Int. J. Production Economics 171 (2016) 116–133

Contents lists available at ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

A review of the literature on the principles of enterprise and supply chain resilience: Major findings and directions for future research

Masoud Kamalahmadi [1], Mahour Mellat Parast *,[2]

North Carolina A&T State University, 1601 E Market Street, Greensboro, NC 27411, USA

ARTICLE INFO

Article history:
Received 21 March 2015
Accepted 26 October 2015
Available online 3 November 2015

Keywords:
Supply chain resilience
Supply chain risk management
Literature review

ABSTRACT

The purpose of this paper is to investigate the research development in supply chain resilience. We undertake a literature survey to review the literature on enterprise and supply chain resilience. We aim to provide a platform for researchers and practitioners trying to identify the existing state of the work, gaps in current research, and future directions on the topic. For this purpose, we employed two methods to collect publications in supply chain resilience. First, we selected keywords and searched the relevant databases and journals. Next, we tracked the references of those papers collected in the first method to look for other publications published in conference proceedings and book chapters. As a result, a sample of 100 papers was collected, studied, and analyzed. We summarize our findings in several areas including enterprise and supply chain resilience definitions, supply chain resilience principles, and supply chain resilience strategies. Based on the assessment, we develop a framework for the principles of supply chain resilience that can be used as a basis for understanding supply chain resilience.

1. Introduction

The past few decades have been notable for major changes in supply chains due to an increasing level of globalization and a higher rate of innovation. The growing role of global supply chains was associated with increased interconnectedness among suppliers and manufacturers, which led to higher dependency among firms in the supply chains and a higher level of supply chain complexity (Blackhurst et al., 2005, Wagner and Bode, 2006; Stecke and Kumar, 2009; Christopher et al., 2011). This, in turn, resulted in supply chains that are efficient during stable business environments, but are highly vulnerable to risks and disruptions.

Supply chains have faced challenges such as high demand variability, short life of products, and different expectations and requirements of customers; adapting to these challenges increased supply chain complexity and resulted in more instability and unpredictability (Stefanovic et al., 2009; Ghadge et al., 2012; Roberta Pereira et al., 2014). As a result of the negative consequences of supply chain disruptions, the academic and practitioner community emphasized the need to address the design of supply chains that are efficient while resilient to disruptions.

Supply chain risk management (SCRM) is "the identification of potential sources of risk and implementation of appropriate strategies through a coordinated approach among supply chain risk members, to reduce supply chain vulnerability" (Jüttner et al., 2003, p. 201). SCRM is concerned with the assessment of sources of risk across the supply chain and the development of strategies to deal with them. A recent MIT Scale Network study found that approximately 60% of managers either did not actively work on SCRM or did not believe their company's risk management practices were effective (Sáenz and Revilla, 2014). According to Fiksel et al. (2015), the main reason for the ineffectiveness of these practices is that traditional risk management relies mainly on risk identification and statistical information, while many risks are unpredictable and unknowable, and statistical information may not exist.

To address this issue, the idea of supply chain resiliency has received more attention in recent years. Fiksel et al. (2015) argued that resilience is an important capability that complements the traditional risk management processes in many companies. Melnyk et al. (2014) stated that resilience is the heart of current supply chain management thinking. Although the concept has been defined by many researchers, there is no comprehensive definition that provides a clear understanding of resilient supply chains. For some, resilience is reactive capabilities for use after a disruption; others perceive resilience as a more proactive effort toward being prepared for disruptions. Melnyk et al. (2014) mentioned that, in view of these divergences, the confusion surrounding the concept is not surprising. For now, we rely on the definition by Ponomarov

* Corresponding author.
E-mail addresses: Mkamalah@aggies.ncat.edu (M. Kamalahmadi), mahour@ncat.edu (M.M. Parast).
[1] Tel.: +1 336 334 7585.
[2] Tel.: +1 336 285 3111.

http://dx.doi.org/10.1016/j.ijpe.2015.10.023
0925-5273/

and Holcomb (2009), a definition that is commonly cited in the supply chain resilience literature: supply chain resilience is "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" (Ponomarov and Holcomb, 2009, p. 131).

In this study, we aim to address two key questions in supply chain resilience: (1) What is the current state of research in supply chain resilience, and (2) What are the gaps in current research that future research should address? We address these research questions by reviewing the articles published in major academic and practitioner journals from 2000 to 2015. We recognize the year 2003 as a turning point on research in supply chain risk management. This view is based on the result of literature review studies on SCRM by Tang and Musa (2010) and Ghadge et al. (2012). Their findings indicated a sudden increase in the number of articles published in SCRM in 2004. We assume that those articles published in 2004 had been started in 2002 and 2003 after the September 11, 2001 attacks, which disrupted many supply chains around the globe.

The remainder of this paper is organized as follows. In Section 2, we provide a literature review of the existing studies of supply chain resilience. In Section 3, we present our research process. In Section 4, we first present several statistics about the characteristics of each research study. Then we provide an overview of the research in supply chain resilience definition, principles, practices, strategies, and measurement. In Section 5, we discuss major findings of this study and outline future directions.

2. Literature review

Three studies have conducted literature reviews on the topic of resilience. In the first study, Bhamra et al. (2011) provided a review of resilience literature in its widest context and later its application within the organization. Using keywords such as "Resilience" and "Resilient SMEs" (small and medium-sized enterprises) on databases and Google Scholar, they collected and analyzed 74 papers, in which 21 papers were on organizational resilience and only 9 papers were on supply chain resilience. They focused on the perspectives, concepts, and methodologies in the resilience literature. Their findings indicate that theory building has been the main focus of researchers within the area of resilience, and empirical studies are lacking. They suggested more focus on empirical methods such as case study and survey, which can significantly add to and validate theoretical constructs.

Ponis and Koronis (2012) reviewed 134 peer-reviewed journal articles. They investigated the concept of resilience in different areas and proposed organizational and supply chain resilience. They identified the antecedents of SC resilience as agility, flexibility, velocity, visibility, availability, redundancy, mobilization of recourses, collaboration, and SC structure knowledge. Finally, Roberta Pereira et al. (2014) employed a systematic literature review approach to find the role of procurement in achieving supply chain resilience. Their research question was concerned with identifying the intra- and inter-organizational issues that must be addressed by procurement in order to create supply chain resilience. They studied 133 papers and limited their focus to 30 of those papers. They found enablers and barriers of supply chain resilience and interconnections between these factors, and investigated their implications in procurement activities. They presented two frameworks: intra- and inter-organizational issues from a procurement perspective to create supply chain resilience; and achieving supply chain resilience through intra- and inter-organizational issues.

Our study differs from previous work in several ways: first, instead of conducting the review on the concept of resilience in other disciplines, we have focused only on organizational and supply chain resilience practices using a comprehensive literature review. Second, our review is exhaustive and covers both practitioners' and academic journals, book reviews, conference proceedings, and other related reviews and reports. Our study covers all publications from 2000 to 2014, collecting publications in two phases: using databases and journals to find articles in the first phase, and then tracking the references of those articles in the second phase. Finally, while previous studies on supply chain risk have primarily focused on large organizations, this study is the first to review the research on risk and resilience practices for small and medium size enterprises (SME) as well as supply chain resilience operationalization and measurement.

3. Research process

In this study, we conducted a literature survey to review the existing literature on supply chain resilience. A literature survey aims at understanding important issues and challenges in a given field, including the current status and theory development of the area (Tang and Musa, 2010). The approach used to collect the relevant publications was comprised of two stages: first, we searched databases and journals by using specific key words; next, we tracked references of the publications obtained in the first stage, to find the literature that we were not able to identify by using databases and journals. In preparing the sample for this study, we only considered the publications after year 2000. We further showed that using year 2000 as the starting point is justified, since the concept of resilience (especially supply chain resilience) was not discussed much before 2000. Fig. 1 presents the outline of the research process used in this study.

Phase 1: Search Databases and Journals. We believe that the quality of a literature review study is driven by the data sources that are used. In order to identify high quality research papers, in line with Ghadge et al. (2012), we decided to use the widely accepted quality rating published by the Association of Business Schools (ABS), UK, as Academic Journal Guide (AJG) 2015 for journals in three different domains of management: Operations Management (OM), Operations Research and Management Science (OR/MS), and General Management (GM) (The ABS Journal Guide, 2015). To identify and collect the published research in supply chain resilience, we used a number of major databases such as *Business Source Complete*, *Engineering Research Database*, *Taylor and Francis Online*, *Google Scholar*, *Emerald*

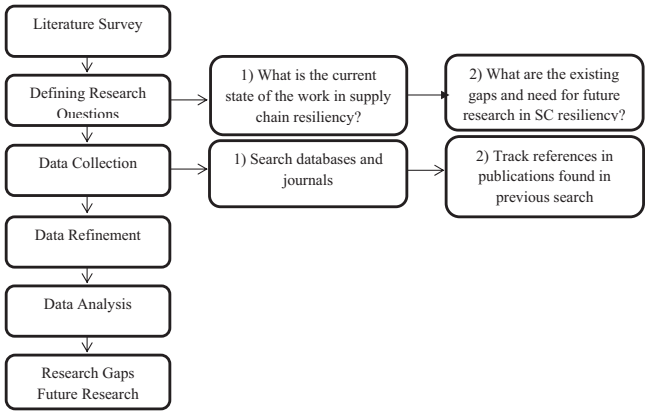

Fig. 1. Research process.

Table 1
Journal classifications based on abs ranking.

Subject field/area	List of journals	AJG ranking[a]
Operations Management (OM)	Journal of Operation Management	4
	Production and Operation Management	4
	International Journal of Production Economics	3
	Supply Chain Management: An International Journal	3
	International Journal of Production Research	3
	Journal of Supply Chain Management	3
	Computer and Industrial Engineering	2
	International Journal of Physical Distribution and Logistics Management	2
	Journal of Business Logistics	2
	International Journal of Logistics: Research and Applications	1
	International Journal of Logistics Management	1
Operations Research and Management Science (OR/MS)	European Journal of Operation Research	4
	Decision Science	3
	Omega: The International Journal of Management Science	3
General Management (GM)	Harvard Business Review	3
	MIT Sloan Management Review	3
	Supply Chain Management Review	3

[a] AJG 2015 ranking in scale of 4.

Insight, and *Science Direct*, along with top journals in OM, OR/MS, and GM. The search keywords were based on the terminologies used in supply chain risk management, such as "supply chain resilience", "resilient supply chain", "enterprise resilience", "organization resilience", and "resiliency in supply chain". Table 1 presents the target journals where the research papers were obtained, with each journal's AJG 2015 ranking in a scale of 4.

Phase 2: Track References of Publications Obtained in Phase 1. The first approach was to search for the articles within a limited number of journals with high score in the three areas of management mentioned based on ABS rankings (Table 1). In order to ensure all related articles are included in the search, we conducted the second stage search to find relevant studies that have been published as conference proceeding or book chapters. In each research paper we studied, we tracked the references in order to further identify relevant studies being cited by the authors. This helped determine whether there were important studies that had not been identified in our literature review.

The preliminary search using two search methods resulted in almost 100 studies. We further refined this sample by setting exclusion criteria for the papers published in areas that were not related to organizational and supply chain resilience (e.g., material resilience). This procedure resulted in 100 quality research publications that are the basis of the literature review presented in this study.

4. Results

4.1. Characteristics of publications

In this section, we present an overview of the body of literature on supply chain resilience. Fig. 2 represents the year-wise distribution of the publications. The data indicates that the concept of resilience emerged in supply chain literature around 2003. This finding is in line with the literature review of SCRM by Tang and Musa (2010) and Ghadge et al. (2012). They regarded challenges and opportunities of outsourcing to low cost countries as the most important factor that motivated research and publication in SCRM in 2003 and 2004.

The figure shows small variations in the number of publications until 2011, when there is a dramatic increase in the number of

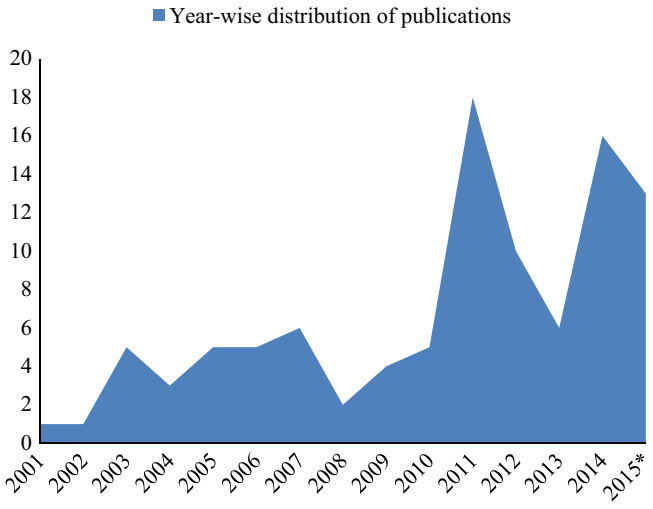

Fig. 2. Year-wise distribution of publications (* up to August 2015).

publications on supply chain resilience. This year (2011) is the turning point for the number of publication in SC resilience, followed by 2014. Since this study has been conducted in the middle of 2015, we expect that the number of publications in the full year 2015 would surpass that of 2011 and 2014. This increase in the number of publications indicates that academic researchers and practitioners are becoming more aware of the importance of resiliency in supply chains.

Fig. 3 represents the journal-wise distribution of the 62 publications that were obtained in the first phase of publication collection. From the 17 identified data sources, the first three journals are from the General Management (GM) category, the next 11 journals are from the Operations Management (OM) category, and the last three journals are from the Operations Research and Management Science (OR/MS) category,. In line with Ghadge et al. (2012), it is clear that, similar to SCRM, supply chain resilience context has been represented mostly within the Operations Management domain. Among the various journal sources, IJPR and SCM-IJ have the most publications. In the second phase of publication collection, a number of journal papers outside the domain of OM, OR/MS, and GM along with conference proceedings and book chapters were added to the 62 Phase 1 publications shown in Fig. 3.

