience of a physical object.
(3) Acknowledging that strategies aimed at improving SCR level can elevate the performance of supply chains, we incorporate "... or even achieve a better state" into the definition.
(4) Recognizing the importance of cost in the resilience of economic systems, we emphasize the efficiency of cost and time in the definition of SCR. This is supported by the arguments of Tukamuhabwa et al. [45] regarding the incomplete nature of resilience definitions without cost considerations, and the focus highlighted by Xiao et al. [46] on reducing costs through rapid and effective coordination in resilient supply chains.

4. CONCLUSIONS

Though the COVID-19 pandemic and the Russo-Ukrainian war have raised more researchers' study interest on supply chain resilience (SCR), there remains a dearth of studies contributing to the definition of SCR. In this article, we aimed to establish a clear and scientifically grounded definition of "supply chain resilience" through a systematic literature review (SLR) and thorough

paper analysis. By adhering to strict exclusion and inclusion criteria during the SLR process, we meticulously selected and analysed 21 papers from a pool of 413 studies. We examined the three typical characteristics of defining SCR and the four pillars theory, and eventually defined "supply chain resilience" based on our understanding.

In summary, this study enhances the comprehension on supply chain resilience definition in three significant ways. First, the study is different from previous articles that solely offer a systematic literature review because we have given a scientifically informed definition of SCR. Second, the paper examines and explains the effectiveness of the three typical characteristics theory and the four pillars theory. Third, by incorporating "time" and "cost" into our definition, commonly used as evaluation criteria for solutions, this study facilitates the assessment of supply chain strategies aimed at improving SCR levels. Finally, it will be easier for researchers to model SCR measurement with this study.

The proposed SCR definition lays a solid foundation for future research, one of the most significant being the development of methodologies and quantitative approaches for measuring SCR levels. By leveraging this definition, we can construct quantitative SCR models that enable us to precisely assess the resilience level of specific supply chains. This quantitative modelling approach facilitates the calculation of the current resilience level, thereby facilitating the identification of areas for improvement. With a clear understanding of the SCR level, stakeholders can devise targeted strategies to enhance supply chain resilience effectively.

However, despite our efforts, this article may be subject to certain limitations. The reliance only on the SCOPUS database for article searching during the SLR process and the restriction to English-language journal papers may have led to the omission of relevant and important studies. Additionally, the subjective nature of both the article selection criteria and papers analysis criteria introduces the potential for judgment bias.

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REFERENCES

[1] M. Christopher, H. Peck, 2004, Building the resilient supply chain, Int.J. Logist. Manag, 15(2), 1–14.

[2] U. Juettner, S. Maklan, 2011, Supply chain resilience in the global financial crisis: an empirical study, Supply Chain Manag: Int. J. 16(4), 246–259.

[3] A. Wieland, C. F. Durach, 2021, Two perspectives on supply chain resilience, Journal of Business Logistics, 42(3), pp.315-322.

[4] Hubs, 2023. Supply chain resilience report 2023 update, https://www.hubs.com/get/supply-chain-resilience-report/, 2023.

[5] European Commission, "Towards a green, digital and resilient economy: our European Growth Model," https://ec.europa.eu/commission/presscorner/detail/en/IP_22_1467, Mar. 02, 2022.

[6] M. Holgado, A. Niess, 2023, Resilience in global supply chains: analysis of responses, recovery actions and strategic changes triggered by major disruptions, Supply Chain Management: An International Journal.

[7] Y. Rannane, H. Mharzi, M. A. El Oualidi, 2022, A systematic review of the supply chain resilience measurement literature, In 2022 14th International Colloquium of Logistics and Supply Chain Management (LOGISTIQUA) (pp. 1-6). IEEE.

