

Supply Chain Resilience (SC-Res) in Catastrophic Disruptions: Towards Mapping Conceptual Frameworks via Selective Literature Reviews

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Abstract

Any management concept cannot be used effectively by practitioners and researchers if a common agreement on its definition is lacking. Such is the case with the term “supply chain resilience”-so many definitions are used that there is little consensus on what it means. Last 30 years and so world’s trade and industrial sectors were blessed with unchanging business environment. The practitioners and researchers were well obsessed with cost-cutting efforts putting the concepts of resilience on the side-lines. The ongoing pandemic and few other catastrophic disasters have caused severe supply chain disruptions that affected most of the economies’ bottom-lines. This has ultimately turned the situation 180 degree. Last 2 years numbers of articles were published on SC-Res. The purpose of this paper is to examine the existing literature to understand the concept of “supply chain resilience”. Various definitions of SCRes, and disruptions are reviewed, categorized, and synthesized. This paper expands readers’ understanding of factors that contribute to the developing of firm resilience to supply chain disruptions. In doing so, it operationalizes firm resilience to understand how supply chain disruption orientated firms can develop resilience to supply chain disruptions. The paper initiated a debate regarding approaches to SC-Res. Although it lauded the utility of studying the SC-Res through resilience lenses – but ultimately fall back to the predecessors approaches through Risk-management lenses.

Keywords: Supply Chain Management, Supply Chain Resilience, Supply Chain disruptions, risk-management, COVID-19, Collaborative resilience, lean

1. Introduction

Almost anything and everything that is produced in the world nowadays may be the result of a supply chain: a series of steps in which raw materials and components are produced, assembled, and then marketed around a single country or the world. Some products can require thousands of steps that include hundreds of businesses in dozens of

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states or countries. The global supply chain is facing the most critical time now for every process. 2020 started with the horrible pandemic COVID. The series of natural disasters are going on in 2021. Pandemic induced lockdown causes disruptions in the supply chain of almost all the sourcing countries. Supply Chain experts and practitioners could never imagine the intensity of the breakdown effect on world economy. The current anxieties about supply chains have reminded us of two adages: “Don’t put all your eggs in one basket,” and “A chain is only as strong as its weakest link.” Supply chains were largely constructed and maintained with little thought given to their resilience. Keeping costs down was paramount. This meant often depending on a single low-cost supplier or producer and limiting inventory size. “Just in time (JIT)” was the concept that reflected the desire to minimize the gap between when an item was produced or purchased, and when it was sold. Supply Chain Management (SCM) emerged as a discipline in 1990s. Most of the theories and models of SCM had been developed when there was more stability in the environment (Christopher and Holweg 2011). Such stabilities enable the decision makers to ignore the fragilities and vulnerabilities of supply chains’ operating practices. Moreover, supply chains of today are exposed to new trends like increased information technology dependence, outsourcing, volatility of demand, decreasing product life cycles, etc. (Peck 2005) – further becoming riskier and more prone to disruptions. COVID-19 pandemic has emerged just in the times when supply chains were being called to be transformed from the phenomenon of the Fourth Industrial Revolution (Fredrico 2020). Future outbreaks of infectious diseases could prove far more disruptive. In addition, any of the increasingly frequent and severe effects of climate change could shut down a production site for weeks or months. Likewise, wars between countries cannot be ruled out, and wars within them are relatively commonplace. Then there is the potential for work strikes, nuclear accidents, earthquakes, mechanical breakdowns, and terrorism.

Supply chain disruptions cause organisations to bear huge losses in terms of profitability, market share, etc. However, in the past few decades, supply chains (SCs) and their various stages have been facing various internal (operational) as well as external challenges. These all challenges make SC and its various stages inefficient, volatile, vulnerable and turbulent. Hendricks and Singhal 2005 – in their study on 885 publicly traded firms – found that over the period between one and two years, after a supply chain disruption is announced, stock prices declined nearly 40 per cent. Also, due to supply chain incidents alone, companies lose productivity for more than half of businesses along with increased cost of working and loss of revenue. The incidents that lead to supply chain disruptions are unpredictable; therefore, it is important for an organisation to be proactive and prepare to bounce back from unforeseen disruptions. The ability of a company to bounce back from a disruption and return to a normal level of performance after a disruption occurs is called Supply Chain Resilience (Sheffi and Rice 2005; Fiksel 2006), in short SC-Res. Many problems related to supply chain management, especially linked to sourcing strategies have caused significant disruptions in different supply chains (Kutzner and Rajal 2020). These and similar