Table 2 has summary statistics on the bibliography we collected. A review of Table 2 and Fig. 3 indicates that among the three areas of management, OM researchers have the most contributions to SC resilience. There are a limited number of studies on supply chain resilience from the OR/MS field. Only 6 articles on SC resilience were found in the OR/MS field, indicating that OR/MS researchers need to address SC resilience using analytical models (optimizations, simulations, etc.). The column which is titled "Others" refers to articles published by researchers outside the domain of the OM, OR/MS, and GM areas, along with conference proceedings and book chapters. This category (Others) plays an important role in the SCRM context, with a great volume of publications on SC resilience.

Several classifications are used in Table 2 to distinguish the characteristics of publications. First, we have looked at author affiliations. Almost 90% of the publications are studies by authors with affiliations from European countries and the US, and the remaining publications are by authors with affiliations from Asia and Australia. In line with Ghadge et al. (2012), this is believed to be driven by the fact that firms in the US and Europe have been more active in supply-chain-related activities such as outsourcing. Therefore, their supply chains are more exposed to risks and vulnerability, and SCRM and SC resilience have received more attention. Dividing the time period of the publications into two halves showed a distinctive progress of SC resilience research. Publications on SC Resilience in the second decade have almost doubled, as shown in Table 2. This shows the increased awareness of the importance of resilience in today's turbulent and dynamic business environment. In terms of research methodology, theory building and conceptual studies are used the most to examine SC resilience. The number of empirical and quantitative works is also increasing in recent years.

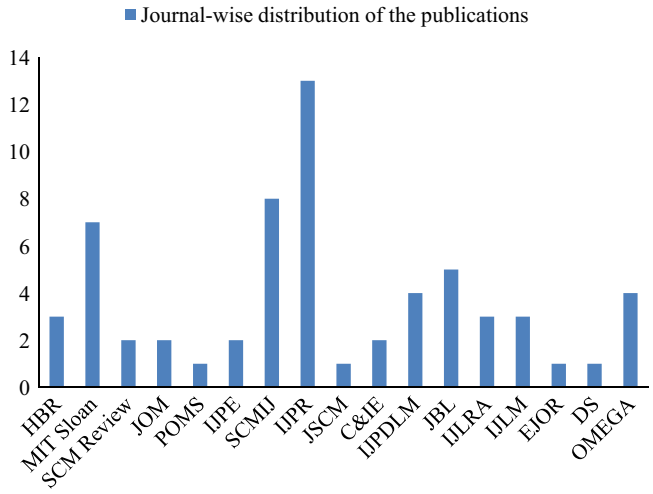

Fig. 3. Journal-wise distribution of 62 phase 1 publications.

Next, we divided the literature of SC Resilience based on the following themes: (1) definition, (2) principles, and (3) measurements. Bhamra et al. (2011) conducted a literature review on resiliency, where the majority of the literature was concerned with SC resilience definition. However, the finding of our study shows the trend has been shifted from resilience definition to resilience principles and understanding its antecedents. Although the number of studies on how organizations and supply chains can be more resilient is increasing, there is a limited number of studies on how resiliency can be actually measured. We also made a distinction between enterprise resilience and SC resilience; we found that the majority of publications (73%) are in SC resilience. With reference to enterprise resilience, about 7% of the studies examine resilience in the context of Small and Medium-Sized Enterprises (SMEs).

4.2. A review of resilience in supply chains

Resilience is a multidimensional and multidisciplinary concept with roots in psychology and ecosystems before being adapted to the supply chain management field (Datta et al., 2007; Ponomarov and Holcomb, 2009; Burnard and Bhamra, 2011; Bhamra et al., 2011; Ponis and Koronis, 2012; Pettit et al., 2013). In order to define supply chain resilience, many researchers have investigated resilience definitions in other disciplines based on the order in which the resilience concept emerged in that field. Ponomarov (2012) studied the concept of resilience from ecological, social, physiological, economic, emergency management, sustainable development, organizational, and SCRM perspectives. Bhamra et al. (2011) presented different definitions of resilience in various fields such as physical systems, ecological systems, socio-ecological systems, psychology, disaster management, individual,

Table 2
Summary statistics of publications on enterprise/supply chain resilience.

	All sources	OM related outlets	OR/MS related outlets	GM related outlets	Others
Number of publications	100	44	6	12	38
	%	%	%	%	%
Author's affiliation					
USA (and Canada)	43	20	2	12	9
Europe (including UK)	47	18	2	0	27
Asia (and Australia)	10	6	2	0	2
Publication time					
2000–2009	32	9	1	5	17
2010–August 2015	68	35	5	7	21
Research methodology					
Conceptual approaches	39	7	0	9	23
Empirical approaches	27	24	0	2	1
Quantitative approaches	24	8	5	0	11
Literature review approach	3	2	0	0	1
Mixed approaches	7	3	1	1	2
Resilience perspective					
Resilience definition	24	7	0	9	8
Resilience principles	68	32	6	3	27
Resilience measurement	8	5	0	0	3
Enterprise/Supply chain					
Enterprise Resilience	27	11	0	5	11
Supply Chain Resilience	73	33	6	7	27

Table 3
Definitions of Enterprise Resilience.

Authors/year	Enterprise Resilience definition
Horne (1997)	*"The ability of a system to withstand the stresses of environmental loading based on the combination/composition of the subsystems, their structural inter-linkages, and the way environmental change is transmitted and spread throughout the entire system"*
Wildavsky (1988)	*"The dynamic capacity of organizational adaptability that grows and develops over time"*
Horne and Orr (1998)	*"A fundamental quality of individuals, groups, organizations, and systems as a whole to respond proactively to significant change that disrupts the expected pattern of events without engaging in an extended period of regressive behavior"*
Mallak (1998)	*"Resilience is the ability of an individual or organization to expeditiously design and implement positive adaptive behaviors matched to the immediate situation, while enduring minimal stress"*
Coutu (2002)	*"The ability of an organization to face reality with staunchness, make meaning of hardship and improvise solutions from thin air"*
Starr et al. (2003)	*"The ability and capacity to withstand systemic discontinuities and adapt to new risk environments"*
Fiksel (2003)	*"The capacity of a system to tolerate disturbances while retaining its structure and function"*
Hamel and Välikangas (2003)	*"Resilience refers to the capacity for continuous reconstruction. It requires innovation with respect to those organizational values, processes, and behaviors that systemically favor perpetuation over innovation"*
Sutcliffe and Vogus (2003), Vogus and Sutcliffe (2007)	*"The maintenance of positive adjustment under challenging conditions such that the organization emerges from those conditions strengthened and more resourceful"*
Sheffi and Rice (2004)	*"It is a firm's ability to absorb disruptions or enables the supply chain network to return to state conditions faster and thus has a positive impact on firm performance"*
Reinmoeller and Van Baardwijk (2005)	*"The capability to self-renew over time through innovation"*
McDonald (2006)	*"Resilience conveys the properties of being able to adapt to the requirements of the environment and being able to manage the environments variability"*
Woods (2006)	*"The capacity to anticipate unsafe and unexpected events for organizational survival in the face of threats, including the prevention or mitigation of failures in the systems"*
Madni and Jackson (2009)	*"A resilient system encompassed the actions including avoiding, adsorbing, adapting to, and recovering from disruptions"*
Burnard and Bhamra (2011)	*"The emergent property of organizational systems that relates to the inherent and adaptive qualities and capabilities that enable an organization's adaptive capacity during turbulent periods. The mechanisms of organizational resilience thereby strive to improve an organization's situational awareness, reduce organizational vulnerabilities to systemic risk environments and restore efficacy following the events of a disruption"*
Lengnick-Hall et al. (2011)	*"The firm ability to effectively absorb, develop situation specific responses to, and ultimately engage in transformative activities to capitalize on disruptive surprises that potentially threaten organizational survival"*
Ates and Bititci (2011)	*"It is a firm's ability to absorb disruptions or enables the supply chain network to return to state conditions faster and thus has a positive impact on firm performance"*
Alberts (2011)	*"Resilience provides an entity with the ability to repair, replace, patch, or otherwise reconstitute lost capability or performance (and hence effectiveness), at least in part and over time, from misfortune, damage or a destabilizing perturbation in the environment"*
Pettit et al. (2013)	*"The capacity for an enterprise to survive, adapts, and grows in the face of change and uncertainty"*
Winston (2014)	*"An ability not just to recover from hits but to avoid problems altogether"*
Gilly et al. (2014)	"First, a reactive capacity of the company to resist an external event; second, a more active capacity to anticipate events and thus open new development pathways."

engineering, organization, and supply chains. Ponis and Koronis (2012) examined resilience in ecology, psychology, organization, and supply chains. Finally, Pettit et al. (2013) referred to ecology, psychology, sociology, risk management, and network theory to define resilience in supply chains. There are also referrals to material science and engineering in previous studies (Sheffi, 2005; Pettit et al., 2010; Cruz Machado and Durate, 2010; Soni and Jain, 2011; Murinho, 2011; Ponis and Koronis, 2012). Since substantial efforts have been made in previous studies to review the concept of resilience in other fields, we do not restate its definition in other streams of literature. Rather, we focus our attention on supply chain resilience. In order to discuss supply chain resilience, it is better to first evaluate resiliency from an organizational (enterprise) perspective, and then extend it to the supply chain. Thus, we will examine the existing definition for supply chain resilience in the literature, and then extend this definition to the supply chain level.

4.2.1. Enterprise resilience

In conjunction with the tables proposed for Enterprise Resilience definitions by Bhamra et al. (2011) and Ponis and Koronis (2012), Table 3 represents an exhaustive source of enterprise resilience definitions examined in the literature. Although we are primarily interested in the period from 2000 to 2015, we have also reviewed definitions prior to 2000, because they served as the basis for enterprise and supply chain resilience.

A review of the above definitions suggests some common themes. First, resilience is a dynamic capability of an enterprise that emphasizes the ability of the enterprise to embrace and respond to change. Second, resilience is highly dependent on the individuals, groups, and subsystems that constitute a system. Therefore, a resilient enterprise first needs resilient individuals, groups, and subsystems. According to Dean Becker, the president and CEO of Adaptive Learning Systems, "More than education, more than experience, more than training, a person's level of resilience will determine who succeeds and who fails" (Coutu, 2002). Unless resilience is instilled into the subsystems of an enterprise, one could not expect to have a resilient enterprise. Thus, one can argue that resilience is embedded within the culture of an organization. Third, to have a resilient organization, the managers should have a complete understanding of the environment and its patterns of change. Fourth, in the face of unexpected changes in the environment, the firm should have the ability to survive, adapt, and respond to changes. This requires the development of certain organizational capabilities. Since disruptions are inevitable, firms need to develop capabilities to mitigate the effects of disruptions (Pettit et al., 2013). Firms must fully understand the new environment, and adapt to changes to ensure the continuity of their businesses (Starr et al., 2003; McDonald, 2006; Madni and Jackson, 2009). After the firm undergoes the survival and adaptation stage, it should be able to respond to the disruption (Coutu, 2002; Lengnick-Hall et al., 2011). The response not only should reposition the firm to its previous status, it should also have the capability to strengthen the firm's position in responding to future disruptions. Finally, responses should be based on flexibility and innovation (Hamel and Välikangas, 2003; Reinmoeller

and Van Baardwijk, 2005; Lengnick-Hall et al., 2011). As the organization faces a disruption, the ability of the firm to maintain its market position is contingent upon development of flexible solutions, and the ability to create new solutions over time, based on the changes on the environment. In addition, since disruptions are unexpected events, disruption mitigation requires a high level of capability to create, design, and implement innovative solutions in a short period of time. Thus, inherent in the concept of innovation is agility, which reflects the capability of the firm to actually implement an innovative solution.

We should realize that the development of a resilient supply chain requires development of certain organizational processes, resources, and capabilities to ensure resilience at the firm level. For example, an innovative firm needs innovative individuals and subsystems. Development of innovative solutions during disruption requires the flexibility to develop alternatives in the face of changes in the environment (Hamel and Valikangas, 2003; Demmer et al., 2011; Christopher and Holweg, 2011; Golgeci and Ponomarov, 2013). Thus, based on the above discussion, we define Firm/Enterprise Resilience as *"the dynamic capability of an enterprise, which is highly dependent on its individuals, groups, and subsystems, to face immediate and unexpected changes in the environment with proactive attitude and thought, and adapt and respond to these changes by developing flexible and innovative solutions"*. Our definition covers all of a resilient enterprise's important characteristics identified in the literature: (1) dynamicity; (2) dependency on individuals; (3) having knowledge of the environment; (4) survival, adaptation, and responsive capabilities; and (5) flexibility and innovativeness.

4.2.2. Supply chain resilience

Since the purpose of this study is to carry out a literature review on supply chain resilience, through the process of studying the state of the art on the topic, we tried to scrutinize all of the available definitions of supply chain resilience. Table 4 is a comprehensive and thorough list of supply chain resilience definitions proposed in the literature.

A review of the definitions shows that they all consider SC resilience as the capability of supply chains to respond to disturbances and disruptions. A disturbance is defined as "a foreseeable or unforeseeable event, which directly affects the usual operation and stability of an organization or an SC" (Barroso et al., 2011). The definitions proposed by Falasca et al. (2008), Ponomarov and Holcomb (2009), and Ponis and Koronis (2012) are more comprehensive.

Falasca et al. (2008) included the probability of disruptions or disturbances, the consequences of disturbances, and response and recovery time in his definition. Ponomarov and Holcomb (2009) considered important elements such as adaptive capability, unexpected events, response and recovery ability, and control over the structure. Ponis and Koronis (2012) discussed proactively planning and designing, anticipating unexpected events, responding adaptively, maintaining control over structure, and transcending to a post-event robust state of operation. Melnyk et al. (2014) stated that resilience consists of two critical and complementary components: (1) resistance capacity, the ability of a system to minimize the impact of a disruption by evading it entirely (avoidance) or by minimizing the time between disruption onset and the start of recovery from that disruption (containment); and (2) recovery capacity, the ability of a system to find a return path (recovery) to a steady state of functionality (stabilization) once a disruption has occurred. They also differentiated between risk and uncertainty: risk considers predictable situations that can adversely affect supply chains; uncertainty considers unpredictable events. Investment in resistance against risk and investment in recovery against uncertainty was recommended.

