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Anurag Tewari

Upstream Supply Chain Vulnerability, Robustness and Resilience: A Systematic Review of Literature

SCHOOL OF MANAGEMENT
M Res Dissertation

MASTERS OF RESEARCH
Academic Year: 2012 - 2013

Supervisor: Dr. Liz Varga
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This thesis is submitted in partial fulfilment of the requirements for the degree of Masters of Research

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ABSTRACT

Purpose: In the last decade, supply chains of many global firms have been exposed to severe and costly supply chain disruptions. Triggered by either a manmade or a natural disaster, these disruptions are often a result of the increased network complexity and interdependency. One of the many contributing factors to this increased network complexity is the conscious effort by organizations to over optimise their efficiency and performance.

The field of supply chain resilience, robustness and vulnerability studies, a new and growing area of knowledge, is contributing towards discovering the causes leading to supply chain disasters and measures to tackle them. Criticized to be highly fragmented and fraught with conceptual ambiguity, the filed has been evolving by incorporating vulnerability and resilience research from other interdisciplinary domains.

This present research aims at mapping the intellectual territory of the resilience, robustness and vulnerability domain by conducting a literature review. The review also aims to establish a conceptual clarity in the definition of terms and constructs relevant to the field and to discover conceptual and methodological gaps in the existing body of literature.

Design/methodology/approach: This literature review is conducted using a systematic review approach which benefits from a clearly defined audit and decision trail. After filtering through 2077 titles, the review is taken up for 43 articles.

Findings: The review demonstrates that the drivers of vulnerability and strategies to tackle it can be grouped into three themes, Structural, Operational and Strategic. The review also demonstrates that the field is still plagued with conceptual ambiguity. By the analysis of the findings, a number of research directions were identified.

Research limitations/implications: Major limitations to this study were the associated personal bias in quality assessment of included and excluded articles. Also, due to blurred definitions of terms and constructs in the literature, the thematic classification of findings could be challenged. Lastly, it cannot be stated with conviction that the chosen 43 articles are sufficient.

Practical implications: This research highlights the future conceptual and methodological prospects in the field of resilience, robustness and vulnerability. The direction of structural research proposed in the thesis has a very high potential to secure future supply chains.

Originality/value: This review is first to address the issue of SCV, SCRel and SCRob. The review provides an extensive overview of the present extant of the vulnerability, robustness research and it proposes a thematic framework to further extend the knowledge in this filed.

Keywords:

Supply Chain, Robustness, Reliability, Risk Mitigation, Upstream, Network

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My warm thanks are due to Dr. David Denyer for his motivation and continuous support and systematic guidance throughout my thesis.

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LIST OF ABBREVIATIONS

JIT: Just in Time

JIS: Just in Sequence

SCRel: Supply chain reliability

SCRes: Supply chain resilience

SCRob: Supply chain robustness

SCRM: Supply chain risk management

SCV: Supply chain vulnerability

SC: Supply Chains

1 INTRODUCTION

1.1 Background

Over the last decade, interest within the supply chain management research has grown in the field of network risk (Albino et al., 1998; Hallikas et al., 2002; Hallikas et al., 2004; Harland et al., 2003). This shift in perception, from a focal firm perspective to a network perspective, reflects the growing acceptance of network effects, especially of a firm's network positioning, on firm level outcomes (Gulati et al., 2000; Reagans and Zuckerman, 2001; Tsai, 2001). In organizational supply chain networks, an increased level of complexity and interdependency coupled with the organizational efforts to over optimise the efficiency and performance of supply chains has resulted in the amplification of supply chain fragility and vulnerability to disruption (Albino et al., 1998). This increased fragility and complexity, are argued to be major contributors to the many severe supply chain disruptions that the world has witnessed over the recent years. Some of these well documented disruptions have resulted in severe financial and reputational loss for prestigious global firms, like Toyota, GM, Apple etc (Pettit et al., 2010; Sheffi, 2001; Sheffi, 2005; Wagner and Bode, 2006), that were highly regarded and quoted for their superior operational excellence. These costly network disruptions have prompted academicians and practitioners to look for constructs influencing supply network risk.