events have prompted researchers to turn their attention toward supply chain resilience (SC-Res) for effective mitigation of disruptions (Tukamuhabwa et al. 2015; Pettit, Craxton and Fiksel 2013). Resilience is a key competency in a world of turbulent change as even the most carefully designed supply chain is susceptible to unforeseen events. Organisations need to develop a collaborative approach with supply chain partners to build resilience against such disruptions (Christopher and Peck 2004; Ponomarov and Holcomb 2009). A supply chain perspective in literal sense would include a chain of at-least three entities – supplier, focal firm, customer, etc. However, the concept of resilience in SCM literature lacks clarity in this sense. Sheffi and Rice 2005, Pettit, Craxton and Fiksel 2013, Mensah and Merkurjev 2014 and Gölgeci and Ponomarov 2015 have clearly focused on firm's supply chain when studying supply chain resilience, while some other researchers (Scholten, Scott and Fynes 2014; Scholten and Schilder, 2015) have taken a broader perspective moving beyond single firm level; however, they have also used the term supply chain resilience. Birkie, Trucco and Kaulio 2014 conducted a systematic review of literature on resilience in supply chains and concluded that supply chain literature focuses on individual firm's resilience. While there is vagueness in supply chain literature on this front, resilience has been studied with focus on enterprise and only supply chain practices of the enterprise are taken into consideration. Ambulkar, Blackhurst and Grawe 2015 stated that there is an ambiguity of the concept of resilience in the context of supply chain disruptions as also noted by previous researchers like Ponomarov and Holcomb 2009, Wieland and Wallenburg 2012, etc. Ambulkar, Blackhurst and Grawe 2015 used the word "firm resilience", to clarify the stand of previous studies on resilience in supply chains. The collaborative role of other supply chain entities in building resilience needs to be explored. In supply chain literature, collaborative approach has been successfully applied in concepts like Collaborative Planning Forecasting and Replenishment (CPFR), Collaborative Transportation Management, etc. (Flidner 2003; Tang 2006; Attaran and Attaran 2007). Agarwal and Srivastava 2019 took similar approach to resilience building and investigated through the concept of collaborative resilience. Resilience can be understood from three perspectives: readiness and preparedness, response and adaption, and recovery or adjustment (Bhamra, Dani and Burnard 2011). Moreover, considering the dynamic of environments, resilience on supply chains must have a strategic perspective. New strategies should be implemented to enhance supply chain's resilience on an adaptative perspective (Tukamuhabwa et al. 2015). Also, organisations focused on resilience must seek for an agile adaptation and be prepared to a more proactive response. To achieve these attributes, those organisations need to have a long-term strategic orientation (Burnard, Bharna and Tsinopolous 2018). Van Hoek 2020 claims for the relevance in learning with the COVID-19 pandemic to improve the future decisions-making in disruption situations. Extant research highlights the importance of system states – namely robustness and resilience – towards mitigating the probability and magnitude of disruptions. However, there appears to be a lack of conceptual guidance surrounding two popular strategies – redundancy and flexibility – that have been proposed to mitigate the impact of disruptions. In this paper, published

research on resilience and robustness in supply chains is considered, alongside research in other areas such as risk, systems theory, social capital theory, ecology etc. It presents a comprehensive discussion on Supply Chain Resilience Framework. The conceptual framework is based on extant literature and refined through a cognitive interoperation. Supply chain resilience can be assessed in terms of two dimensions: vulnerabilities and capabilities. The Zone of Resilience is defined as the desired balance between vulnerabilities and capabilities, where it is proposed that firms will be the most profitable in the long term. The main objective of this paper is to analyse disruption propagation in the supply chain in order to design resilient supply chain structure. The subsidiary objectives are (1) to consider sustainability factors, (2) to address the gap related to the ambiguity surrounding the dimensions and definitions of firms' supply chain resilience, and (3) to gain an in-depth understanding of resilience. The paper concludes that the differences in utility between redundancy and flexibility as means to enhance resilience and robustness is influenced by interactions between the supply chain, the disruption characteristics (inclusive of speed of onset and time horizon) and the decision maker. It employs a multidisciplinary literature review. For this, key articles from the various databases, relevant to the selected theme were selected initially. Afterwards, backwards and forwards approach was used, leading to a collation of more than 100 research articles published from 1999 to June 2021. We took resort to open sources, that is Google Scholars, Emerald, JSTOR, Taylor and Francis, Wiley E-Books, etc. which were accessed through Remotex- e-Library of Bangabandhu Sheikh Mujibur Rahman Maritime University.

2. Sequential Development of Various Paradigms of Supply Chain

Rajesh 2017 has shown that paradigm shifts in Supply Chains Concepts occurred in 2(two) separate streams: (1) Lean-Green-Sustainable Supply Chains whose focus is on reducing wastes; and (2) Agile-Leagile-Resilient Supply Chains whose focus is on reducing vulnerabilities. Sharma, et al. 2020 carried out systematic literatures review (SLR) in the field of Lean, Agile, Resilience, Green and Sustainable paradigms in SCM. They found that most of the research were conducted in the manufacturing sector, whereas very less research was reported from the service sector. It was observed that most research in this domain focused either on the focal company or supplier selection, and no study addressed the effect of these paradigms on the inbound and outbound logistics. Large number of researchers applied either analytical techniques or statistical tools. Based on these studies, they arrive at six different **performance measures: overall performance, competitive advantages, operational performance, economic performance, social performance and environmental performance**. It was observed that initially, green, resilient, agile and sustainable paradigm emerged as the performance measures and terms used were greenness or GSC, resilience or SC resilience, agility or agile supply chain, in the SC. Later, agile, green and resilient were established/used as the separate/have many practices known as resilient practices, green practices, agile practices and now known as individual paradigms which affects the SC

performance. In the selected studies, mostly all researchers made a common argument, except lean (has extensively researched area/have extant literature), all the other agile, green and resilient paradigms are new or in nascent stage. In addition to this, assessment of leanness, agility, greenness, resilient and sustainability is restricted to firm level and not yet explored fully to entire SC process in the literature.