Based on the above discussion, we define supply chain resilience as *"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"*. Several terms such as adaptability, flexibility, and agility are implicit in this definition and will be discussed later. The above definition considers three phases for supply chain resilience, which are shown in Fig. 4. These stages are described here:

1) Anticipation: supply chain and operation managers should anticipate the occurrence of disruptions and prepare their supply chains for any expected and unexpected changes in the environment. The impacts of the disturbances should be completely understood, and probability of their occurrences must be

Table 4
Definitions of Supply Chain Resilience (SCRES).

Authors/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 disruptions, 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"*
Jüttner 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., (2012b)	*"Resilience is referred to as 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"*
Brandon-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"*
Roberta 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"*
Kim et al. (2015)	*"We define supply network resilience as a network-level attribute to withstand disruptions that may be triggered at the node or arc level."*

Fig. 4. Three phases of supply chain resilience.

minimized. Contingency plans should be prepared for emergencies.

2) Resistance: As soon as a foreseen or unforeseen disturbance is detected in a supply chain, the ability of the chain to resist and deactivate the perturbation before it expands would play a vital role in ensuring the continuity of the operations. A well-prepared supply chain entraps interruptions in this phase.
3) Recovery and responses: If the disturbances potentially have the ability to disrupt the supply chain, immediate and effective responses based on the available resources are needed to minimize the negative impacts of disruptions on the chain. Well-prepared responses should not only have the ability to reposition the firm to its pre-disruption status, but also to transcend the disturbance and restore the firm's positions to a higher level that can lead to competitive advantages. We need to mention that as we talk about the pace of responses, we enter the realm of one of the most important aspects of resiliency: agility. More information about agility can be found in the next sections.

In the next sections, we discuss how operationalization of these dimensions of supply chain resilience can be implemented to enhance the competitiveness of the supply chain.

4.3. Supply chain resilience principles

Many researchers have tried to define principles of supply chain resilience. Although sometimes these elements have been used interchangeably by different authors, we try to distinguish them and identify ultimate supply chain resilience principles. For this purpose, we review principles of supply chain resilience introduced by Christopher and Peck (2004), a source frequently cited that serves as a basis for understanding supply chain resilience (Briano et al., 2010; Christopher et al., 2011; Mandal, 2012).

Christopher and Peck (2004) defined four principles for supply chain resilience: (1) supply chain reengineering, (2) collaboration, (3) agility, and (4) SCRM culture. Later, Christopher et al. (2011) adapted the model of Christopher and Peck (2004) for resilient supply chains to develop strategies for mitigating global sourcing risks. Mandal (2012) examined principles of supply chain resilience introduced by Christopher and Peck (2004) on a sample of IT professionals in India. His findings indicate that supply chain managers must take reengineering, collaboration, agility, and SCRM culture into account when designing supply chains. Wilding (2013) introduced the four principles proposed by Christopher and Peck (2004) as four pillars for supply chain resilience. Finally, Scholten et al. (2014) considered the four principles along with knowledge management as five capabilities for developing SC resilience.

The supply chain resilience principles introduced by Christopher and Peck (2004) are shown in Fig. 5. The arrows represent the relationships among the key variables in the model. In the following sections, we will review the literature to support the inclusion of the variables and their relationships, and how the model evolved over time.

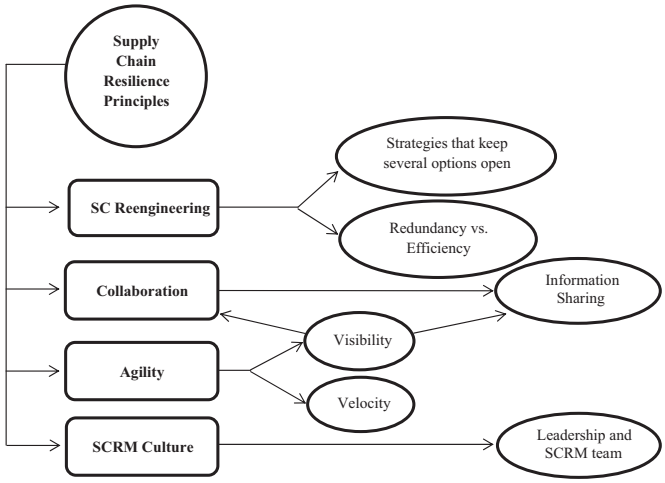

Fig. 5. Supply chain resilience principles (Christopher and Peck, 2004).

4.3.1. Supply chain reengineering

Supply chains are mainly designed to achieve the two objectives of cost optimization and customer satisfaction. Given the risks inherent in supply chains, the need to incorporate SCRM into the design of supply chains has become more significant (Wilding, 2013). Therefore, traditional supply chains need to be redesigned to integrate resiliency into their design. Ponomarov and Holcomb (2009) and Scholten et al. (2014) emphasized reengineering of supply chains and the need to incorporate build in resilience. Christopher and Peck (2004) underlined the importance of the following factors for reengineering of supply chains: (1) supply chain understanding, (2) supply base strategy (risk awareness of suppliers), and (3) design principles for supply chain resilience based on strategies assessment of the trade-off between redundancy and efficiency.

As we review the literature on supply chain resilience, the two practices of flexibility and redundancy are widely discussed and associated with resiliency. Table 5 presents the list of studies that emphasized flexibility and redundancy with respect to supply chain resilience.

In this context, flexibility is defined as the ability to take different positions to better respond to abnormal situations and rapidly adapt to significant changes in the supply chain (Lee, 2004). Having flexible transportations systems, flexible production facilities, flexible supply base, flexible capacity, and flexible labor arrangements are examples of the ways flexibility can enhance resilience (Tang, 2006a; Tomlin, 2006; Tang and Tomlin, 2008; Yang and Yang, 2010; Colicchia et al., 2010). On the other hand, another way to achieve resiliency is through creating redundancies across a supply chain. Having multiple suppliers, safety stock, overcapacity, and backup suppliers are instances of redundancies in supply chains (Sheffi, 2005; Tang, 2006a; Tomlin, 2006; Sodhi and Lee, 2007; Knemeyer et al., 2009).

A fundamental question in supply chain resilience is the relative importance of flexibility vs. redundancy, and under what conditions one should be emphasized less or more, taking into account the limited resources of organizations to develop capabilities associated with both flexibility and redundancy. Although researchers have used different methodologies to examine supply chain resilience, the discussion on flexibility vs. redundancy is still ongoing. Table 6 presents a review of the literature on flexibility vs. redundancy. A study by Urciuoli et al. (2014) reveals that safety stock, multiple suppliers, flexible contracts, rerouting, and flexibility in design or capacity are the most-used strategies in the energy industry.

Table 5
Flexibility vs. Redundancy.

Authors/year	Flexibility	Redundancy	Authors/year	Flexibility	Redundancy
Sheffi (2001)		*	Jüttner and Maklan (2011)	*	
Rice et al. (2003)	*	*	Carvalho and Cruz-Machado (2011)	*	*
Rice and Caniato (2003)	*	*			
Christopher and Peck (2004)	*	*	Carvalho et al. (2011)	*	*
Chopra and Sodhi (2004)	*	*	Gunasekaran et al. (2011)	*	
Peck (2005)	*		Christopher and Holweg (2011)	*	
Sheffi\, (2005)	*	*	Soni and Jain (2011)	*	
Sheffi and Rice (2005)	*	*	Blackhurst et al. (2011)		*
Sheffi (2006)	*	*	Carvalho et al. (2012a)	*	*
Tang (2006b)	*	*	Carvalho et al. (2012b)	*	
Tomlin, (2006)	*	*	Klibi and Martel (2012)	*	*
Falasca et al. (2008)	*	*	Ponis and Koronis (2012)	*	*
Datta et al. (2007)	*		Wicher and Lenort (2012)	*	
Ponomarov and Holcomb (2009)	*	*	Pettit et al. (2013)	*	
			Johnson et al. (2013)	*	
Briano et al. (2010)	*	*	Pal et al. (2014)	*	*
Pettit et al. (2010)	*		Urciuoli et al. (2014)	*	*
Zsidisin and Wagner (2010)	*	*	Azadeh et al. (2014)	*	*
			Melnyk et al. (2014)	*	*

Table 6
A review of the literature on flexibility vs. redundancy.

Authors/year	Flexibility vs. Redundancy	Methodology
Sheffi and Rice (2005)	While investing in redundancy increases cost, investment in flexibility is the most important step a company can take to be more resilient.	Empirical study
Sheffi (2005)	Flexibility is superior to redundancy, because it helps firms not only with disruptions but also with day to day operations.	Conceptual study
Datta et al. (2007)	Flexibility is needed in all elements of the supply network.	Agent-based modeling
Manuj and Mentzer (2008)	Supply chain flexibility is one of the important factors that affect the selection of risk management strategies.	Empirical study
Ratick et al. (2008)	Building emergency backup and storage facilities is a powerful and flexible tool to help firms improve the resilience of supply chains.	Mathematical Programming
Zsidisin and Wagner (2010)	Flexibility and redundancy help supply chain managers mitigate the effects of supply chain disruptions. Flexibility is more beneficial when sources of risks are extended supply chains. When risks stem from forces outside the control of SC participants (i.e., supply market risks), redundancy is more beneficial	Survey
Christopher and Holweg (2011)	Structural flexibility which builds flexible options into the design of supply chains is the key in responding to disruptions.	Empirical study
Jüttner and Maklan (2011)	Redundant resources seem primarily to address the flexibility and velocity of the supply chain and consequently improve resilience.	Empirical study
Blackhurst et al. (2011)	Five of the seven firms discussed holding safety stock throughout the supply chain as a primary strategy to mitigate the impact of disruptions. While carrying high levels of inventory throughout the entire supply chain can actually decrease resilience, understanding where inventory should be strategically placed, in what form it should be held, and how much is necessary can give a company a competitive advantage, and can increase their supply chain resilience.	Empirical study
Carvalho et al. (2012a)	Both strategies are effective in reducing the negative effects of disturbances in a supply chain. Flexibility has a lower total cost than redundancy. However, creating redundancy results in better lead time ratio.	Simulation
Ponis and Koronis (2012)	Flexibility is an antecedent for agility, and agility along with redundancy are two antecedents of resilience.	Literature review
Sawik (2013)	Supplier protection and pre-positioning emergency stock are effective strategies to improve the resilience of a supply chain.	Mathematical Programming
Azadeh et al. (2014)	Redundancy and visibility are the most important factors of resilience.	Simulation

Another stream of research in supply chain reengineering examines concepts such as density, complexity, and node critically as the main characteristics that need to be considered in designing resilient supply chains (Craighead et al., 2007; Falasca et al., 2008; Blackhurst et al., 2011; Brandon-Jones et al., 2014; Cardoso et al., 2015; Kim et al., 2015). Craighead et al. (2007) defined density as the geographical spacing of nodes within a supply chain, complexity as the total number of nodes and material flows (forward, backward, or within-tier) in a given supply chain, and node critically as the importance of a node within a supply chain. Considering two disruption mitigation capabilities, warning and recovery, they found design characteristics of a supply chain (density, complexity, and node critically) fortify the severity of disruption, while mitigation capabilities moderate the effects of design characteristics and reduce disruption severity. Falasca et al. (2008) developed a simulation model to measure the resilience of three supply chain design characteristics identified by Craighead et al. (2007), and examined the relationships between these characteristics and the overall resilience of the supply chain. They argue that their simulation model will provide the foundation for a quantitative framework for future studies in supply chain resilience. Blackhurst et al. (2011) found that density and complexity are inversely related to supply chain resilience. As the number of nodes increases, a supply chain would become more complex and more prone to disruptions. On the other hand, suppliers located in risk-prone areas and/or geographically clustered would increase the likelihood of disruptions within a supply chain. Brandon-Jones et al. (2014) identified scale, in terms of the number of suppliers, as the strongest aspect of supply base complexity in moderating the relationship between supply visibility and both resilience and

robustness. Cardoso et al. (2015) considered different structures in supply chains and discussed how much investment is required for each structure to increase supply chain resilience. Finally, Kim et al. (2015) argued that a firm's failure to manage supply disruptions is often the result of a lack of understanding of the supply network; they suggested a network perspective to examine supply chain resilience. They provided insights into the effects of each structure on the level of resiliency of the supply chain, and they developed a metric to measure the resiliency of a supply chain network based on the total number of node/arc disruptions.

Blackhurst et al. (2005) conducted an empirical study on supply chain disruptions considering the impact of global sourcing, and found that redesigning supply chains based on resilience required both an understanding of the tradeoff between costs and flexibility in global supply chains, and an understanding of dynamic supply chain models to apply the dynamic nature of disruptions to the design models. Based on several case studies, Christopher et al. (2011) found that most companies do not have a structured supply chain risk management and mitigation system. Their finding indicates that global sourcing and network reengineering is one of the most common strategies to global sourcing risk mitigation. Mandal (2012) conducted a survey of India industries on antecedents of supply chain resilience, and found supply chain reengineering as an important factor for building resilience in supply chains. Finally, Winston (2014) stated that to be resilient, firms must transform their strategies in three ways: (1) vision: they must rethink their vision, embracing radical innovation and a long-term mind-set; (2) values: redefine their valuation methods to account for unpriced costs and benefits; and (3) partners: pursue new forms of partnerships to achieve goals beyond the reach of individual firms.