Within the existing literature on supply network risk ,the aspects of supply chain resilience, robustness and vulnerability are relatively unexplored(Wagner and Bode, 2006). Most of the supply chain resilience literature is theoretical and taxonomical; focused largely at identifying characteristics and constructs that may have an influence on supply chain resilience (Ponomarov and Holcomb, 2009). However the literature falls short of addressing the complex interplay of

relationships between these constructs (Ponomarov and Holcomb, 2009). Motivated by this fact, in my doctoral research , I intend to investigate the existing debates within the supply chain resilience, robustness, and vulnerability literature. Resilience and vulnerability would be investigated particularly for low probability and high impact events, which result in longer duration disruptions. These disruptions often originate in the extended supplier or logistics networks and are difficult to manage using conventional measures like inventory. Since these disruptions are radically different from the normal day to day variations in demand or delays in supply components, we will intentionally avoid investigating minor demand or supply variations; instead the focus of this research will be on long and severe catastrophic disruptions that originate in the upstream supply chain of a focal manufacturing or retailing firm.

Within the vulnerability and resilience domain, there is evidence of a mediating effect of network structure. In the process of this review I attempt to gain useful insights regarding the moderating effect of network structure variables on resilience, robustness and vulnerability.

In the supply chain risk and disruption research, the structural aspect of network has not yet been fully explored. Network structure or design is a critical component of supply chain reliability (Adenso-Diaz et al., 2012). Historically, the supply chain design of most firms was driven by the sole objective of attaining cost efficiency (Stecke and Kumar, 2009) through strategies of global sourcing, lean manufacturing and supplier consolidation (Fisher, 1997; Hult et al., 2004). However, due to these strategies the modern supply chains have become longer, more complex, tightly coupled, highly interdependent and more prone to disruption (Harland et al., 2003; Christopher and Peck, 2004; Hendricks and Singhal, 2005; Tang, 2006). A study of upstream

supply network structure and resilience will provide useful insights to mitigate risk originating from catastrophic supply chain disruptions.

1.2 Objective Of The Review And Review Question

With the aim of interrogating the supply chain resilience literature in a structured and objective manner, I undertake a systematic literature review. The objective of the review is to discover and synthesise valid arguments from empirical and conceptual literature on supply chain vulnerability (SCV), supply chain robustness (SCRob) and supply chain resilience (SCRes). An encompassing picture of the overall subject area would help channelize future research efforts.

From my personal understanding of the phenomenon of network resilience, I am particularly interested to establish structural aspects of supply chain resilience. But since the domain has not yet matured enough to carry a systematic review, I propose to investigate all the aspects of vulnerability, robustness and resilience in upstream supply chain network. Motivated by my objectives leading to the review, I propose the following review question and sub question to look at resilience from both the broader supply chain context and the specific network structure context. The review question for this study is

What are the aspects of upstream supply chain vulnerability and resilience?

This will be investigated using the following three sub questions

Q1. What are the drivers of supply chain vulnerability and resilience?

Q2. What are the supply network strategies that influence vulnerability or resilience?

Supply chain strategies could include any of the following: creating globalized or localized supply chains , single or multiple sourcing, centralized or decentralized distribution , decisions on outsourcing , reduced supplier base,

using technological innovations , favourable or unfavourable network topologies.

Q3. What are the structural properties of supply networks that influence resilience, robustness or vulnerability?

Structural properties are defined from a network theory perspective and may include any of the following: Number of possible connections, Positioning of a node in a network, Size of the network vertical and horizontal, Centrality, Structural holes, Network ties, strong or weak, Number of roles played by each actor (especially critical roles), Distinctive capabilities, and Network tier structure and shape, composition, ownership, levels of vertical and horizontal integration, location, complexity, flexibility.

1.3 Structure Of The Review

This review is divided into seven chapters; Figure 1.1 provides their names in a chronological order.