3. Supply Chain Disruptions

High levels of uncertainty and complexity make business organisations vulnerable to supply chain disruptions (Knemeyer, Zinn and Eroglu 2009; Ambulkar, Blackhurst and Grawe 2015; Fan et al. 2016). A supply chain disruption is defined as an event that disrupts the flow of goods or services in a supply chain system (Revilla and Saenz 2017; Truong and Hara 2018). Companies that have long and complex supply chains face risks of disruptions from their own suppliers as well as from suppliers of suppliers and so on. Disruptions may arise at one point along a supply chain but have repercussions or impact on other entities of the supply chain as well. Firms have begun to address the importance of investment in supply chain disruption management to mitigate the impact of disruptions (Jüttner and Maklan 2011; Wieland and Wallenburg 2013; Dubey et al. 2018). The outbreak of COVID-19 had impacted normal supply and demand patterns, leading to large losses in sales and disruptions in logistics and supply chain systems. The leading economies have entered into recession after a decade of expansion (Birmingham and Tan 2020; Cecere 2020). It can have severe negative consequences on firm performance at multiple levels, as well as on customers and suppliers (Hendricks and Singhal 2003; Wagner and Bode 2008). While the literature discusses how disruptions affect organisational performance (Hendricks and Singhal, 2003), many firms do not invest in disruption mitigation strategies and do not develop dynamic capabilities to make their supply chain robust and resilient. There are two main reasons for this. First, it would be challenging to quantify the long-term benefit of investment in the capabilities of a supply chain to mitigate disruptions from low-probability high-impact events, so from a cost-benefit perspective, managers are reluctant to commit to such investment (Tang 2006). Second, managers need to know the relative importance of different disruption risk drivers and their impact on organisational performance. Surprisingly, with the exception of a few studies (Wagner and Bode 2008; Parast 2021), there is limited research on the impact of different disruption risk drivers on firm performance and supply chain performance outcomes. Surveys show that 75% organisations face some sort of disruption in the supply chain each year (Scholten, Stevenson and Van Donk 2020). Walker 2020 reports that recent coronavirus epidemic has resulted in many international retailers closing operations in China. As China has a pivotal role in global supply chains, the negative effects of these disruptions are global (Walker 2020). Guha-Sapir and Ph 2015 observed that due to erratic and obvious population growth and the climate changes, the occurrences of supply chain disruptions are on the rise. Parast 2021 proposes four broad conceptual strategies – **insurance, expediting, strategic adaptive capability and reconfiguration**

– that each uniquely serve to reduce the probability and magnitude of supply chain disruptions. Ripple effect in the supply chain occurs if a disruption at a supplier end cannot be localized and cascades downstream impacting supply chain performance. Christopher and Peck 2004 proposed a typology for conceptualising disruptions from a supply chain perspective. In their framework, there are five supply chain disruption risks sorted into three categories, namely, disruption risks internal to the firm (**process and control**), disruption risks external to the firm but internal to the supply chain (**demand and supply**) and disruption risks external to the supply chain (**environmental**). Supply side disruptions take place in the upstream side of a firm's supply chain (Wagner and Bode 2008). By improving supplier product quality and eliminating uncertainties, firms would be able to minimize supply risk. A supplier's financial stability and its ability to have a strong market position, both technologically and financially, have also been recognized as important factors in managing supply risk. Supply disruption can also occur as a result of operational inefficiency in the suppliers' end, deviations in product quality and quantity, logistics and transportation delays or poor coordination between a supplier and the firm (Kumar et al. 2016; Sarker et al. 2016). Product quality and service quality can significantly contribute to reducing supply disruption, especially when they extend across the entire supply chain (Tse and Tan 2012). In addition, suppliers should have the capability to adapt to changes in market demand (such as customer preferences) and the capability to remain competitive through new product development (Zsidisin and Ellram 2003). Supply disruptions can affect outbound logistics and consequently deteriorate supply chain performance in terms of delivery time. Firms are exposed to demand disruption as a result of disruption in the downstream side of the supply chain (Jüttner 2005). Demand disruption can arise from incidents such as disruptions in the distribution of products to customers because of transportation delays or other logistical inefficiencies or from unstable and unpredictable customer demand. Demand variations such as changes in order quantity, shorter product life cycle and the introduction of new products pose significant risks to the firm. COVID-19 showed that customers who engage in panic buying and social distancing cause volatility in demand with a ripple effect in supply chains. A fundamental activity in a supply chain is to properly match demand and supply. Demand disruption also occurs when a firm is not able to properly match supply and demand, as a result of either forecast inaccuracy, a ripple effect or from inefficient coordination in the supply chain. A classic example of a mismatch between supply and demand happens due to the bullwhip effect, when demand fluctuation is further amplified across the upstream of the supply chain; this fluctuation affects forecast accuracy, capacity utilization and production planning, which all lead to operational inefficiency. In addition, the supply chain of a firm will be negatively affected as a result of fluctuations in demand. Process disruption occurs as a result of disruption in a firm's internal operations; examples are capacity limitation, machine failure, quality problems and inefficient IT infrastructure. According to Hopp and Spearman 2000, process variability is increased by variations in process selection, production design and management decisions. One of the key aspects of organisational processes is their