4.3.2. Supply chain collaboration

Supply chains are extended across the globe, which affects their risk of disruptions. This suggests that supply chain vulnerability is a network-level phenomenon that needs to be addressed. Hence, the management of risk within a supply chain should be examined from a network perspective (Christopher and Peck, 2004). Risk management in a supply chain with high interconnectedness cannot be properly examined unless a high level of collaboration, cooperation, and partnership exists among the entities. Pettit et al. (2010) define collaboration as the ability to work effectively with other entities for mutual benefits. Faisal et al. (2006) construe collaboration as the "glue that holds supply chain organizations in a crisis together". Collaboration and cooperation reduces uncertainty by distributing risk (Reinmoeller and Van Baardwijk, 2005). According to Sheffi (2001), as lead times are becoming longer, emphasizing collaboration leads to better risk management in supply chains. An empirical study by Wieland and Wallenburg (2013) on the influences of relational competencies (communication, cooperation, and integration) on supply chain resilience showed that communicative and cooperative relationships have a positive effect on resilience, while integration does not have a significant effect. Bakshi and Kleindorfer (2009) studied investments for supply chain resilience and found cooperative contracts among partners in a supply chain leads to efficient investment in supply chain security and resilience. The result of a survey conducted by Soni et al. (2014) showed that collaboration is ranked second among fourteen enablers of supply chain resilience. Borecki et al. (2014) analyzed resilience and relational dynamics within a triadic buyer-supplier-supplier context, and found the triad resilience level changes with respect to the level of interaction among supply chain partners in the industry. Finally, Scholten and Schilder (2015) showed how specific collaborative activities like information sharing increase supply chain resilience through their impact on visibility, velocity, and flexibility. Despite the emphasis on collaboration and cooperation as key principles of supply chain resilience, recent studies by Christopher et al. (2011) and Wilding (2013) show that most firms overlook the importance of investment in collaboration. Two elements which are mainly prerequisite for building cooperative relationships between parties are (1) Inter-firm trust, and (2) Information sharing.

4.3.2.1. Trust. According to Faisal et al. (2007), trust facilitates cooperation and collaboration both within the organization and across partners in the supply chain. Sinha et al. (2004) stated that lack of trust is one of the major factors that increases supply chain risks. Ponomarov (2009) studied the mutual trusting behaviors of buyer-supplier resilience and found that a greater degree of mutual trusting behaviors can cause greater relational resilience in buyer–supplier relationships. His findings suggest that the longer the relationship orientation is, the stronger the relationship between mutual trusting behaviors becomes. Wicher and Lenort (2012) described a trusted network as a network where there is a certain degree of trust between the entities, where problems and challenges are openly discussed. In their study, trusted network is a requirement for design of the cooperative relationship and consequently it enhances resilience of supply chains. Finally, respondents of the survey conducted by Soni et al. (2014) ranked trust as the seventh important enabler of supply chain resilience out of fourteen drivers.

4.3.2.2. Information sharing

4.3.2.2.1. Information sharing as a driver for collaboration. According to Christopher and Peck (2004), the key priority for collaborative working and risk reduction should be the creation of a supply chain community where there is exchange of information among members of the supply chain. Mandal (2012) showed that collaboration can only happen when every member receives relevant information efficiently and effectively. Wicher and Lenort (2012) stated that collaboration and relationships can be improved by data and information sharing, building trusted network, forecasting, and planning. Information sharing plays an important role both before and after a disruption in a supply chain. Investment in information sharing and monitoring performance can help identify potential problems in a supply chain (Melnyk et al., 2014). On the other hand, in accord with Soni and Jain (2011), such post-disruption collaboration and information sharing is likely to have an effect on the system's ability to deal with future disruptions during all three phases: before, throughout and after an incident. We will further discuss that the improvement in supply chain visibility is achieved through close collaboration with customers and suppliers (Christopher and Peck, 2004).

4.3.2.2.2. Information sharing as a driver of resiliency. Some authors argue for considering information sharing as a separate driver of resilience (Datta et al., 2007; Soni et al., 2014). Datta et al. (2007) considered information sharing along with flexibility, monitoring, and decentralized structure as four drivers of supply chain resilience. Soni et al. (2014) considered 10 enablers for supply chain resilience where information sharing, visibility, and collaboration are considered three separate drivers. They also considered internal and external knowledge sharing as two antecedents of resilience in large enterprises. Finally, in a multi-case analysis, six out of seven firms emphasized the need to have predefined communication protocols in order to mitigate the effects of disruptions through effective information sharing (Blackhurst et al., 2011). All firms in their study stressed the need to develop supplier relationship management programs to mitigate supply risk.

4.3.3. Agility

Agility is defined as "the ability of a supply chain to rapidly respond to change by adapting its initial stable configuration" (Wieland and Wallenburg, 2013). Agility has been discussed in the literature from two different perspectives: (1) as a driver of resilience; and (2) as a separate element being examined as part of agile supply chains (Carvalho and Cruz-Machado, 2011; Carvalho et al., 2012a, 2012b). Since the focus of this study is resilience in supply chains, we address the first viewpoint and review the literature of agility in supply chain resilience.

Bakshi and Kleindorfer (2009) suggest that agility emphasizes "rapid system reconfiguration in the face of unforeseeable changes". Wieland and Wallenburg (2013) stated that resilience has two dimensions: (1) The proactive dimension, which is concerned with robustness, and (2) reactive dimension, which deals with agility. Thus, agility is connected with responsiveness of supply chains in case of disruptions and emergencies (Christopher and Peck, 2004; Ponomarov and Holcomb, 2009). Cabral et al. (2012) conducted a case study on Volkswagon, and found agility as the most important component of their business. Among the 14 enablers of supply chain resilience defined by Soni et al. (2014), agility received the highest rank, followed by collaboration, visibility, and risk management culture. Blackhurst et al. (2011) noted that four out of seven firms in their study discussed the need to quickly redesign their supply chains to reduce the impact of disruptions. In a study by Sullivan-Taylor and Branicki (2011) on 11 SME decision makers, rapidity (i.e., agility) was perceived by the managers as an important capability to enhance resilience.

Two dimensions of agility suggested by Christopher and Peck (2004) are visibility and velocity (Faisal et al., 2006; Wieland and Wallenburg , 2013; Scholten et al., 2014; Azadeh et al., 2014). It should be noted that in some studies, flexibility is also assumed to be a dimension of agility (Chopra and Sodhi, 2004; Tang and Tomlin, 2008; Christopher et al., 2011; Ponis and Koronis, 2012; Scholten et al., 2014). Thus, further clarification is needed to properly address the relationship between agility and flexibility.

4.3.3.1. Visibility. Francis (2008) defined visibility as "the identity, location and status of entities transiting the supply chain, captured in timely messages about events, along with the planned and actual dates/times of these events" (Francis, 2008, p. 182). Visibility is simply defined as the ability to see one end of the pipeline, from the other end (Christopher and Peck, 2004). Pettit et al. (2013) defined visibility as the knowledge of the status of operating assets and the environment. The achievement of supply chain visibility is based upon close collaboration with customers and suppliers, and it is an outcome of investment in information sharing (Christopher and Peck, 2004; Barratt and Oke, 2007; Soni et al., 2014; Brandon-Jones et al., 2014). Visibility has been examined from two perspectives:

4.3.3.1.1. Visibility as a driver for agility. The first perspective is that visibility is one of drivers of agility. Datta et al. (2007) used agent-based modeling of complex production/distribution systems to improve resilience. They reported that incorporating true sensors at different parts of the supply chain and monitoring them regularly is a key element of agility, which enhances resilience. According to Wieland and Wallenburg (2013) visibility enables managers to know about the changes; thus, it is a prerequisite for response. They hypothesized and further verified that communication and cooperation will improve agility and resilience by enhancing visibility of functions and operations. Azadeh et al. (2014) studied the best policy in bringing the resilient factors into an SC transportation system with fuzzy parameters. Their result shows the important role of visibility and redundancy among the factors of resilience. The difference in their outputs after applying the visibility policy is significant, and they recommended that SCs be reengineered with the visibility characteristic.

4.3.3.1.2. Visibility as a driver for resilience. Visibility is assumed to be a driver of resilience, but separate from agility (Blackhurst et al., 2005; Jüttner and Maklan, 2011; Carvalho and Cruz-Machado, 2011; Soni and Jain, 2011, Ponis and Koronis, 2012, Johnson et al., 2013; Wilding, 2013; Brandon-Jones et al., 2014). Blackhurst et al. (2005) conducted an empirical study to understand how to properly mitigate the effects of disruptions. They assumed visibility as an element in the disruption discovery phase. Based on their interviews with managers in several industries, they found that all managers stressed visibility as a key factor in mitigating the effects of disruptions. The results of an empirical study by Blackhurst et al. (2011) showed that all seven firms in the study discussed the need for increased visibility within the supply chain. In addition, six firms highlighted the need for systems that help them monitor their supply chains in real time to be able to make strategic decisions to avoid (or mitigate) disruptions, while five firms noted the importance of monitoring individual nodes within a supply chain. Through conducting a multiple case study, Jüttner and Maklan (2011) found that sharing risks and knowledge across the chain improves supply chain resilience by improving supply network visibility. Wilding (2013) introduced collaboration, SC engineering, agility, and SCRM culture as four pillars of supply chain resilience. Finally, Brandon-Jones et al. (2014) conducted a survey and collected data from 264 UK manufacturing plants. Their results suggest that supply chain connectivity and information-sharing resources lead to a supply chain visibility capability that enhances resilience and robustness.

4.3.3.2. Velocity. The concept of speed is inherent to agility (Prater et al., 2001; Wieland and Wallenburg, 2013). For the purpose of incorporating speed (and consequently time) into agility, the concept of velocity has been introduced; velocity is one of the important building blocks of agility (Scholten et al., 2014). Christopher and Peck (2004) suggested that velocity means distance over time. Velocity in a risk event determines the loss that happens per unit of time (Jüttner and Maklan, 2011). Barroso et al. (2011) emphasized the role of recovery speed by stating that supply chain resilience is achievable by redesigning the supply chain to mitigate adverse incidents and disruptions. Velocity is closely related to flexibility and adaptability, where it is concerned with the pace of flexible adaptations (Stevenson and Spring, 2007). Based on this relationship, some authors considered velocity in their flexibility definitions (Fiksel, 2006; Soni and Jain, 2011). Multiple case studies by Jüttner and Maklan (2011) found that velocity had a positive impact on the companies' revenue targets and supported flexibility by adding pace to the supply system's adaptability. However, when being compared to flexibility, velocity places a stronger emphasis on the efficiency rather than the effectiveness of the supply chain's response and recovery (Smith, 2004). Manuj and Mentzer (2008) differentiate three forms of velocity: the rate at which a risk event happens, the rate at which losses happen, and how quickly the risk event is discovered. Jüttner and Maklan (2011) then added the supply chain's risk-event recovery speed to different forms of velocity.

Christopher and Peck (2004) suggested three basic foundations for improved supply chain velocity: (1) using streamlined processes, which means doing activities in parallel rather than in series, and e-based rather than paper based, (2) eliminating non-value- added time, which means minimizing the time for activities that do not add value from the customers' perspective, and (3) reduction in bound lead times, which means being able to respond rapidly, and cope with short term changes. Several authors emphasized the role of lead-time reduction in resilience enhancement. Spiegler et al. (2012) mentioned that supply chains

will experience drastic changes in their resilience performance when lead-time changes. Tang (2006a) introduced lead-time reduction as a strategy to reduce disruption impacts. Production and transportation lead-time reductions are emphasized by Carvalho and Cruz-Machado (2012) as practices that enhance agility and resilience. Jutner and Maklan (2012) suggested splitting up the market into two regions to shorten the lead time and increase the downstream velocity of the supply chain. Findings of Jutner and Maklan (2012) and Carvalho et al. (2012a, 2012b) indicated that redundant resources address velocity of the supply chain by reducing lead times. Finally, Kristiano et al. (2014) argued that reducing inbound lead times and non-value-added times will provide opportunities to improve SC velocity.

Wieland and Wallenburg (2013) who studied the effects of relational competencies (communication, cooperation, integration) on agility reported that communication and cooperation have positive effects on agility through enhancing visibility and speed (velocity). According to Carvalho et al. (2011), the deployment of agile and resilient practices is mainly related to improvement in supplier flexibility and velocity as well as improvement in responsiveness of suppliers to changes in markets or to unexpected events. Wicher and Lenort (2012) contended that velocity would enhance supply chain resilience through the process design phase. Evidence of incorporating velocity in the design of processes in their study includes shorter waiting time, higher flexibility, and faster reaction to market requirements.

4.3.4. SCRM culture

According to Christopher and Peck (2004), organizations need to embrace a culture for SCRM in order to create a resilient organization. This emphasis on organizational culture has been previously addressed as an important factor in success of other management practices, e.g., a culture for quality for Total Quality Management (TQM). Organizational behavior and characteristics are important drivers in the evolution toward resilient and sustainable enterprises (Moore and Manring, 2009). Sheffi (2005) stated that the key difference between successful and unsuccessful response to disruption is organizational culture. Companies such as Dell, Toyota, and Zara have been successful in creating the culture of flexibility. Waters (2007) also mentioned that risk management should be an essential element of every organization that is embedded into its corporate culture.

Barton and Christianson (2006) underlined the importance of organizational- and people-oriented soft processes to create resilience, and called for more studies on the topic. Seville et al. (2006) pointed out that resilience issues often relate more to the softer, less tangible aspects of an organization, such as its culture, leadership, vision, and soft managerial practices such as effective communication and relationships within the organization and with key customers and stakeholders. Ates and Bititci (2011) studied the role of culture and change management in resilience in SMEs. Their finding suggests that culture and change management seem to be viewed separately in SMEs; culture management is driven by rewarding employees and internal communication activities, and there is not much emphasis on communicating with customers, competitors, and suppliers in managing change and culture. Their findings also showed that incorporating, developing, and implementing change capabilities is paramount to making progress toward sustainability and resilience in organizations. Meanwhile, Christopher et al. (2011) argued that creating a global sourcing risk management culture along with global sourcing reengineering are the two most common approaches to global sourcing risk mitigation. The results of an empirical study by Mandal (2012) showed that a culture of risk management must be embedded implanted in the focal firm and across its supply chain partners. Finally, Soni et al. (2014) reported risk management culture as one of the major enablers of resilience, along with agility, collaboration, and visibility.

Culture is difficult to define and even more difficult to change (Sheffi, 2005). A review of the literature on organizational culture as it pertains to resilience finds two aspects emphasized: leadership and innovation.