Figure 1-1: Systematic review structure

Chapter one introduces the background and motivations leading to this review. It also presents the review objectives and the review questions and sub questions. This is followed by chapter two that provides a description of the key terms and definitions relevant to the phenomenon and it also positions the field of enquiry within the existing management literature. The chapter also provides a rational for the proposed literature positioning. Chapter three provides a detailed description of the methodology for the systematic review. The chapter provides an account of the search strategy such as keywords, search strings, along with description of the selection and appraisal criterion. A detail of the review panel supporting this research is also included in this chapter. Chapter four illustrates the descriptive statistics of the selected literature. The chapter describes the chronological distribution of articles, geographical location of authors and provenance of these articles, the type of journals that include these articles, theoretical and methodological approaches used for the studies. Chapter five presents a synthesis of the findings discovered in the text that is relevant to the review question. Chapter six presents a discussion of these findings and evaluates the insights gained in the process. The chapter also discusses about the existing gaps in the literature and provides directions about future research. Finally chapter seven concludes with a discussion about the limitations for this study and with a reflection on my personal learning during the review process.

2 POSITIONING THE FIELD OF ENQUIRY

2.1 Introduction

This chapter presents the literature positioning of my research. The positioning of my literature review has two overlapping literature domains within the wider domain of supply chain management. The first domain is of Supply chain vulnerability / resilience literature and the second domain is of supply chain strategy/ capability/ performance literature. The supply chain vulnerability/ resilience literature is also a part of the risk and disruption research literature. Figure 2.1 presents an overview of these domains and their overlap. The contribution of my review will be to the literature of supply chain management.

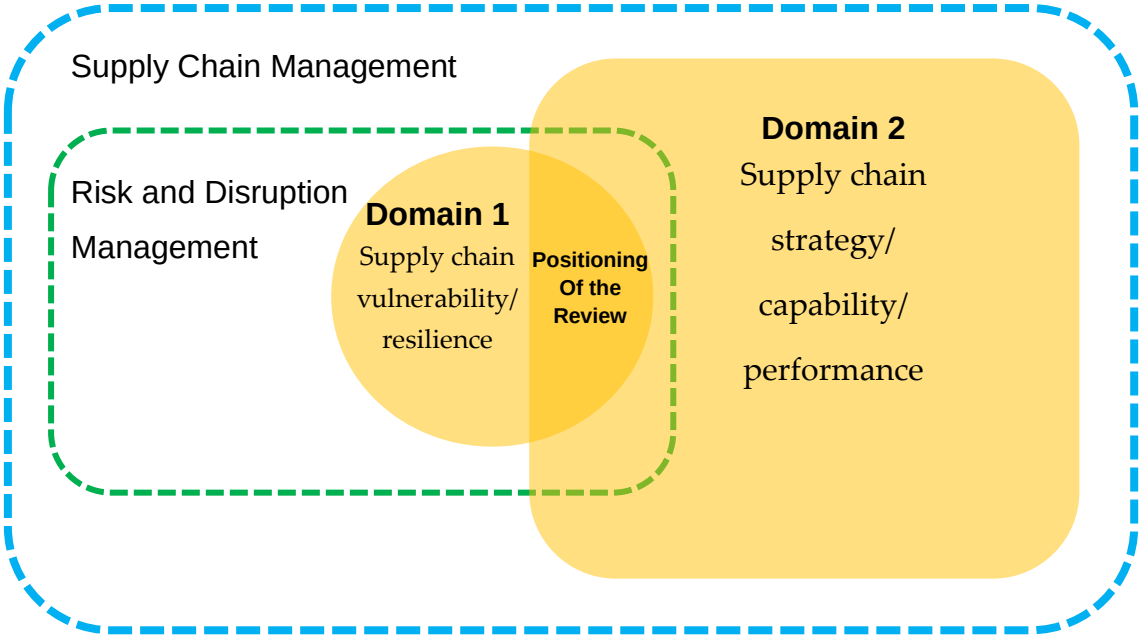

Figure 2-1 Literature positioning

The phenomenon of my interest lies in the investigation of upstream supply chain disruptions. Since risk and disruption research is a very extensive literature domain, I have chosen to focus on the aspects of vulnerability, resilience and robustness, a sub domain of disruption research.