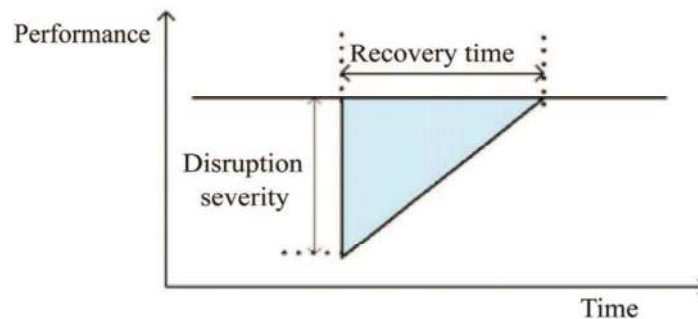
adaptability to respond to changes in the internal and external environment (Valença et al. 2013). Organisations can minimize process variability by implementing cross-functional teams, improving communication systems between departments and making effective use of knowledge sharing procedures (Flynn et al. 1995). In fact, the implementation of management programs such as total quality management was popularized because of their ability to minimize process disruptions. Incidents such as pandemics, epidemics, natural disasters (such as earthquakes), socio-political instability, economic downturns and terrorist attacks are examples of environmental disruption (Parast, 2020; Gunessee and Subramanian, 2020). These events are exogenous to the firm and its supply chain, they happen infrequently and their impact on a firm's supply chain can be significant. The negative impact of environmental disruptions on supply chains can be substantial, as production facilities, logistics and transportation systems are vulnerable to natural disasters or terrorist attacks.

4. Approaches to Resilience

Resilience is the capacity to anticipate, absorb, and adapt to disruption(s). Operationalising the idea of resilience is quite difficult. Resilience is an emergent property of complex systems that is revealed in the face of uncertain events, and as such is very hard to measure. Resilience increases the efficiency of the system, and its processes start functioning easily and quickly from a disrupted state. Adaptive capacity is the prime capability associated with resilience, encompassing the abilities to rapidly exploit new opportunities, manage complex and interconnected systems, and read and respond to signals of change. This adaptive capacity can appear either like change or stasis. There is a real challenge in moving from the conceptual to the practical without falling in the trap of reverting to traditional risk management approaches. Risk management approach often do not capture the richness of insight that a resilience lens could bring to bear. In fact, most systems for which we will be interested in their resilience, have non-normal risk distributions with fat tails (or black swans) that undermine the very essence of the standard risk management tools. Holling 1973 was one of the early researchers to note that systems have two properties – resilience and stability. He defined resilience as the ability of systems to absorb changes, and stability as the ability of systems to return to a state of equilibrium. The concept of resilience was first defined by Timmerman 1981, as a measure of a system's capacity to absorb and recover from a disastrous event. Reich 2006 examined three psychological principles as control, coherence and connectedness as key components of resilience. Economic resilience refers to the ability of a system to absorb damages or losses. Rose 2004 elaborated that resilience can be of two types: inherent which is the ability in normal circumstances and adaptive which is the ability in crisis situations. From an organisational perspective, resilience is concerned not just with recovery, flexibility and crisis management, but also with a source of competitive advantage (Coutu 2002; Hamel and Valikangas 2003) and “the capacity for continuous reconstruction”. The idea of resilience suggests the speed with which a chain can return to normal working after

some kind of damage. Sheffi 2005 has affirmed that: “resilience represents the ability of a material to recover its original shape following a deformation. In the corporate world, resilience refers to the ability of a company to bounce back from a large disruption -this includes, for instance, the speed with which it returns to normal performance levels (production, services, fill rate, etc.)” Barroso et al. 2015 suggest a “resilience triangle” where two parameters are shown: the disruption severity (severity or magnitude of loss damage) and the recovery time (the damping time).

The “resilience triangle”



Source : (Barroso et al. 2015, p.20)

According to the authors, the smaller the triangle is, the more resilient the company or supply chain is.