4.3.4.1. Leadership. For the purpose of changing the culture of an organization, the role of leaders and top managers are critical. Christopher and Peck (2004) noted that within the process of cultural change at the organizational level, nothing is possible without the support and commitment from the leadership. Wilding (2013) stated that instilling a risk management culture requires the leadership to review company policies and practices, to determine their impact on the risk profile of the supply chain. Demmer et al. (2011) stated that top management's role in engendering innovation is critical in SMEs. Rice and Caniato (2003) emphasized education and training for security and resilience as the most common practices. The results of an empirical study by Blackhurst et al. (2011) also showed that education and training of supply chain employees was identified by six of the seven firms as a major factor in enhancing their firm's capabilities in supply chain resilience.

4.3.4.2. Innovation. Innovation is a key element for an enterprise's long-term survival and growth, and it plays a crucial role in how the firm adapts and responds to changes in the environment (Santos-Vijande and Alvarez-Gonzalez, 2007). Innovation does not happen in a vacuum; to institutionalize innovation in an organization, there should be an organization-wide set of shared beliefs and understanding about innovation (Sharifirad and Ataei, 2012). It has been found that the level of innovativeness in an organization is associated with the culture of learning and participative decision-making (Hurley and Hult, 1998). Martins and Martins (2002) stated that cultural change requires in-depth analyses of values, beliefs, and behavior patterns, where innovation and creativity play a critical role in this process. Dobni (2008) noted that the extent to which an organization can be regarded as innovative will be determined by its culture.

Although innovation has been regarded as a key element for a firm's long term survival and growth, the role of innovation in increasing the resilience of an enterprise has been relatively overlooked. Reinmoeller and Van Baardwijk (2005) underlined the role of innovation on resilience, and found among the resilient companies they studied, the emphasis on innovation increased by 235% over 20 years. They concluded that companies could be able to overcome disturbances and disruptions, and adapt to rapid changes in the environment, only when they allocate enough resources to innovation. Golgeci and Ponomarov (2013) stated that resilience may be viewed as a key dimension of a firm's survival, and innovativeness as one of the key enablers of resilience. The results of their empirical study on the impact of firm innovativeness on effective responses to supply chain disruptions indicated that both firm innovativeness and innovation magnitude are positively associated with supply chain resilience. Akgün and Keskin (2014) studied 112 firms to investigate the relationship between organizational resilience capacity, product innovation, and firm performance. Their results showed significant associations between resilience-capacity variables and a firm's product innovativeness, where product innovativeness mediates the relationship between a firm's resilience and its performance.

4.4. Supply chain resilience principles framework

While the literature on principles of supply chain resilience is substantial, there is a lack of an overarching framework for supply chain resilience. Therefore, we present a framework for the

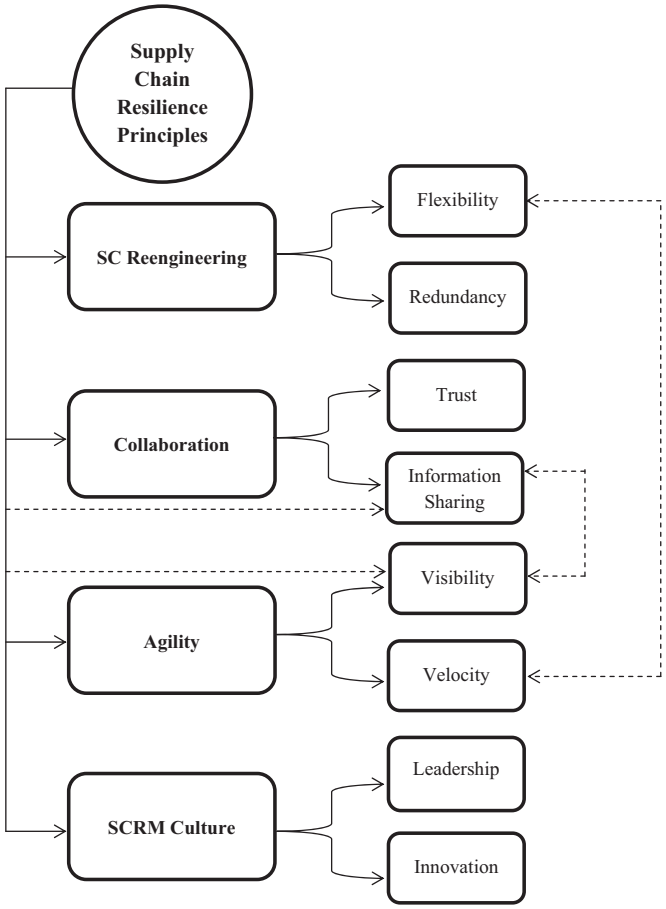

Fig. 6. Supply chain resilience principles framework. (The arrows represent the relationships among the key variables in the model, based on the review of the literature; these relationships were reported in several studies. The dotted arrows represent the relationships which were reported in a few studies and need more investigations.)

principles of supply chain resilience in Fig. 6, based on the existing body of knowledge in the literature. Our framework provides an appropriate conceptualization of supply chain resilience and incorporates major components of a resilient supply chain as discussed in the literature. We argue that our framework incorporates the suggestions and findings of all previous studies into a cohesive, unified, and comprehensive model. Thus, we believe this model could be used by researchers in future studies to examine supply chain resilience in a more systematic way.

In our discussion in Section 4.3.1. *Supply chain reengineering*, we discussed how this reengineering is achievable through incorporating redundancy and/or flexibility into the supply chain. Although the discussion on redundancy and flexibility has a relatively rich history, there is limited scholarly work on the relative importance of flexibility and redundancy in enhancing supply chain resilience.

Based on our discussion in Section 4.3.2. *Supply chain collaboration*, collaboration is not possible unless members of a supply chain have developed channels to share information and develop trust. More studies on collaboration are needed to provide insight into how information sharing before and after a disruption can enhance supply chain performance.

From our discussion in Section 4.3.3. *Supply chain agility*, agility has two antecedents: visibility and velocity. Making an informed decision on the status of a disrupted supply chain and the courses of action to be taken is only possible when the decision makers have the complete knowledge of the status of their system, and they can easily navigate how their decision can affect different entities of the chain. In addition, velocity, which is related to the pace of the response to disturbances, has not received enough attention in the literature. Few studies have pointed out the relationship between velocity and other elements of the framework such as flexibility and innovation.

Finally, based on our discussion in Section 4.3.4. *SCRM culture*, developing responsive actions with regard to an abnormal situation is much easier and more effective when each individual and subsystem is prepared and can contribute to the development of a more rapid and effective solution. We also highlighted how a culture of innovation and having innovative individuals can facilitate an effective and immediate response to a disruption. In this context, the role of the innovation culture and SCRM culture needs to be addressed.

We need to stress that the principles and antecedents of each principle should not be viewed as independent elements in the framework. These factors are highly dependent on each other. As pointed out, the relative importance and significance of key principles of supply chain resilience (e.g., the respective relationships of flexibility and agility, innovation and velocity, and information sharing and visibility) are interesting topics for research which have received less attention in the literature. We provide a more comprehensive overview of the directions for future studies in Section 5.3. *Discussion: Findings and Future Directions*.

4.5. Supply chain resilience strategies

While the main discussion of the publications under review in this study is on supply chain resilience definitions and principles, some researchers classified strategies for SC resilience. Roberta Pereira et al. (2014) stated that supply disruptions are more critical when they occur upstream in the chain. Therefore, it is not surprising that most of the strategies suggested in the literature are sourcing strategies and deal with the upstream part of the chain. Table 7 outlines the studies on SC resilience strategies.

In addition to the discussion on proposed strategies for supply chain resilience, several studies have examined the effectiveness of these strategies as well as their impact on supply chain design characteristics. Table 8 presents the literature pertaining to SC resilience strategies, their effectiveness, and their impact on supply chain design.

4.6. Integration of resilient supply chains with other management practices

After initiating and growing the concept of resilient supply chains, some researchers have started investigation on the comparison and integration of different practices of management. Christopher and Rutherford (2004) integrated agile and resilient supply chains with six sigma practices, and found that with an agile six sigma approach, supply chains can reduce internal sources of risk while improving efficiency and effectiveness. Cruz Machado and Durate (2010) proposed a framework to address resilient, lean, agile, and green supply chains and the tradeoffs among these paradigms. Later, Carvalho et al. (2011) and Carvalho and Cruz-Machado (2011) identified the attributes of a supply chain that is resilient, lean, agile, and green. All these paradigms were found to contribute to information frequency increasing, integration level increasing, production lead-time reduction, and transportation lead-time reduction. However, “capacity surplus” and “inventory level” increases may only provide the supply chain with added agility and resilience characteristics. Finally, Cabral et al. (2012) developed a conceptual Analytical Network Process (ANP) model to select the best Lean, Agile, Resilient, and Green (LARG) automotive SCM practices. Their model is able to prioritize the best factors in LARG and cope with the vagueness and

Table 7
Supply chain resilience strategies.

Chopra and Sodhi (2004)	Categorized risks into disruption, delay, forecast, procurement, receivables, capacity, and inventory. They then assessed the impact of the following strategies in each subset of risk: **(1) Add capacity, (2) Add inventory, (3) Redundant suppliers, (4) Increase responsiveness, (5) Increase flexibility, (6) Aggregate or pool demand, (7) Increase capabilities,** and **(8) Have more customer accounts.** They suggested managers should (1) create a shared and organization-wide understanding of SC risk through stress testing, and (2) find how to adapt a general risk mitigation approach to the circumstances of their particular company through tailoring a risk management approach.
Tang (2006b)	Introduced nine robust strategies: **(1) Postponement, (2) Strategic stock, (3) Flexible supply base, (4) Make and buy, (5) Economic supply incentives, (6) Flexible transportation, (7) Revenue management, (8) Dynamic assortment planning,** and **(9) Silent product rollover.** They claimed having a robust supply chain strategy could make a firm more resilient. They mentioned three successful case studies in Nokia, Li and Fung, and Dell companies.
Tomlin (2006)	Classified disruption management strategies into two categories: **(1) Operational mitigation: Strategies based on suppliers and inventory prior to disruption**, and (**2) operational contingency: Strategies based on flexibility after disruption.** He found supplier reliabilities and nature of disruptions in terms of frequency and lengths are key determinants of the optimal strategy. He then discussed which strategy is superior based on the overall strategy of focal firm, taking into account organizational and contextual parameters.
Manuj and Mentzer (2008)	Categorized risk events into currency, transit time, forecast, quality, safety, business disruption, survival, inventory and tools ownership, culture, dependency and opportunism, oil price increase. They identified the most important antecedents (temporal focus, SC Flexibility, SC Environment (Supply and Demand Risks) to selection of risk management strategies ((**1) Postponement, (2) Speculation, (3) Hedging, (4) Control/Share/Transfer, (5) Security, and (7) Avoidance**) and linking the antecedents to appropriate strategies.
Melnyk et al. (2014)	Considered eight strategies including **(1) Indirect investment, (2) Discovery, (3) Information, (4) Supply chain design, (5) Buffers, (6) Operational flexibility, (7) Security,** and **(8) Preparedness**, and divided resilience into four phases: avoidance, containment, stabilization, and return. They then investigated how resilience investments in each strategy affect the four phases of resilience in different ways.
Chopra and Sodhi (2014)	Suggested three solutions to build resilience: **(1) Segmenting or Regionalizing** supply chains; **(2)** Limit losses in performance by **avoiding too much centralization** of resources; and **(3) Overinvesting in protection,** which may be more profitable than not investing enough in the long run.
Chowdhury et al. (2015)	The most preferred resilience strategies to mitigate the vulnerabilities are: **(1) back-up capacity**, **(2) building relation with buyers and suppliers**, **(3) quality control**, **(4) skill and efficiency development**, **(5) ICT adoption**, **(6) demand forecasting**, **(7) responsiveness to customers**, and **(8) security system improvement**.

Table 8
Supply chain resilience strategies and their effectiveness.

Ratick et al. (2008)	Based on the strategy of building emergency backup and storage facilities in order to improve SC resilience, they developed a mathematical model to find the number and location of facilities. They emphasized this strategy as a powerful and flexible tool to assist firms to improve resiliency in the SC.
Klibi and Martel (2012)	Proposed supply network design models incorporating resilience-seeking formulations, in the context of the multi-period location–transportation problem. A generic solution approach was also proposed to produce effective and resilient supply network designs. Their results show that the quality of the user response anticipation incorporated in a design model is a critical issue: significant gains can be made by using more precise representations of delivery decisions (routes vs. flows) and stochastic models based on scenario samples.
Losada et al. (2012)	Presented a bi-level mixed integer linear program for protecting an uncapacitated median type facility network against worst case losses considering the role of facility recovery time on system performance and probability of multiple disruptions over time. They also used three decomposition approaches to solve large problem instances. Their analysis highlights the tradeoff between protection investment and efficiency gains.
Sawik (2013)	Proposed a new mathematical programming approach for the selection of resilient supply portfolio based on supplier protection and backup emergency inventory strategies. A resilient supply portfolio is identified with protected suppliers capable of supplying parts in the face of disruption events.
Boone et al. (2013)	Investigated the impacts of strategic alignment of inventory on resilience and continuity. They examined the impact of a well-aligned approach to inventory management on resilience and continuity via a longitudinal study. Their result indicates inventory management is indeed effective in improving continuity and resilience.
Gong et al. (2013)	Presented a framework for supply chain restoration which takes into consideration disruptions to the services provided by infrastructure systems. They identified and modeled the interdependencies between the supply chain network and infrastructures, and used the model to develop supply chain restoration plans that can improve the company's resilience to disasters.
Isotupa et al. (2014)	Studied the trade-off between SCRM solutions and Risk Management Insurance (RMI) techniques solutions for supplier disruptions. The result shows that the solution is a function of both the frequency and the severity of loss. They found SCRM solutions, such as dual sourcing, are optimal when the duration of disruption (severity) is low and arranging loss financing (RMI solution) is optimal when the duration of disruption is expected to be high. For moderate severity, a combination of SCRM and RMI minimizes the percentage of lost sales.
Rajesh and Ravi (2015)	Using grey methodology, they addressed a supplier selection model to develop a resilient supply chain. Taking an electronics supply chain as a case study, with six alternative suppliers, grey possibility values for supplier selection were calculated and the suppliers were prioritized. They considered the following attributes for a resilient supplier: quality, cost, flexibility, velocity, visibility, vulnerability, collaboration, risk awareness, continuity, technology, R&D, safety, and environmental concerns.
Torabi et al. (2015)	Considering several proactive strategies such as suppliers' business continuity plans, fortification of suppliers, and contracting with backup suppliers, they proposed a stochastic programming model to address supplier selection and order allocation to build a resilient supply base under operational and disruption risks.
Wang et al. (2015)	They examined contingent rerouting strategies for enhancing supply chain resilience, taking a supplier's point of view. They proposed an optimization model to determine the rerouting strategy for product flow in a supply chain under disruptions.
Yang and Xu. (2015)	Two supply chain recovery methods, contingent sourcing and government aid, were considered for grain processor recovery. Finding indicated that (1) a processor prefers timely full recovery, and (2) government aid as an intervention means is indispensable but cannot fully replace the backup supplier.
Ambulkar et al. (2015)	Studied how resource reconfiguration and risk management infrastructure can mediate the relationship between different types of disruptions and a firm's resilience. In this context, they found resource reconfiguration plays a critical role in high-impact disruptions. However, risk management infrastructure is the key factor in response to low-impact disruptions.

ambiguity of its elaborated features and interrelatedness. In summary, integration of resilient supply chain with other practices s such as lean, agile, and green supply chain is nascent, which is at its early stage of development theory development.