A primary investigation of supply chain disruption and risk literature indicates that there is a very mature body of literature in the field of supply chain disruption and supply chain risk(Hallikas et al., 2004; Chopra and Sodhi, 2004; Finch, 2004; Jüttner et al., 2003; Jüttner and Maklan, 2011; Kleindorfer and Saad, 2005; Spekman and Davis, 2004; Svensson, 2000). However, the contribution in SCV, SCRes and SCRob was found to be highly fragmented (see page viii for list of abbreviations). The SCV and SCRes literature lacks clarity of definition and conceptualization (Wagner and Neshat, 2012). A systematic literature review targeted at these constructs will be helpful to gain insight into the existing debates and disagreements within the domain.

The primary objective of any risk management literature is to assist the decision makers in mitigating and managing the risks. The process of risk mitigation can be argued to have four crucial aspects; identification of sources, analysis of risk, strategies to manage risk and finally monitoring future risk (Zsidisin and Wagner, 2010). The aspects of strategy formulation and monitoring risk relates to the second literature domain of this systematic literature review: the literature on supply chain strategy and capability. A synthesis of literature in this field will help understand the design of strategic interventions and the moderating effect of these upon risk and vulnerability.

The rest of the chapter is structured as follows. The chapter starts with definitions of terms used for these domains followed by a discussion of further literature streams chosen within each domain.

2.2 Domain of Supply Chain Vulnerability and Resilience

The end of the 90's and the early years of this century saw many supply chain academicians publishing using the terms SCRM and SCV (Albino et al., 1998;

Chopra and Sodhi, 2004; Finch, 2004; Jüttner et al., 2003; Svensson, 2000; Christopher and Lee, 2004; Svensson, 2002a). However post 9/11, the discussion shifted from SCV to terms like SCRes, SC Rob and SCRel (Ponomarov and Holcomb, 2009; Christopher and Peck, 2004; Jüttner and Maklan, 2011; Goetschalckx et al., 2012; Nair and Vidal, 2011).Vulnerability, resilience, robustness etc are a multidisciplinary constructs (Ponomarov and Holcomb, 2009). Researchers in the field of supply chain have adopted the definitions of these constructs from fields like Engineering, Ecology, Psychology, (Ponomarov and Holcomb, 2009) and have operationalized and modified these definitions to suit the supply chain context. In the next section, I present the definitions of these terms from a supply chain context.

2.2.1 Supply Chain Vulnerability (SCV)

Many long and severe supply chain disruptions from recent years have exposed the inherent risk embedded in modern supply chains. This has led to the evolution of supply chains vulnerability as an independent domain (Christopher and Lee, 2004).

Despite two decades of SCV studies, the field is still fraught with conceptual disagreements regarding the formative elements of vulnerability and its operational definition (Wagner and Neshat, 2012). Among the early SCV researchers, Svensson , (Svensson, 2000; Svensson, 2002a; Svensson, 2002b), is the most widely cited. The author argues that the concept of SCV is grounded within the risk and contingency planning literature and its definition can be approached in two dimensions; a disruption event and the resulting consequence. Svensson (2002b) goes on to defines SCV as

"the construct of vulnerability consists of two components: disturbance and the negative consequence of disturbance. A disturbance is defined as a random quantitative or qualitative deviation from what is normal or expected. A negative consequence of disturbance refers to a deteriorated goal accomplishment in terms of economic costs, quantitative deviations such as increased cycle times and down times"

(Svensson, 2002b: pp 15)

The author further argues that this unexpected disruption event could have its origin within the supply chain or external to it and it is often caused by time and relationship dependencies in the chain.

Similar to Svensson (2002a) and Svensson (2002b), in another pioneering cross sector SCV and SCRes research, at the Cranfield University Centre for Logistics, Helen Peck, (Peck, 2005; Peck, 2006), and co researchers have also grounded SCV in traditional risk and risk management literature. Peck (2006) relates vulnerability to something being at risk or having a likelihood or probability to be lost or damaged. This definition of vulnerability, used by Peck (2005) and Peck (2006), is adopted from the Collins English dictionary; as the authors deliberately chose to avoid the existing academic disagreement in defining the SCV construct. The disagreement in principle is about the question that what constitutes vulnerability? Is it the asset at risk or the factors/ drivers leading to a loss? This is evident from the SCV approach adopted by Pettit et al. (2010) amd Jüttner et al. (2003). Jüttner et al. (2003) propose vulnerability to be;

''the propensity of risk sources and risk drivers to outweigh risk mitigating strategies, thus causing adverse supply chain consequences''.