5. Supply Chain Resilience

One of the substantiated issues in supply chain dynamics is resilience. A resilient supply chain can help us to overcome the volatility of global business and deliver a sustainable future. The literary roots of supply chain resilience can be traced back in to the late 1950s. The bullwhip effect, first introduced by Forrester 1958, is a foundational theory for the operations and supply chain management discipline, and it directly relates to demand risks and how those can cause disruption throughout the supply chain. Supply chain resilience has been defined by a number of disciplines. Multiple definitions of supply chain resilience already exist in the literature. Ali, Mahfouz and Arisha 2016 have summarized those which are listed in Table 1:

Table 1: SC-Res Definitions

Authors	SC-RES definitions
Rice and	Resilience is widely used to characterize an organisation’s ability

Caniato 2003, p. 25	to react to an unexpected disruption, such as one caused by a terrorist attack or a natural disaster, and restore normal operations
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
Sheffi and Rice 2005, p. 41	The ability to bounce back from a disruption
Datta, Christopher and Allen 2007, p. 189	Supply chain resilience is defined as 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
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
Klibi, Martel and Guitouni 2010, p. 287	“... resilience is the capability of a SCN to avoid disruptions or quickly recover from failures”
Pettit, Fiksel, and Croxton 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, pp. 925-926	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 favourable than the one prior to the event, thus gaining competitive advantage

5.1 Dilemma in Concepts of Supply Chain Resilience (SC-Res) and Supply Chain Risk Management (SCRM)

The need for resilience arises from the premise that all risks cannot be avoided and firms can overcome disruption threats to their supply chains by developing resilience that allows them to carry on providing goods and services to the customers (Tukamuhabwa et al., 2017; Sahebjamnia, Torabi and Mansouri 2018; Bhamra et al. 2011). Resilient firms are relatively better prepared to deal with disruptions and organise internal resources, capabilities and systems in a better way in the face of disruptions (Ambulkar, Blackhurst and Grawe 2015; Ponomarov and Holcomb 2009;

Martins de Sa et al. 2019). The extant literature on SC-Resilience suggests that environmental uncertainties and disruptions are not restricted to organisational boundaries; rather they impact the entire supply chain. It is therefore critical for the firms to develop capabilities that are aligned with their supply chain partners in order to overcome both anticipated and sudden changes (Chowdhury and Quaddus 2017; Ponomarov and Holcomb 2009; Ali, Mahfouz and Arisha 2017). Most of the researchers considered Supply Chain Resilience is a critical component of Supply Chain Risk Management (Ponomarov and Holcomb 2009), and a relatively new and yet underexplored research area of management as a whole as mentioned by Ponis and Koronis 2012,- but other fields started to challenge this equilibrium-focused meaning of resilience. They have suggested that resilience does not just relate to the ability of a system to “bounce back” after an impending event, but also to the capacity to adapt and transform. The operations and supply chain management literature remains surprisingly disconnected from these debates. These perspectives need to be integrated in the context of the supply chain as a system. Supply chain resilience is then no longer understood in terms of stability, but in terms of adaptation and transformation. The first study on resilience in supply chain was conducted in the UK, in 2000 when transportation disruptions happened due to fuel protests, and then due to outbreak of Foot and Mouth Disease in early 2001. Researchers in Cranfield University had conducted a large-scale study on supply chain resilience based on these two incidents (Christopher and Peck 2004). Its objective was to develop understanding, and thereby increase the ability of industries in UK to deal with disruptions in their supply chains. Christopher and Peck 2004 defined supply chain resilience as the ability of supply chain to return to its original or more desirable state after being disrupted. They presented four principles, which could build resilient supply chains. First, resilient supply chains could be built through re-engineering of existing supply chains whose only objectives have been to optimise cost and customer service. For supply chain re-engineering, the authors further provided detailed recommendations like **supply chain understanding**, **supply chain design principles** and **supplier base strategy**. Second, **collaboration with supply chain members** could help mitigate risk and build resilient supply chains through planning and supply chain intelligence. Third, **supply chain agility** achieved through visibility across supply chains and through reduction in the velocity with which products moved through the supply chains. Fourth, resilience could be built in supply chains by creating a supply chain risk management culture. Almost during the same time in 2002, a study on supply chain resilience was conducted at Massachusetts Institute of Technology. It was motivated by disruptions caused due to 9/11; and it analysed numerous secondary cases of disruptions followed by interviews with managers spanning across a range of industries involved with disrupted organisations. The authors identified vulnerabilities that organisations were exposed to and presented a framework. They defined resilience as an organisation’s ability to bounce back from disruptions quickly. Through in-depth analysis of case studies, they concluded that resilient organisations could be built through redundancy, flexibility and right culture