4.7. Resilience in small and medium-sized enterprises (SMEs)

The review of literature in supply chain resilience shows there is a very limited scholarly work on resilience practices in SMEs.

Table 9
Articles on resilience in SMEs.

Authors/year	Summary of the article on SMEs resilience
Ates and Bititci (2011)	Developed a conceptual framework for change process in SMEs to create resilience with five categories: prepare, plan, implement, embed, and review. **Finding:** Sustainability and resilience in SMEs will be enhanced by (1) ability to embrace organizational and people dimensions as well as operational aspects of change management, and (2) paying attention to long-term planning and external communication to drive change proactively.
Demmer et al. (2011)	Identified key antecedents of resilience in large enterprises and used a case study of Demmer Corporation to examine whether these strategies are applicable for SMEs. Key antecedents of resilience identified in this article are: eliminate allegiance to the status quo, internal knowledge sharing; search for new knowledge; identify new options and entrepreneurially opportunities; externalize some innovation; support portfolio of strategic experiments; make renewal an equal partner to optimization. **Finding:** The antecedents of resilience of large corporations also apply to SMEs. Additional factors that may engender resilience in SMEs were found: Top management serving as the champion of innovation/A mission-focused, organic organizational structure/A robust strategic planning process with an entrepreneurial focus/The embedding of the company into value streams of major customers/and Investing in human resources focused on enhancing innovation capabilities.
Chan (2011)	Aimed to answer the following questions: What approach(es) could the SMEs adopt in capturing the criteria for organizational resilience? What objective and systematic decision aid(s) could be used to evaluate the criteria? For the first question he proposed an approach by using the viable system model (VSM). Regarding the second question, an evaluation of the criteria that relate to organizational resilience is performed by multicriteria decision aid (MCDA) based on Superiority and Inferiority Ranking (SIR) methodology. **Findings:** This article takes the first step to integrate the VSM and MCDA approaches as an analytical support tool to help management with objective and systematic means for enhancing organizational resilience. The result shows that the proposed approach provides management with an objective and systematic means to make organizational resilience decisions by evaluating various structural arrangements of an organization for achieving adaptation in a changing business environment.
Gunasekaran et al. (2011)	Introduced a framework for SME resilience and competitiveness and then application of this framework was discussed based on a survey with 40 SME companies. The framework is based on: (1) Internal factors: Organizational behavior/Managerial characteristics/Quality. (2) Enabling factors: Use of technology/Supply chain integration and flexibility/Generation of capital/Location & marketing, and (3) External factors: Globalization. **Findings:** This paper identifies areas where an SME would need external support to be resilient and competitive. Location and marketing together with quality are not viewed as competitive advantage by SMEs. Human resource development and knowledge management in SMEs need attention to support resilience. SMEs need help in having access to the market through different platforms and financial resources. SMEs need support to create new business and in exporting their products with suitable logistics resources.
Sullivan-Taylor and Branicki (2011)	Utilized the Weick and Sutcliffe (2001) four-category framework to examine SMEs perceptions about their existing capabilities to cope with extreme events: Resourcefulness, Technical, Organizational, and Rapidity. **Findings:** There was a tendency for the SME managers to focus on 'muddling through' extreme events. This in part was attributed to constraints in the areas of resourcefulness, technical, and organizational capabilities. However, rapidity was seen by the managers as an important existing capability.
Bhamra et al. (2011)	Explored the literature surrounding SMEs and examined resilience within the context of SMEs. Based on a literature review of 74 sources, they investigated the resiliency concept in different disciplines. **Findings:** There appears to be a strong focus around building theories and definitions of resilience. However, the literature is lacking in empirically-driven studies. In other words, there is little on how organizations, particularly SMEs, can enhance resilience. There is also a need to conduct good quality empirical-based research to properly recognize the potential of developing resilient characteristics within organizations and supply chains. There is future scope to apply systems-engineering resilience thinking to the aspect of SME resilience considering the SME as a sub-system within the extended supply chain.
Burnard and Bhamra (2011)	Focused on addressing detection and activation within the response of an organization to disruptive events. A conceptual framework of a resilient organizational response was presented. **Findings:** Lack of strategic planning and focus on short-term benefits during the decision-making process can severely limit an SME's ability to respond to disruptive events effectively. The phases of detection and activation within the resilient response framework may also be limited by the low degree of standardization and formalization within SMEs. Several factors that can cause an SME to fail are identified including insufficient forward planning, issues with cash flow, inability to capture and manage innovation, lack of investment, lack of business experience, and limited external support.
Pal et al. (2014)	Concentrated on the constraints faced by Swedish textile SMEs, primarily during the economic crises of the past two decades, and identified the antecedents and their degrees of influence on economic resilience. Based on a literature review, the enablers of resilience are: assets and resourcefulness, dynamic competitiveness, and learning and culture. **Findings:** The respondents to the survey considered resourcefulness factors as the most essential factors and dynamic competiveness factors as the least important factors during the recent economic downturn. For the Swedish SMEs the keys to develop resilience are: (a) investment finance and cash flow, (b) material assets and networking, (c) strategic and operational flexibility, and (d) attentive leadership.

Gunasekaran et al. (2011) defined an SME as a company that employs about 50–200 people. SMEs make up over 70% of the world's production (Ates and Bititci, 2011). While SMEs play a significant role in the national economies of countries, research on resilience practices at SME's is surprisingly limited, and has not received much attention. Table 9 represents the literature of resilience in the context of SMEs.

4.8. Supply chain resilience measurement

Despite the growing number of publications on supply chain resilience, there are few studies that discuss supply chain resilience measurement. In the following section, we review the studies that examined the measurement of resilience.

Carvalho and Cruz Machado (2007) stated that SC resilience can be measured only after the occurrence of a disturbance. However, the question on how to measure the SC resilience still remains unclear. They considered diversity, adaptability, and cohesion as the main capabilities of SC resilience. They then propose an SC Resilience Index and an SC Resilience Indicator. The former is a function of diversity, adaptability and cohesion, while the latter is a function of the amount of change the system can undergo, and the degree of self-organization. Using the index and the indicator, it is possible to assess the SC resilience: the SC Resilience Index will allow evaluating the SC resilience capabilities

and the SC Resilience Indicator will allow measuring the system reaction to disturbances.

Falasca et al. (2008) aimed at developing a quantitative approach for assessing supply chain resilience to disasters based on three dimensions (density complexity, and nodes critically) introduced by Craighead et al. (2007). Density can be measured by the number of nodes divided by the average inter-node distance. Complexity can be measured as a function of the total number of nodes plus the total number of forward, backward, or within-tier flows in the supply chain. Finally, node critically can be measured as a combination of the relative importance of a given node and the number of non-redundant inbound and outbound flows from that node. They developed a simulation model to measure supply chain resilience. Murino et al. (2007) presented a methodological procedure to determine the set of decision variables that affect the resilience of the supply chain. Using system dynamics simulation and design of experiments (DOE), based on three performance measures (stock level, number of suppliers, production time (speed)) and their correlation, a resilience function was developed. However, they found only that the numbers of suppliers, the speed, and their interactions strongly impact resilience variation.

Carvalho (2011) used an inductive research approach to develop a resilience assessment model. Performing an exploratory case study in the Portuguese automotive supply chain, she developed a supply chain resilience assessment model and two resilience indices: a resilience index of on-time delivery to capacity shortage, and a resilience index of on-time delivery to materials shortage. She examined the proposed indices through a case study in the automotive supply chain.

Cabral et al. (2012) developed an analytic network process (ANP) model to measure four capabilities of a supply chain with respect to agility, lean, resilience, and green principles. Their model is based on several practices including capacity surplus, replenishment frequency, integration level, information frequency, inventory level, production lead time, transportation lead time, and three performance indicators including service level, lead time, and costs. Using their model, it is possible to measure agility, leanness, resilience, and greenness of a supply chain, prioritize them, and choose the best practices to increase each capability.

Soni et al. (2014) proposed a model using graph theory that holistically considers all the major enablers of resilience and their interrelationships. The uniqueness of this model lies in its ability to quantify resilience by a single numerical index. The enablers of resilience in this study are agility, collaboration, information sharing, sustainability, risk and revenue sharing, trust, visibility, risk management culture, adaptive capability, and structure. As the review of the above articles suggests, while the above studies shed light on measuring resilience, this area is not fully developed and warrants more research.

Munoz and Dunbar (2015) quantified evaluation of multiple transient response measures across multiple tiers in a supply chain to develop a metric for operational supply chain resilience. Their analysis showed that individual dimensions of resilience can explain the transient response at the single-firm level, while aggregation of multiple resilience dimensions across multiple tiers has greater capacity to explain the performance response to supply chain disruptions. Finally, Kim et al. (2015) differentiated between disruptions in nodes/arcs and disruptions in the entire supply chain network, and proposed a metric for supply network resilience based on the total number of node/arc disruptions.

5. Discussion: findings and future directions

In this study, we examined two questions in the context of supply chain resilience:

1. What is the current state of the work in supply chain resilience?
2. What are the existing gaps and need for future research in supply chain resilience?

For this purpose, we employed a literature survey to review the literature of supply chain resilience in SCRM, and investigated the research tendencies of the field. It is one of the first literature reviews in the SCRM area specifically focused on particularly devoted to the study of enterprise and supply chain resilience. We employed two methods to collect the related literature on supply chain resilience. In the first method, we selected some keywords and used databases and journals to find publications in high quality journals in three areas of management: Operations Management, Operations Research and Management Science, and General Management. We used the quality rating published by the Association of Business Schools to distinguish between high and low quality journals. We further tracked the references of articles obtained by using the first method to identify other relevant publications (e.g., conference proceedings, book chapters).Through this process we identified over 120 publications that were further refined to be limited to those specifically related to supply chain resilience. After this process, 100 publications were selected and studied carefully. Below, we summarize the findings and future research directions on supply chain resilience based on our comprehensive review of the literature.

5.1. Characteristics of publications

In Table 2, we presented year-wise and journal-wise distribution of the publications, followed by some statistics about the focus of the paper, publication date, authors' affiliation, research methodology, theoretical perspective on resilience, the scope of resilience, and whether it examines enterprise resilience or supply chain resilience. The data shows an increase in momentum in 2003 for research in supply chain resilience, and that the majority of studies are conducted by researchers in the US and Europe. In line with Ghadge et al. (2012), we attribute this to the level of outsourcing in these two regions, which attracted both scholars and practitioners to address supply chain resilience.

From reviewing journal-wise publication figures and the research focus on each area of management, it was found that the number of publications in OR/MS in supply chain resilience is very limited. Therefore, future studies would benefit from utilizing OR/MS methods in understanding supply chain resilience. Since the OR methods such as optimization and stochastic modeling have the ability to model the dynamic nature of the environment and incorporate risk, researchers are encouraged to utilize these tools to examine SC resilience. While we saw more empirical studies in SC resilience, the literature is not rich enough, and more research is needed to examine and validate the theoretical foundations of supply chain resilience. We also observed a number of articles that used mixed methodologies; this is believed to be an important direction for future research, where using multiple methods would enhance the theory development and testing in supply chain resilience.

Our review of the literature also suggests that the research in supply chain resilience has shifted from resilience definitions, principles, and measurement to understanding the principles of supply chain resilience. Future studies could investigate how these principles can be operationalized, and properly measured. Nevertheless, there are a limited number of studies that focus on SC resilience measurement. We also noticed that SC resilience has attracted higher attention than enterprise resilience. Understanding enterprise resilience would provide valuable insight on the development of resilience at the supply chain level, which could be an interesting and relatively untapped area of research.

5.2. Enterprise and supply chain resilience

We reviewed the literature for all the definitions of enterprise and supply chain resilience in order to identify the key elements and dimensions of enterprise and supply chain resilience. In this context, in order to resolve the confusion regarding the meaning of enterprise and supply chain resilience, we proposed a definition for each of the two concepts based on the existing body of literature. To do so, we reviewed all the existing definitions, extracted the common themes in the definitions, and used them to create a comprehensive proposed definition for each concept.

5.3. Supply chain resilience principles

In the context of supply chain resilience principles, we realized that the framework suggested by Christopher and Peck (2004) has been used as a basis for later studies in supply chain resilience. Therefore, we used their framework as a basis for our study, and examined the evolution of the principles of supply chain resilience in the related literature. At the end, we summarized our findings and proposed a more detailed and dynamic model for supply chain resilience. We discussed the elements of the framework, examined the existing research, and identified current gaps in the literature.