(Jüttner et al., 2003: pp 200)

The definition is addressed from the perspective of risk drivers and not from the perspective of a disruptive event. The most important aspect of this definition is the recognition of the fact that vulnerability refers to losses that are beyond the existing risk mitigation strategies of the firm. This brings in the dimension of unknown and unplanned risk and likelihood of losses incurred due to such risks. A similar argument is presented by Pettit et al., (2010), the authors define SCV as

"fundamental factors that makes an enterprise susceptible to disruptions"
(Pettit et al., 2010: pp 6)

However, to define SCV, most of the Supply chain researchers have used the two dimension approach, disruptive event and consequence, as suggested by Svensson (2002a) and Svensson (2002b). In line with this, Sheffi and Rice (2005) define SCV as the likelihood of disruption and severity of the consequences; Albino et al. (1998) define vulnerability of a production supply chain system as negative impact on a systems' performance due to an unexpected and unavoidable disruption and Wagner and Bode (2006) relate it to probability of occurrence and the severity of disruption caused by it.

Thus, we can conclude that the present SCV literature puts the construct of vulnerability in the domain of risk from unexpected unavoidable disruptive events. The leading SCV researchers view vulnerability as a three dimensional construct: the likelihood of a disruptive event, the resulting negative consequences due to it, such as loss or damage, and the contributing drivers that outweigh the employed risk mitigation strategies of the firm.

2.2.2 Supply Chain Resilience (SCRes)

Contemporary supply chain risk and disruption research is moving from the domain of focal firm to the network level(Harland et al., 2003). The network perspective of risk acknowledges the diffusive nature of risk and the inability of firms to be able to completely mitigate all its risks (Peck, 2006). This has prompted academicians to investigate these risks and resulting disruptions with another complementary dynamic network phenomenon called 'Resilience'.

Originating in multiple disciplines, the phenomena of supply chain resilience has evolved from many interdisciplinary literature (Ponomarov and Holcomb, 2009). The literature of supply chain resilience finds its theoretical foundations in research streams like Network Theory, Graph theory, Systems Theory, and Institutional theory. In the supply chain literature Christopher and Peck (2004) and Sheffi and Rice (2005) can be considered as pioneer contributors to the SCRes research domain. Reporting the findings from a UK Transport department funded research project on network resilience of UK's economic activities, Christopher and Peck (2004) chose to use a dictionary definition of resilience conceptualized from the study of ecosystems. The authors argued supply chains to have a similarity with network of ecosystems; they defined resilience as

"The ability of a system to return to its original state or move to a new, more desirable state after disruption." (Christopher and Peck, 2004: pp 2)

The authors further argued that flexibility and adaptive capacity of a resilient system, in order to reach to a new more desirable state, is the key dimension of the phenomenon. Sheffi (2005)compare a supply chain's disruption resilience to the process of "shock absorption", an analogy symbolically referring to the

amount of abusive stress the supply levels can withstand. The authors define resilience to be the ability of a system to bounce back from an event of disruption. In other SCRes research, following these two studies, most of the academicians have approached resilience within the same framework as Christopher and Peck (2004) or Sheffi and Rice (2005). The only difference is that some authors have stressed more upon the adaptive capacity of the system while others have focused on the capacity of the system to survive or recover . Table 6.1 presents some of the widely quoted definitions and authors from the SCRes research.