(Sheffi and Rice 2005). The authors also asserted that while redundancy in the form of safety stock, multiple suppliers, back up sites, etc., can build resilience in organisations, it also adds costs, while on the other hand flexibility in supply chain elements like supply, conversion process and distribution is a cost-effective manner of increasing resilience. Culture of the organisation was identified as a major element in resilience. There have been many instances in which organisations suffered a setback because front-line employees were not clear on their roles in case of emergency situations. Rice and Caniato 2003 studied past responses of various organisations to supply chain disruptions across wide range of industries, and thereby highlighted the importance of preparedness for dealing with unexpected events of supply chain disruptions. They focused on redundancy and flexibility of primary importance for building a secure and resilient supply network. Ponomarov and Holcomb 2009 conducted literature review to integrate the existing perspectives of resilience from diverse fields. Based on the understanding derived from this extensive review, they highlighted key elements like **logistics capabilities** and **top management support** and proposed a framework of supply chain resilience. Pettit, Croxton and Fiksel 2013 developed a measurement tool called Supply Chain Resilience Assessment and Management. The authors collected data on perceptions of managers in supply chain field through focus group interviews in manufacturing and service industries on different capabilities and vulnerabilities of supply chains. They identified seven vulnerability factors that were composed of 40 specific attributes and 14 capability factors composed of 71 attributes. Some examples of supply chain vulnerabilities identified were turbulence like man-made or natural disasters, threats, external pressures, etc., while capability factors are efficiency, visibility, anticipation, etc. The authors argued that supply chain resilience could be achieved by striking balance between vulnerabilities and capabilities of supply chain. A supply chain with high vulnerabilities would lead to high risk, while the one with high capabilities will lead to erosion to profits. Through mixed method triangulation they identified that there existed 311 linkages between supply chain vulnerabilities and capabilities. Blackhurst, Dunn and Craighead 2011 used systems theory and resource-based view of firm as theoretical foundations for supply resiliency of firm. The authors conducted a multi-industry empirical research based on the qualitative research; a framework of supply resiliency comprising 19 supply chain characteristics linked to resiliency was derived. Johnson, Elliott and Drake 2013 explored the three dimensions of social capital to build supply chain resilience. They conducted qualitative research using interviews and documents to understand how **cognitive, structural** and relational aspects of social capital facilitate **collaboration, visibility, flexibility**, etc., in supply chains, which ultimately increases supply chain resilience. Golgeci and Ponomarov 2015 conducted a survey-based research in multi-industry setting to examine the role of **firm innovativeness** in building supply chain resilience. The authors found that firm innovativeness is positively associated with supply chain resilience. Mensah and Merkurjev 2014 analysed supply chains and risks faced by them and gave strategies and tools like increasing supply chain flexibility, developing corporate culture, etc., to

build supply chain resilience. Ambulkar, Blackhurst and Grawe 2015 conducted a large-scale empirical research to test the antecedents of resilience of firm's supply chain. The authors found that supply chain disruption orientation along with resource configuration and risk management infrastructure are important for building resilience. Scholten and Schilder 2015 explored the role and influence of collaboration in building supply chain resilience through qualitative investigation in food processing industry. The authors found that collaborative activities like **communication, information sharing**, etc., increase visibility and flexibility, which further leads to supply chain resilience. Recently researchers have approached different industries with the agenda of investigating resilience building phenomenon like grocery supply chain, fashion retail and pharmaceutical sector etc. It is implemented through the balance of **buffer-oriented** and **process-oriented strategies** (Zsidisin and Ellram 2003). Buffer-oriented strategies (such as keeping safety stock, sourcing from multiple suppliers) are based on developing surplus or redundant resources (Vanpoucke and Ellis 2020). Even though these strategies limit the supply chain loss due to disruption, they do little to reduce the probability of these disruptions and contribute to the inefficiencies (Vanpoucke and Ellis 2020; Talluri et al. 2013). The process-oriented strategies are based on developing the ability to sense possible disruptions through appraising, monitoring and certifying suppliers (Vanpoucke and Ellis 2020). These strategies are executed based on capabilities such as **flexibility, visibility, collaboration and redundancy** (Ali, Mahfouz and Arisha 2017). Resilient supply chains can anticipate and curtail the negative effects of disruptive events while reducing the time of recovery to normal activity in a meaningful way. Firms that are better able to minimize the duration and severity of disruptions to their supply chains relative to the competitors are more resilient (Christopher and Peck 2004; Scholten, Stevenson and Van Dok 2020) and are able to use it as a strategic weapon to achieve competitive advantage (Scholten, Stevenson and Van Dok 2020). Research shows that besides overcoming disruptions, SC-Resilience can directly influence performance outcomes of the organisation. Christopher and Peck 2004 and Mena, Van Hoek and Christopher 2018 listed out a broader number of categories of supply chain risks, including supply, demand and control risks. In a recent Journal of SCM webinar on 'COVID-19 and supply chain', Ellram (JSCM 2020) builds upon these findings by stating that a lot of the resilience challenges have arisen from a cost obsession and short-term cost focus in supply chain management. She indicates that the move to low-cost country sourcing has led to long pipelines and limited local backup supply. Finally, Ellram claims that the fixation on financial statements has led to extended payment terms and inventory being moved to the balance sheets of suppliers, while lean techniques may have been applied to widely, reducing agility in the supply chain. The globalisation of the supply chain can indeed achieve a cost of goods sold benefit through economies of scale and the location of production in regions with factor cost benefits. Globalisation, however, also lengthens the logistics pipeline, and this introduces the risk of delivery delays and a dependency on remote sources (Harrison, Van Hoek and Skipworth 2014). A reduction of the