[8] P. P. Datta, M. Christopher, P. Allen, 2007, Agent-based modeling of complex production/distribution systems to improve resilience, Int. J. Logist, Res. Appl. 10 (3), 187–203.
[9] R. Li, Q. Dong, C. Jin, et al., 2017, A new resilience measure for supply chain networks, Sustainability, 9(1), p.144.
[10] M. Kamalahmadi, M. M. Parast, 2016, A review of the literature on the principles of enterprise and supply chain resilience: Major findings and directions for future research, 171, 116-133.
[11] J. P. Ribeiro, A. Barbosa-Povoa, 2018, Supply Chain Resilience: Definitions and quantitative modelling approaches–A literature review, Computers & industrial engineering, 115, pp.109-122.
[12] R. Mishra, R. K. Singh, 2022, A systematic literature review on supply chain resilience in SMEs: learnings from COVID-19 pandemic, International Journal of Quality & Reliability Management, 40(5), pp.1172-1202.
[13] E. Sawyerr, C. Harrison, 2019, Developing resilient supply chains: Lessons from high-reliability organisations, Supply Chain Management: An International Journal, 25, 77–100.
[14] Y. Han, W. K. Chong, D. Li, 2020, A systematic literature review of the capabilities and performance metrics of supply chain resilience, International Journal of Production Research, 58(15), pp.4541-4566.
[15] J. B. Rice, F. Caniato, 2003, Building a secure and resilient supply network, Supply Chain Manag, Rev. 7(5), 22–30.
[16] R. S. Gaonkar, N. Viswanadham, 2007, Analytical framework for the management of risk in supply chains, IEEE Trans, Autom. Sci. Eng. 4(2), 265–273.
[17] S. Y. Ponomarov, M. C. Holcomb, 2009, Understanding the concept of supply chain resilience, Int. J. Logist Manag. 20(1), 124–143.
[18] H. Carvalho, S. G. Azevedo, V. CruzMachado, 2012, Agile and resilient approaches to supply chain management: influence on performance and competitiveness, Logist, Res. 4, 49–62.
[19] S. T. Ponis, E. Koronis, 2012, Supply chain resilience: definition of concept and its formative elements, J. Appl. Bus, Res. 28(5), 921–930.
[20] C. Roberta Pereira, M. Christopher, A. LagoDaSilva, 2014, Achieving supply chain resilience: the role of procurement. Supply Chain Manag, Int. J. 19(5/6), 626–642.
[21] S. A. Melnyk, D. J. Closs, S. E. Griffis, et al., 2014, Understanding supply chain resilience, Supply Chain Manag, Rev. 18(1), 34–41.
[22] E. Brandon-Jones, B. Squire, C. W. Autry, et al., 2014, A contingent resource-based perspective of supply chain resilience and robustness, J. Supply Chain Manag, 50(3), 55–73.
[23] M. Falasca, C. W. Zobel, D. Cook, 2008, A decision support framework to assess supply chain resilience, In: Proceedings of the 5th International ISCRAM Conference, Washington.
[24] A. P. Barroso, V. H. Machado, V. CruzMachado, 2011, Supply chain resilience using the mapping approach, In: Dr. Pengzhong, Li(Ed.), Supply Chain Management.
[25] S. Adana, S. Cevikparmak, H. Celik, et. al, 2022, Connecting Decision-Making to Resilience: The Importance of Decentralization and Supply Chain Orientation in a Post-COVID World, In Supply Chain Resilience: Reconceptualizing Risk Management in a Post-Pandemic World (pp. 133-149).
[26] N. O. Hohenstein, E. Feisel, E. Hartmann, et al., 2015, Research on the phenomenon of supply chain resilience: a systematic review and paths for further investigation, International journal of physical distribution & logistics management, 45(1/2), pp.90-117.
[27] Y. Kim, Y. S. Chen, K. Linderman, 2015, Supply network disruption and resilience: A network structural perspective, Journal of operations Management, 33, pp.43-59.
[28] N. Ahmadian, G. J. Lim, J. Cho, et al, 2020, A quantitative approach for assessment and improvement of network resilience, Reliability Engineering & System Safety, 200, p.106977.
[29] L. O. Tedeschi, J. P. Muir, D. G. Riley, et al., 2015, The role of ruminant animals in sustainable livestock intensification programs, International Journal of Sustainable Development & World Ecology, 22(5), pp.452-465.
[30] J. Vargas, D. González, 2016, Model to assess supply chain resilience, International Journal of Safety and Security Engineering, 6(2), pp.282-292.
[31] V. Dixit, N. Seshadrinath, M. K. Tiwari, 2016, Performance measures based optimization of supply chain network resilience: A NSGA-II+ Co-Kriging approach, Computers & Industrial Engineering, 93, pp.205-214.
[32] A. K. Sahu, S. Datta, S. S. Mahapatra, 2016, Evaluation and selection of resilient suppliers in fuzzy environment: Exploration of fuzzy-VIKOR, Benchmarking: An international journal, 23(3), pp.651-673.

[33] N. Cruickshank, 2020, He who defends everything, defends nothing: proactivity in organizational resilience, Transnational Corporations Review, 12(2), pp.94-105.
[34] S. Hosseini, D. Ivanov, J. Blackhurst, 2020, Conceptualization and measurement of supply chain resilience in an open-system context, IEEE Transactions on Engineering Management, 69(6), pp.3111-3126.
[35] C. W. Hoy, 2015, Agroecosystem health, agroecosystem resilience, and food security, Journal of Environmental Studies and Sciences, 5(4), pp.623-635.
[36] A. Zavala, D. Nowicki, J. E. Ramirez-Marquez, 2019, Quantitative metrics to analyze supply chain resilience and associated costs, Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability, 233(2), pp.186-199.
[37] G. Behzadi, M. J. O'Sullivan, T. L. Olsen, 2020, On metrics for supply chain resilience, European Journal of Operational Research, 287(1), pp.145-158.
[38] M. Fattahi, K. Govindan, R. Maihami, 2020, Stochastic optimization of disruption-driven supply chain network design with a new resilience metric, International Journal of Production Economics, 230, p.107755.
[39] I. G. Sahebi, S. P. Toufighi, G. Karakaya, et al., 2021, An intuitive fuzzy approach for evaluating financial resiliency of supply chain, OPSEARCH, pp.1-22.
[40] K. Sadeghi, M. Q. H. Abadi, 2024, Sustainable supply chain resilience for logistics problems: Empirical validation using robust and computational intelligence methods, Journal of Cleaner Production, 437, p.140267.
[41] I. Ali, S. Nagalingam, B. Gurd, 2018, A resilience model for cold chain logistics of perishable products, The International Journal of Logistics Management, 29(3), pp.922-941.
[42] S. R. Greene, 2020, How Nuclear Power Can Transform Electric Grid and Critical Infrastructure Resilience, Journal of Critical Infrastructure Policy, Volume, 1(2).
[43] S. Meng, W. Dong, H. Hu, et al., 2021, Analysis of supply chain's resilience in crowd networks, International Journal of Crowd Science, 5(2), pp.166-184.
[44] E. P. Karan, S. Asgari, and S. Asadi, 2023, Resilience assessment of centralized and distributed food systems, Food Security, 15(1), pp.59-75.
[45] B. R. Tukamuhabwa, M. Stevenson, J. Busby, et al., 2015, Supply Chain Resilience: Definition, Review and Theoretical Foundations for Further Study, International Journal of Production Research 53 (18), 5592–5623.
[46] R. Xiao, T. Yu, X. Gong, 2012, Modeling and Simulation of Ant Colony's Labor Division with Constraints for Task Allocation of Resilient Supply Chains, International Journal on Artificial Intelligence Tools 21 (3): 1–19.

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