Table 2-1: Resilience definitions

Author	Resilience definition
(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
(Sheffi and Rice, 2005)	" A company's resilience is function of its competitive position and the responsiveness of supply chain"
(Tang, 2006)	"robust supply chain strategy would enable a firm to deploy the associated contingency plans efficiently and effectively when facing a disruption. Therefore, having a robust supply chain strategy could make a firm become more resilient.
(Peck, 2005)	"the ability of a system to return to its original or desired state after being disturbed"
(Fiksel, 2006)	"the capacity for an enterprise to survive, adapt, and grow in the face of turbulent change"
(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"

2.2.3 Supply Chain Robustness (SCRob)

The concept of robust design is said to be first introduced in the 1960's by Genuchi Taguchi for the purpose of robust experiment design (Mo and Harrison, 2005). Taguchie's idea of robust experiment design suggests that every process has a design factor, that is controllable, and a noise factor that cannot be controlled. The objective of an efficient design is to make a system robust to the system's noise and the same principle has been adopted in the design of robust supply chains. Defining supply chain robustness towards changing environmental and operational conditions, Goetschalckx et al. (2012) quote

"The capability of the supply network to adapt to these changing conditions and execute its function efficiently under a variety of future conditions is called supply network robustness. "

(Goetschalckx et al., 2012:pp 121)

Thus, it can be concluded that SCRob concerns the network preserving its functionality, irrespective of disruptions.

2.2.4 Streams in Supply Chain Vulnerability / Resilience Literature

The literature on SCV and SCRes has two perspectives; first towards customers and second towards suppliers (Svensson, 2002c). There are not many peer reviewed contributions in the domain and most of the research papers have simultaneously tackled both upstream and downstream vulnerability (Peck, 2005; Sheffi and Rice, 2005; Svensson, 2000; Svensson, 2002a; Svensson, 2002b; Wagner and Bode, 2006). Figure 2-2 represents the streams within the literature. The research bifurcates into two broad categories: one dealing with causes and

drivers of vulnerability / resilience and the second dealing with strategies and methods to deal with it. Figure 2-2 presents a decision tree based depiction of the literature streams. The green boxes in the figure shows the domain streams selected for the review, whereas the grey boxes are indicative of literature streams that have been excluded from this systematic review.

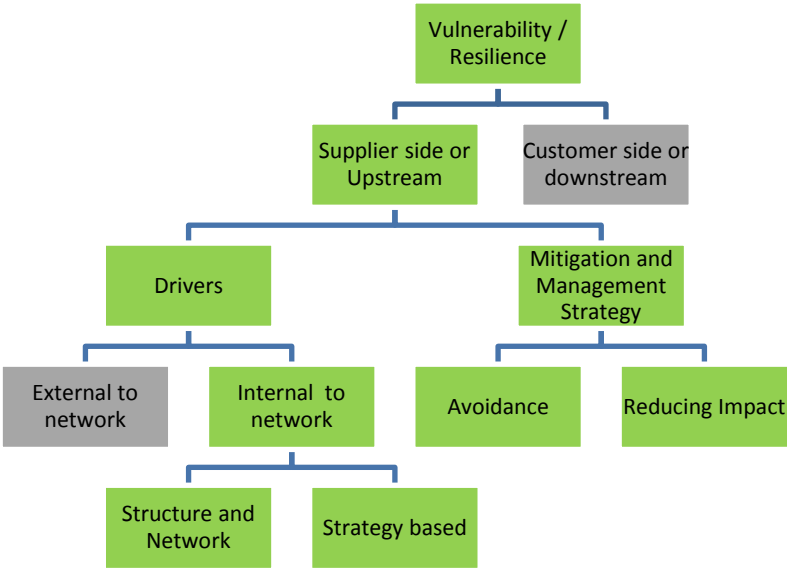

Figure 2-2 The SCV and SCRes literature streams selected (represented in green) and excluded (represented in Grey) in the review

The literature on drivers have accumulated contributions from (Jüttner et al., 2003; Svensson, 2000; Svensson, 2000; Svensson, 2002a; Svensson, 2002a; Svensson, 2002b; Peck, 2005; Peck, 2006) . The drivers can be categorized into two themes: one an internal supply chain dependent dimension and second an external environment dimension. Here too, an independent treatment of the dimensions is not covered in the present literature. However, from the internal supply chain dimension there are some studies focusing just on the structural aspects of drivers (Adenso-Diaz et al., 2012; Craighead et al., 2007; Nair and Vidal, 2011; Wagner and Neshat, 2010).