Our study provides several directions for future research in supply chain resilience. In the context of supply chain redesign and reengineering, a fundamental question still unresolved is the relative importance of flexibility vs. redundancy. While both flexibility and redundancy are being emphasized, there is little theoretical or anecdotal evidence to suggest which one should be emphasized first. Therefore, one of the key questions is to determine organizational and contextual factors that could impact flexibility or redundancy within a resilient supply chain. In addition, the relationship between several key elements of supply chain resilience is not well understood and articulated in the literature. For example, the literature is not clear on whether there is a relationship between flexibility and velocity. Also, there is little insight into the dynamics and development of an SCRM culture, and how a culture of innovation can enhance supply chain resilience. Finally, an important research question within the domain of supply chain resilience is the tradeoff between investment in capabilities to increase resilience (e.g., flexibility, redundancy, and visibility) and their associated cost. This requires more empirical studies that examine the relationship between different elements of our framework and their effect on improving supply chain resilience. Future studies should also address resilience through assessment of the tradeoff among improvements in capabilities, their associated costs, and their impact on SC resilience.

5.4. Supply chain resilience strategies

Sourcing strategies are the main strategies that are discussed and assessed in the literature. While some authors broadly investigated several strategies that enhance supply chain resilience, some studies examined a particular strategy, and assessed its impact on supply chain resilience, both quantitatively and empirically. However, there is a gap in the literature on the advantages and disadvantages of these strategies, which requires a comparative analysis of implementing different strategies. This area is open for future researchers to investigate the impact and relative importance of different strategies using empirical and analytical tools.

5.5. Resilient supply chain vs. other management practices

A new trend emerging in the literature is comparing and integrating different management practices such as lean, agile, resilient, and green into a cohesive framework. Further investigation is warranted on the characteristics of a supply chain design based on each of these practices, and developing strategies to integrate all of them into a unified framework.

5.6. Resilience in SMEs

Another finding of this study was a new trend focused on resilience in the context of small and medium-sized enterprises (SMEs). As stated by Ates and Bititci (2011), SMEs constitute over 70% of the world's production, and they are more vulnerable to disruptions. A literature review by Bhamra et al. (2011) showed there is little information on how organizations, particularly SMEs, can enhance resilience. Demmer et al. (2011) found that the antecedents of resilience of large corporations also apply to SMEs. However, questions remain on how SMEs can enhance resilience, and whether resilience principles associated with large enterprises are also applicable to SMEs. This area is open for future studies and needs both empirical and analytical studies.

5.7. Supply chain resilience measurement

The literature in SCRM is sparse on how the resilience of supply chains can be measured and analyzed. Only a few articles discuss supply chain resilience measurement. Without understanding the level of resilience of a system, it would be difficult to assess the response and reaction of the supply chain during disruptions. Thus, future studies should examine development of measures that can evaluate the supply chain resilience.

6. Conclusion

In this study, we conducted a literature survey to review the existing body of knowledge in supply chain resilience. Through this process we identified 100 publications, including journal papers, conference proceeding, and book chapters. The target publications of this study covered a broad spectrum of areas such as large organizations, small and medium-sized enterprises, and global and regional supply chains. The concept of resilience from an organizational and a supply chain perspective was reviewed, and its principles were identified.

Through conducting a comprehensive review of the literature in supply chain resilience within a 15-year timeframe (2000–2015), we discussed the evolution of supply chain resilience and examined different definitions and concepts related to organizational resilience. We then proposed new definitions for enterprise and supply chain resilience that reflect different stages of resilience. We proposed a supply chain resilience timeline and a framework for the principles of supply chain resilience that emerged as the result of our literature review. We hope the findings of this study provide a comprehensive basis for future studies in the area of supply chain resilience.

Acknowledgments

This research was supported by an award from the National Science Foundation (NSF), "Research Initiation Award Grant: Understanding Risks and Disruptions in Supply Chains and their Effect on Firm and Supply Chain Performance", Award Number 1238878.

References

Akgün, A., Keskin, H., 2014. Organisational resilience capacity and firm product innovativeness and performance. Int. J. Prod. Res. 52 (23), 6918–6937.

Alberts, D.S., 2011. The agility advantage: a survival guide for complex enterprise and endeavors. The Command and Control Research Program Publication. Department of Defense, Washington, USA.

Ates, A., Bititci, U., 2011. Change process: a key enabler for building resilient SMEs. Int. J. Prod. Res. 49 (18), 5601–5618.

Ambulkar, S., Blackhurst, J., Grawe, S., 2015. Firm's resilience to supply chain disruptions: scale development and empirical examination. J. Oper. Manag. 33–34, 111–122.

Azadeh, A., Atrchin, N., Salehi, V., Shojaei, H., 2014. Modelling and improvement of supply chain with imprecise transportation delays and resilience factors. Int. J. Logist.: Res. Appl. 17 (4), 269–282.

Bakshi, N., Kleindorfer, P., 2009. Co-opetition and investment for supply-chain resilience. Prod. Oper. Manag. 18 (6), 583–603.

Barratt, M.A., Oke, A., 2007. Antecedents of supply chain visibility: a resource-based theory perspective. J. Oper. Manag. 25 (6), 1217–1233.

Barton, M., and Christianson, M. (2006) Organizational resilience: a social mechanisms perspective. Symposium presented at the 2006 annual academy of management meeting, 11–16 August, Atlanta, GA.

Barroso, A.P., Machado, V.H., Cruz Machado, V., 2011. Supply chain resilience using the mapping approach. In: Dr. Pengzhong, Li (Ed.), Supply Chain Management. InTech, ISBN: 978-953-307-184-8. http://dx.doi.org/10.5772/15006, Available from: ⟨http://www.intechopen.com/books/supply-chain-management/supply-chain-resilience-using-the-mapping-approach⟩.

Bhamra, R., Dani, S., Burnard, K., 2011. Resilience: the concept, a literature review and future directions. Int. J. Prod. Res. 49 (18), 5375–5393.

Blackhurst, J., Craighead, C.W., Elkins, D., Handfield, R.B., 2005. An empirically derived agenda of critical research issues for managing supply-chain disruptions. Int. J. Prod. Res. 43 (19), 4067–4081.

Blackhurst, J., Dunn, J., Craighead, C., 2011. An empirically derived framework of global supply resiliency. J. Bus. Logist. 32 (4), 374–391.

Boone, C.A., Craighead, C.W., Hanna, J.B., Nair, A., 2013. Implementation of a system approach for enhanced supply chain continuity and resiliency: a longitudinal study. J. Bus. Logist. 34 (3), 222–235.

Borecki, D.Y., Rofcanin, Y., Gürbüz, H., 2014. Organisational resilience and relational dynamics in triadic networks: a multiple case analysis. Int. J. Prod. Res., 1–29.

Brandon-Jones, E., Squire, B., Autry, C.W., Petersen, K.J., 2014. A contingent resource-based perspective of supply chain resilience and robustness. J. Supply Chain Manag. 50 (3), 55–73.

Briano, E., Caballini, C., Giribone, P., Revetria, R., 2010. Objectives and perspectives for improving resiliency in supply chains. WSEAS Trans. Syst. 9 (2), 136–145.

Burnard, K., Bhamra, R., 2011. Organisational resilience: development of a conceptual framework for organisational responses. Int. J. Prod. Res. 49 (18), 5581–5599.

Cabral, I., Grilo, A., Cruz Machado, V., 2012. A decision-making model for Lean, Agile, Resilient and Green supply chain management. Int. J. Prod. Res. 50 (17), 4830–4845.

Cardoso, S.R., Barbosa-Póvoa, A.P., Relvas, S., Novais, A.Q., 2015. Resilience metrics in the assessment of complex supply-chains performance operating under demand uncertainty. Omega 56, 53–73.

Carvalho, H., Cruz Machado, V., 2007. Designing principles to create resilient supply chains. In: Proceedings of the 2007 Industrial Engineering Research Conference, pp. 186–191.

Carvalho, H. (2011) Resilience index: proposal and application in the automotive supply chain. In: Proceedings of the 18th EUROMA Conference, Cambridge, UK, 3–6 July.

Carvalho, H., Cruz-Machado, V., 2011. Integrating Lean, Agile, Resilience and Green paradigms in supply chain management (LARG_SCM). In: Dr. Pengzhong, Li (Ed.), Supply Chain Management. InTech, ISBN: 978-953-307-184-8. http://dx.doi.org/10.5772/14592, Available from: http://www.intechopen.com/books/supply-chain-management/integrating-lean-agile-resilience-and-green-paradigms-in-supply-chain-management-larg-scm-.

Carvalho, H., Duarte, S., Machado, V.C., 2011. Lean, Agile, Resilient and Green: divergencies and synergies. Int. J. Lean Six Sigma 2 (2), 151–179.

Carvalho, H., Barroso, A.P., Machado, V.H., Azevedo, S., Cruz-Machado, V., 2012a. Supply chain redesign for resilience using simulation. Comput. Ind. Eng. 62, 329–341.

Carvalho, H., Azevedo, S.G., Cruz Machado, V., 2012b. Agile and resilient approaches to supply chain management: influence on performance and competitiveness. Logist. Res. 4, 49–62.

Chan, J.W.K., 2011. Enhancing organisational resilience: application of viable system model and MCDA in a small Hong Kong company. Int. J. Prod. Res. 49 (18), 5545–5563.

Chowdhury, M.H., Quaddus, M.A., 2015. A multiple objective optimization based QFD approach for efficient resilient strategies to mitigate supply chain vulnerabilities: the case of garment industry of Bangladesh. Omega0305-0483 . http://dx.doi.org/10.1016/j.omega.2015.05.016, Available online 25 June 2015.

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

Christopher, M., Rutherford, C., 2004. Creating supply chain resilience through agile six sigma. Critical EYE Publications, Available from: ⟨http://martin-christopher.info/wp-content/uploads/2009/12/critical_eye.pdf⟩.

Christopher, M., Holweg, M., 2011. Supply Chain 2.0': managing supply chains in the era of turbulence. Int. J. Phys. Distrib. Logist. Manag. 41 (1), 63–82.

Christopher, M., Mena, C., Khan, O., Yurt, O., 2011. Approaches to managing global sourcing risk. Supply Chain Manag.: Int. J. 16 (2), 67–81.

Chopra, S., Sodhi, M.S., 2004. Managing risk to avoid supply-chain breakdown. MIT Sloan Manag. Rev. 46 (1), 53–62.

Chopra, S., Sodhi, M.S., 2014. Reducing the risk of supply chain disruption. MIT Sloan Manag. Rev. 55 (3), 72–80.

Colicchia, C., Dallari, F., Melacini, M., 2010. Increasing supply chain resilience in a global sourcing context. Prod. Plann. Control 21 (7), 680–694.

Coutu, D.L., 2002. How resilience works. Harv. Bus. Rev. 80 (5), 46–56.

Craighead, C.W., Blackhurst, J., Rungtusanatham, M.J., Handfield, R.B., 2007. The severity of supply chain disruptions: design characteristics and mitigation capabilities. Decis. Sci. 38 (1), 131–156.

Cruz Machado, V., Durate, S., 2010. Tradeoffs among paradigms in supply chain management. In: Proceedings of the 2010 International Conference on Industrial Engineering and Operations Management, Dhaka, Bangladesh, January 9–10, 2010.

Datta, P.P., Christopher, M., Allen, P., 2007. Agent-based modeling of complex production/distribution systems to improve resilience. Int. J. Logist. Res. Appl. 10 (3), 187–203.

Demmer, W.A., Vickery, S.K., Calantone, R., 2011. Engendering resilience in small- and medium-sized enterprises (SMEs): a case study of Demmer Corporation. Int. J. Prod. Res. 49 (18), 5395–5413.

Dobni, C.B., 2008. Measuring innovation culture in organizations. Eur. J. Innov. Manag. 11 (4), 539–559.

Faisal, M.N., Banwet, D.K., Shankar, R., 2006. Supply chain risk mitigation: modeling the enablers. Bus. Process. Manag. J. 12 (4), 535–552.

Faisal, M.N., Banwet, D.K., Shankar, R., 2007. Information risks management in supply chains: an assessment and mitigation framework. J. Enterp. Inf. Manag. 20 (6), 677–699.

Falasca, M., Zobel, C.W., Cook, D., 2008. A decision support framework to assess supply chain resilience. In: Proceedings of the 5th International ISCRAM Conference, Washington.

Fiksel, J., 2003. Designing resilient, sustainable systems. Environ. Sci. Technol. 37 (23), 5330–5339.

Fiksel, J., 2006. Sustainability and resilience: toward a systems approach. Sustain.: Sci. Pract. Policy 2 (2), 14–21.

Fiksel, J., Polyviou, M., Croxton, K.L., Pettit, K.J., 2015. From risk to resilience: learning to deal with disruption. MIT Sloan Manag. Rev. Winter issue.

Francis, V., 2008. Supply chain visibility: lost in translation? Supply Chain Management: An International Journal 13 (3), 180–184.

Gaonkar, R.S., Viswanadham, N., 2007. Analytical framework for the management of risk in supply chains. IEEE Trans. Autom. Sci. Eng. 4 (2), 265–273.

Ghadge, A., Dani, S., Kalawsky, R., 2012. Supply chain risk management: present and future scope. Int. J. Logist. Manag. 23 (3), 313–339.

Gilly, J.P., Kechidi, M., Talbot, D., 2014. Resilience of organisations and territories: the role of pivot firms. Eur. Manag. J. 32, 596–602.

Golgeci, I., Ponomarov, S.Y., 2013. Does firm innovativeness enable effective responses to supply chain disruptions? An empirical study. Supply Chain Manag.: Int. J. 18 (6), 604–617.

Gong, J., Mitchell, J.E., Krishnamurthy, A., Wallace, W.A., 2013. An interdependent layered network model for a resilient supply chain. Omega: Int. J. Manag. Sci. 46, 104–116.

Gunasekaran, A., Rai, B.K., Griffin, M., 2011. Resilience and competitiveness of small and medium size enterprises: an empirical research. Int. J. Prod. Res. 49 (18), 5489–5509.

Hamel, G., Välikangas, L., 2003. The quest for resilience. Harv. Bus. Rev. 81 (9), 52–63.