number of suppliers can create leverage in negotiating payment terms and prices, but it also increases the dependency on those suppliers for continued supply. Dependency and supply risk is one of the two axes in the most well-known supplier segmentation from Kraljic 1983. In this segmentation, it is advised that for critical bottleneck supplies, companies focus on ensuring supplies rather than on cost savings, and for more strategic supplies, companies should adopt a more collaborative approach. Further, supply chain techniques that are suggested in literature to combat supply chain risks include active information sharing throughout the supply chain. There is an obvious difference between supply chain resilience management and traditional risk management. Risk management focuses on risk minimization while supply chain resilience management pays attention to how to recover from unforeseen interruptions and make a competitive advantage. At the same time, the ultimate goal of the supply chain is still to maximise profits while meeting the reduction of market demand. Therefore, the relationship between cost and benefit should be considered in the process of resilience optimisation. According to the definition of resilience, the supply chain management optimisation strategy can be divided into the following three categories: (1) Supply chain reconstruction, (2) Supply chain coordination, and (3) Supply chain agility. Therefore, improving the quality of the relationship between supply chain members, introducing a **reputation mechanism** and increasing the degree of **information sharing** can increase the speed of response, contributing to improving the health of the supply chain. Enterprises or organisations can take measures based on the supply chain resilience management optimisation strategy to achieve pre-prevention and post-remediation and improve the flexibility of the supply chain while ensuring the basic effectiveness of the supply chain.

5.2 Supply chain resilience conceptual clarity: linking the constructs in a concept mapping framework

Resilience is an ability that is cultivated and maintained (Seville, Opstal and Vargo 2015) by understanding the relationships that exist. Without understanding their interactions the premises of SC-Res cannot be achieved within the supply only by focusing on the individual concepts (Ponomarov and Holcomb 2009; Bhamra, Dani and Burnard 2011). Furthermore, these complex relationships and dynamic interactions among SC-Res constructs should be linked to improve conceptual clarity. Reviewed literature has identified five core SC-Res capabilities (1. Abilities to anticipate; 2. Abilities to adapt; 3. Abilities to respond; 4. Abilities to recover; and 5. Abilities to learn) to build a resilient supply chain. For managers, the advantages of these five capabilities are: First, the five SC-Res capabilities encompass the full range of supply chain risk management (SCRM) strategies (proactive, concurrent and reactive) and thus provide a mechanism to cope with risks and changes from varied sources. Second, supply chain disruptive events have increased over the years, and SC-Res is considered as a fundamental way of coping with such disturbances (Christopher and Peck 2004;

Sheffi and Rice 2005). The concept mapping framework links SC-Res phases and strategies, and the required capabilities, elements and practices needed to maintain a competitive advantage. Third, by refining these five capabilities, managers are in a position to assess their resilience weaknesses and strength, and the effectiveness of the elements and practices that support these capabilities. Thus, managers can use these capabilities as an evaluative tool to assess their overall resilience and thereby improve and manage their SC-Res. There are three constructs used to define SC-Res: **phases, strategies and capabilities**. Utility of SC-Res in the SCM domain still lacks clarity. Tighter construct definitions are needed to enhance the usefulness of the concept. The elements and practices identified to support SC-Res capabilities can be used to understand their application and value in different industry perspectives. Despite the blossoming literature on the topic, there is a need to apply well-established theoretical lenses to ground the usefulness of the concept in the SCM domain – in particular, theories that consider the dynamic and non-linear relationships of supply chain functions. Indeed, studies have suggested theories that can address the complexities of the SC-Res phenomenon – for example, complex adaptive systems (Day 2014; Tukamuhabwa et al. 2015), contingency theory (Brandon-Jones et al. 2014), social capital (Johnson et al. 2013) and strategic choice (Pereira et al. 2014). Also, the applicability of theories such as high-reliability organisations (La Porte 1996) and normal accident theory (Perrow 1999) that address organisational safety is also considered to test their usefulness in SC-Res studies. Although many research has attempted to measure SC-Res capabilities (Azevedo et al. 2013; Pettit et al. 2013), only few studies have focused on the multi-dimensional nature of SC-Res (Vugrin et al. 2011). The interactions of the constructs are crucial; any proposed metrics should take a holistic view of SC-Res by extending its application in practice beyond the boundaries of a single firm (Ambulkar et al., 2015). Such measures pose challenges for organisations with complex global supply chains; nevertheless, identifying suitable indicators and metrics of SC-Res capabilities would represent a significant advance in research and practice. Finally, the idea of “bouncing back” from adversity while sustaining operations and thriving in the process is promising; however, building SC-Res capabilities is not cheap. Trade-off decisions between SC-Res investment and cost need to be further investigated (Jüttner and Maklan 2011; Pereira et al. 2014). These decisions can involve the question of when to invest in spare capacities to reduce vulnerabilities, and where to minimise such investments to cultivate adaptive capabilities. A balance between capability and vulnerability is desirable to achieve balanced resilience (Pettit et al. 2013).

6. Conclusion

Because of the COVID-19, supply chains are facing their most tough times which has never been seen before. Now, the question of how best to increase supply-chain resilience is now front and centre. Supply chains today are complex and global. Also,

the relationships are actually a network where many-to-many relationships exist in a network between many customers and many suppliers. For these reasons, Supply chain risks are increasing in number and frequency, affecting the normal operation and stability of the supply chain and hence the ability of supply chains to fulfil commitments. Therefore, supply chains must be resilient to risks overcoming their vulnerabilities and to react effectively to its negative effects. Supply chain practices were developed during a period of higher stability and less environmental volatility. The practices like lean, JIT, etc. – while increasing profitability and performance – have also rendered supply chains vulnerable and fragile. This had led to increase in supply chain disruptions more than ever. Since supply chain disruptions by their very nature are such that the disruption may happen at one point in supply chain, its impact is borne by other supply chain members as well. The concept of SC-Res offers a way for supply chains to harness capabilities that enable them to bounce back and/or move forward from adversity to achieve business continuity. Likewise, building SC-Res is seen as an essential strategic capability to improve a firm's competitiveness by turning disruptive events, and changes in the market and the environment into opportunities. In such a scenario, this paper has endeavoured to explore and analyse the concept of resilience in supply chain from various angles. Organisations must first build individual resilience within their organisations before making collaborative efforts and investments with supply chain partners. Collaborative culture and design resilience into operations were found to have strong causal effect or led to other factors of collaborative resilience. Alignment of resilience goals between two organisations and adapting together after a disruption were other two factors, which were found to be very prominent. Managers should focus on the causal factors for starting with the process, and then move on to the prominent factors since they lead to effective implementation and long-term or continuous success. Thus, managers must take measures in order to mitigate the potentially negative effects of risks, whether on the directly affected company, or on other supply chain companies that may be affected, due to the relationship of dependency between supply chain companies. So, the strategies adopted should mitigate the negative impact of determined risks, the ones that have high negative impact and likelihood. Not returning to business as usual after COVID-19 is not only an opportunity to avoid needing to relearn risk management lessons again in the future but also an opportunity for supply chain managers to move beyond risk mitigation into creating a more sustainably de-risked and resilience supply chain. This can advance the contribution of supply chain managers in the company and perhaps society, from problem solvers that get the supply chain back up and running to preventing supply chain disruptions for the good of business and society. However, when examining the literature this paper found many inconsistencies surrounding the various aspects of the idea, suggesting that further theoretical explanations on the topic are warranted. This paper synthesised the results of analysing open sources academic articles to search for the constructs used to define SC-Res. One of the significant findings to emerge from the reviewed definitions is the common terms and themes implied to describe these

capabilities, despite the diversity of definitions. The five core SC-Res capabilities identified are the ability to anticipate, adapt, respond, recover and learn. The reviewed literature further revealed 27 essential elements needed to support SC-Res capabilities. Ali, Mahfouz and Arisha 2016 has reduced them to 13 essential elements and related practices which were identified to support the five SC-RES capabilities, and those were connected back to the resilience strategies and phases to present an integrated approach to the concept in managerial practices. In an attempt to consolidate and link the features of SC-Res to improve clarity, Ali, Mahfouz and Arisha 2016 provides a holistic model of SC-Res through a concept mapping approach. The concept mapping classifies the different features of SC-Res and establishes the complex relationships and dynamic interactions between them. To handle supply chain disruptions, the approach needs to shift from “silo” to “inclusive”. Agarwal and Srivastava 2019 has advanced the focus of resilience research from individual organisation to collaborative level where collaborative resilience can be understood through its eight critical success factors. There needs to be a shift in the approach towards building resilience at a fundamental level. Managers need to include other supply chain members into decision making and resilience building process – they need to build collaborative resilience in supply chains. The concept of collaborative resilience is related to and grounded into pre-existing supply chain practices and concepts.

International trade is underpinned by the concept of comparative advantage, which holds that a country should produce what it is relatively good at and import those items that are relatively more expensive for it to produce. Supply-chain resiliency, however, will necessarily mean making some economically inefficient decisions, as countries will want to strengthen their national security by producing items for which they do not enjoy a comparative advantage.

All the fall-out effects of any pandemic cannot be bad only – they offer enormous opportunities too. Last 30 years Supply chains were obsessed with lean, JIT and other cost-saving, interdependent, and tech-savvy approaches. The COVID-19 crisis has revealed that interconnectedness brings benefits as well as risks to us all. To address some of these risks, supply chains will need to be rethought, with more emphasis put on resilience. The challenge will be to find resilience models that strike a necessary balance ensuring that industries continue their growths without taking resorts of expensive alternatives.

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