Horne, J.F., 1997. The coming age of organizational resilience. Bus. Forum 22 (2/3/4), 24–28.

Horne, J.F., Orr, J.E., 1998. Assessing behaviors that create resilient organizations. Employ. Relat. Today 24, 29–40.

Hurley, R.F., Hult, G.T., 1998. Innovation, market orientation, and organizational learning: An integration and empirical examination. Journal of Marketing 62, 42–54.

Isotupa, K.S., Kelly, M., Kleffner, A., 2014. Building Resilient Supply Chains Using Supply Chain and Traditional Risk Management and Insurance Techniques (11.02.2014).

Johnson, N., Elliott, D., Drake, P., 2013. Exploring the role of social capital in facilitating supply chain resilience. Supply Chain Manag.: Int. J. 18 (3), 324–336.

Jüttner, U., Peck, H., Christopher, M., 2003. Supply chain risk management: outlining an agenda for future research. Int. J. Logist. 6 (4), 197–210.

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

Kim, Y., Chen, Y., Linderman, K., 2015. Supply network disruption and resilience: a network structural perspective. J. Oper. Manag. 33–34, 43–59.

Klibi, W., Martel, A., 2012. Modeling approaches for the design of resilient supply networks under disruptions. Int. J. Prod. Res. 135 (2), 882–898.

Knemeyer, A.M., Zinn, W., Eroglu, C., 2009. Proactive planning for catastrophic events in supply chains. J. Oper. Manag. 27 (2), 141–153.

Kristiano, Y., Gunasekaran, A., Helo, P., Hao, Y., 2014. A model of resilient supply chain network design: a two-stage programming with fuzzy shortest path. Expert Syst. Appl 41, 39–49.

Lee, H., 2004. The triple-A supply chain. Harv. Bus. Rev. 10, 2–12.

Lengnick-Hall, C.A., Beck, T.E., Lengnick-Hall, M.L., 2011. Developing a capacity for organizational resilience through strategic human resource management. Hum. Resour.Manag. Rev. 21 (3), 243–255.

Losada, C., Scaparra, M.P., O'Hanley, J.R., 2012. Optimizing system resilience: a facility protection model with recovery time. Eur. J. Oper. Res. 217 (3), 519–530.
Madni, A.M., Jackson, S., 2009. Towards a conceptual framework for resilience engineering. IEEE Syst. J. 3, 181–191.
Mallak, L., 1998. Putting organizational resilience to work. Ind. Manag. 40, 8–13.
Mandal, S., 2012. An empirical investigation into supply chain resilience. IUP J. Supply Chain Manag. IX (4), 46–61.
Manuj, I., Mentzer, J.T., 2008. Global supply chain risk management strategies. Int. J. Phys. Distrib. Logist. Manag. 38 (3), 192–223.
Martins, E., Martins, N., 2002. An organizational culture model to promote creativity and innovation. SA J. Ind. Psychol. 28 (4), 58–65.
McDonald, N., 2006. Organisational resilience and industrial risk. In: Hollnagel, E., Woods, D.D., Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate, Hampshire, pp. 155–179.
Melnyk, S.A., Closs, D.J., Griffis, S.E., Zobel, C.W., Macdonald, J.R., 2014. Understanding supply chain resilience. Supply Chain Manag. Rev. 18 (1), 34–41.
Moore, S.B., Manring, S.L., 2009. Strategy development in small and medium sized enterprises for sustainability and increased value creation. J. Cleaner Prod. 17, 276–282.
Munoz, A., Dunbar, M., 2015. On the quantification of operational supply chain resilience. Int. J. Prod. Res. http://dxdoi.org/10.1080/00207543.2015.1057296, Available online 25 June 2015
Murinho, T., Romano, E., C. Santillo, L., 2011. Supply chain performance sustainability through resilience function. In: Proceedings of the 2011 Winter Simulation Conference, Napoli, Italy.
Pal, R., Torstensson, H., Mattila, H., 2014. Antecedents of organizational resilience in economic crises – an empirical study of Swedish textile and clothing SMEs. Int. J. Prod. Econ. 147, 410–428.
Peck, H., 2005. Drivers of supply chain vulnerability: an integrated framework. Int. J. Phys. Distrib. Logist. Manag. 35 (4), 210–232.
Pettit, T.J., Fiksel, J., Croxton, K.L., 2010. Ensuring supply chain resilience: development of a conceptual framework. J. Bus. Logist. 31 (1), 1–21.
Pettit, T.J., Croxton, K.L., Fiksel, J., 2013. Ensuring supply chain resilience: development and implementation of an assessment tool. J. Bus. Logist. 34 (1), 46–76.
Ponis, S.T., Koronis, E., 2012. Supply chain resilience: definition of concept and its formative elements. J. Appl. Bus. Res. 28 (5), 921–930.
Ponomarov, S.Y., 2009. Summary brief understanding operational and relational resilience in buyer-supplier dyads. Soc. Market. Adv. Proc., 325.
Ponomarov, S.Y., Holcomb, M.C., 2009. Understanding the concept of supply chain resilience. Int. J. Logist. Manag. 20 (1), 124–143.
Ponomarov, S.Y., 2012. Antecedents and Consequences of Supply Chain Resilience: A Dynamic Capabilities Perspective (Ph.D. dissertation (Business Administration)). The University of Tennessee, Knoxville, TN.
Prater, E., Biehl, M., Smith, M.A., 2001. International supply chain agility — tradeoffs between flexibility and uncertainty. Int. J. Oper. Prod. Manag. 21, 823–839.
Rajesh, R., Ravi, V., 2015. Supplier selection in resilient supply chains: a grey relational analysis approach. J. Clean. Prod. 86, 343–359.
Ratick, S., Mecham, B., Aoyama, Y., 2008. Locating backup facilities to enhance supply chain disaster resilience. Growth Change 39 (4), 642–666.
Reinmoeller, P., Van Baardwijk, N., 2005. The link between diversity and resilience. MIT Sloan Manag. Rev. 46 (4), 61–65.
Rice, J.B., Caniato, F., 2003. Building a secure and resilient supply network. Supply Chain Manag. Rev. 7 (5), 22–30.
Rice, J.B., Caniato, F., Fleck, J., Disraelly, D., Lowtan, D., Lensing, R., Pickett, C., 2003. Supply Chain Response to Terrorism: Creating Resilient and Secure Supply Chains, Supply Chain Response to Terrorism Project: Interim Report of Progress and Learnings. MIT Center for Transportation and Logistics, Massachusetts.
Roberta Pereira, C., Christopher, M., Lago Da Silva, A., 2014. Achieving supply chain resilience: the role of procurement. Supply Chain Manag.: Int. J. 19 (5/6), 626–642.
Sáenz, M.J., Revilla, E., 2014. Creating more resilient supply chains. MIT Sloan Manag Rev Summer issue.
Santos-Vijande, M.L., Alvarez-Gonzalez, L.I., 2007. Innovation and organizational innovation in total quality oriented firms: the moderating role of market turbulence. Technovation 27 (9), 514–532.
Sawik, T., 2013. Selection of resilient supply portfolio under disruption risks. Omega: Int. J. Manag. Sci. 41 (2), 259–269.
Scholten, K., Scott, P.S., Fynes, B., 2014. Mitigation processes – antecedents for building supply chain resilience. Supply Chain Manag.: Int. J. 19 (2), 211–228.
Scholten, K., Schilder, S., 2015. The role of collaboration in supply chain resilience. Supply Chain Manag.: Int. J. 20 (4), 471–484.
Seville, E., Brunsdon, D., Dantas, A., Le Masurier, J., Wilkinson, S., Vargo, J., 2006. Building organizational resilience: a summary of key research findings. Resilient Organizations Research Programme, Christchurch, New Zealand, August 2006.
Sharifirad, M.S., Ataei, V., 2012. Organizational culture and innovation culture: exploring the relationships between constructs. Leadersh. Organ. Dev. J. 33 (5), 494–517.
Sheffi, Y., 2001. Supply chain management under the threat of international terrorism. Int. J. Logist. Manag. 12 (2), 1–11.
Sheffi, Y., 2005. Preparing for the big one. IEE Manuf. Eng. 84 (5), 12–15.
Sheffi, Y., Rice, J.B., 2005. A supply chain view of the resilient enterprise. MIT Sloan Manag. Rev. 47 (1), 41–48.
Sheffi, Y., 2006. Resilience reduces risk. Logist. Q. 12 (4), 12–14, available at.
Sinha, P.R., Whitman, L.E., Malzahn, D., 2004. Methodology to mitigate supplier risk in an aerospace supply chain. Supply Chain Manag. 9 (2), 154–168.
Smith, R., 2004. Operational capabilities for the resilient supply chain. Supply Chain Pract. 6 (2), 24–35.
Sodhi, M., Lee, S., 2007. An analysis of sources of risk in the consumer electronics industry. J. Oper. Res. Soc. 58 (11), 1430–1439.
Soni, U., Jain, V., 2011. Minimizing the vulnerabilities of supply chain: a new framework for enhancing the resilience. In: Proceeding of the 2011 IEEE IEEM, pp. 933–939.
Soni, U., Jain, V., Kumar, S., 2014. Measuring supply chain resilience using a deterministic modeling approach. Comput. Ind. Eng. 74, 11–25.
Spiegler, V.L.M., Naima, M.M., Wikner, J., 2012. A control engineering approach to the assessment of supply chain resilience. Int. J. Prod. Res. 50 (21), 6162–6187.
Starr, R., Newfrock, J., Delurey, M., 2003. Enterprise resilience: managing risk in the networked economy. Strategy Bus. 30, 70–79.
Stecke, K., Kumar, S., 2009. Sources of supply chain disruptions, factors that breed vulnerability, and mitigating strategies. J. Market. Channels 16 (3), 193–226.
Stefanovic, D., Stefanovic, N., Radenkovic, B., 2009. Supply network modelling and simulation methodology. Simul. Model. Pract. Theory 17 (4), 743–766.
Stevenson, M., Spring, M., 2007. Flexibility from a supply chain perspective: definition and review. Int. J. Oper. Prod. Manag. 27 (7), 685–713.
Sullivan-Taylor, B., Branicki, B., 2011. Creating resilient SMEs: why one size might not fit all. Int. J. Prod. Res. 49 (18), 5565–5579.
Sutcliffe, K.M., Vogus, T.J., 2003. Organizing for resilience. In: Cameron, K.S., Dutton, J.E., Quinn, R.E. (Eds.), Positive Organizational Scholarship: Foundations of a New Discipline. Berrett-Koehler, San Francisco, pp. 94–110.
Tang, C., 2006a. Perspectives in supply chain risk management. Int. J. Prod. Res. Econ. 103 (2), 451–488.
Tang, C., 2006b. Robust strategies for mitigating supply chain disruptions. Int. J. Logist. Res. Appl. 9 (1), 33–45.
Tang, C., Tomlin, B., 2008. The power of flexibility for mitigating supply chain risks. Int. J. Prod. Econ. 116 (1), 12–27.
Tang, O., Musa, S., 2010. Identifying risk issues and research advancements in supply chain risk management. Int. J. Prod. Econ. 133 (1), 25–34.
The ABS Journal Guide, 2015. ABS Academic Journal Quality 2015. Available at: ⟨http://charteredabs.org/academic-journal-guide-2015-view/⟩.
Tomlin, B., 2006. On the value of mitigation and contingency strategies for managing supply chain disruption risks. Manag. Sci. 52 (5), 639–657.
Torabi, S.A., Baghersad, M., Mansouri, S.A., 2015. Resilient supplier selection and order allocation under operational and disruption risks. Transp. Res.: Part E 79, 22–48.
Urciuoli, L., Mohanty, S., Hinsta, J., Boekesteijn, E.G., 2014. A multiple case study approach on oil and gas supply chains to Europe. Supply Chain Manag.: Int. J. 19 (1), 46–63.
Vogus, T.J., Sutcliffe, K.M., 2007. Organizational resilience: towards a theory and research agenda. In: Proceedings of the IEEE International Conference on Systems, Man and Cybernetics, ISIC, 7–10 October, Montreal, p. 3418.
Wang, X., Herty, M., Zhao, L., 2015. Contingent rerouting for enhancing supply chain resilience from supplier behavior perspective. Int. Trans. Oper. Res., 1–22.
Wagner, S.M., Bode, C., 2006. An empirical investigation into supply chain vulnerability. J. Purch. Supply Manag. 12 (6), 301–312.
Waters, D., 2007. Supply Chain Risk Management: Vulnerability and Resilience in Logistics. Kogan Page Limited, London.
Weick, K.E., Sutcliffe, K.M., 2001. Managing the unexpected — assuring high performance in an age of complexity. Jossey-Bass, San Francisco.
Wicher, P., Lenort, R., 2012. The ways of creating resilient supply chains, [CD-ROM]. In: Proceedings of CLC 2012: Carpathian Logistics Congress. pp. 688–694.
Wieland, A., Wallenburg, C.M., 2013. The influence of relational competencies on supply chain resilience: a relational view. Int. J. Phys. Distrib. Logist. Manag. 43 (4), 300–320.
Wildavsky, A., 1988. Searching for Safety. Transaction Books, New Brunswick, NJ.
Wilding, R., 2013. Supply chain temple of resilience. Logist. Transp. Focus 15 (11), 54–59.
Winston, A., 2014. Resilience in a hotter world. Harv. Bus. Rev. 92 (4), 56–64.
Woods, D.D., 2006. Essential characteristics of resilience for organizations. In: Hollnagel, E., Woods, D.D., Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate, Aldershot, UK, pp. 69–76.
Yang, Y., Xu, X., 2015. Post-disaster grain supply chain resilience with government aid. Transp. Res. Part E 76, 139–159.
Yang, B., Yang, Y., 2010. Postponement in supply chain risk management: a complexity perspective. Int. J. Prod. Res. 48 (7), 1901–1912.
Zsidisin, G.A., Wagner, S.M., 2010. Do perceptions become reality? The moderating role of supply chain resiliency on disruption occurrence. J. Bus. Logist. 31 (2), 1–20.