In the stream of literature on vulnerability mitigation and management strategies, contributions have been made on avoidance strategies and impact reduction strategies. However, in this as well, due to an early stage of conceptualization, both the perspectives have been simultaneously tackled in the literature.

2.3 Domain of Supply Chain Strategy, Capability and Performance

The traditional strategic management thinking on the competing firms perspective, as argued in the five force model (Porter, 1979), is being replaced by the competing network perspective (Harland, 1996). The transformation is reflective of the evolving need of the new global business and manufacturing paradigms. Aligning with the changing global business environment, supply chain managers and business decision makers have also adopted new and novel strategies for achieving operational excellence, such as Lean manufacturing, Just in Time, Just in sequence, agile supply chains, and flexible manufacturing (Childerhouse and Towill, 2003; Naylor et al., 1999; Shah and Ward, 2003). Regarding the usefulness and contextual use of these strategies, the literature is divided into two dominant school of thoughts, one that focus on cost efficiency through lean operations, while the other that advocates service efficiency through agile and responsive supply chain (Fisher, 1997). In an organizational context, the effectiveness and success of such strategies can be measured through supply chain performance measures. (Morash et al., 1996) presents a model representing the example and interplay of supply chain strategies, capabilities and performance. See Figure 2-3.

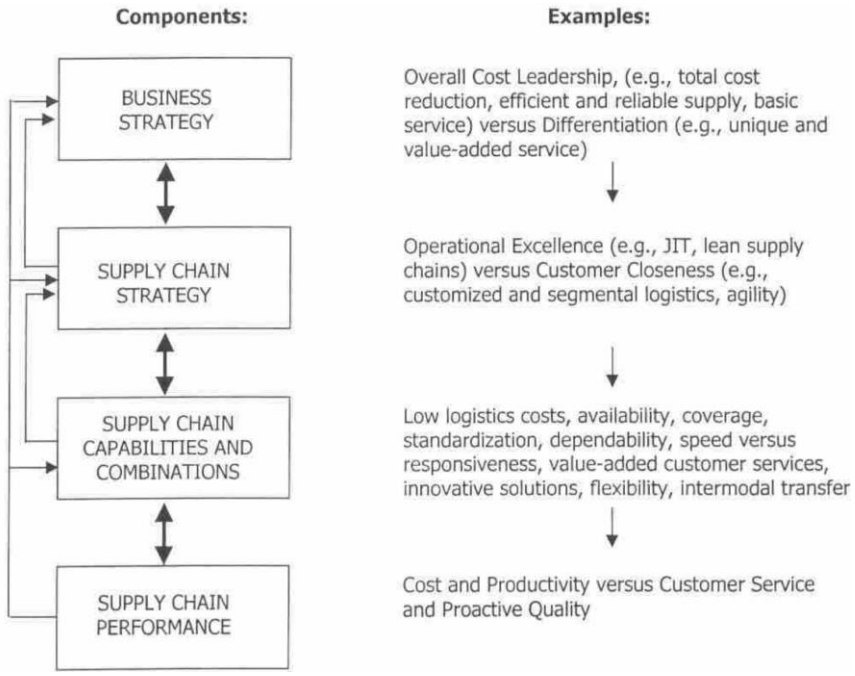

Figure 2-3: Supply chain strategies, capability and performance

Adopted from (Morash et al., 1996)

However, the researchers from the domain of supply chain risk literature argue that some of these strategies, aimed at efficiency and operational excellence, lead to an escalation of supply chain risk (Finch, 2004; Jüttner et al., 2003; Peck, 2005). There is a trade-off of efficiency and risk that needs to be subjectively ascertained.

For the purpose of this systematic literature review, I have a focus on strategies that have an influence on resilience or vulnerability. The major three strategies are Lean, Agile and Flexible and they can be positioned to influence both the customer side, that is downstream, and the supplier side, that is upstream, supply chains. Aligning to my review question, I only propose to look at the upstream supply chain strategies.

The Figure 2-4 presents supply chain strategy literature stream. The green boxes represent the selected literature stream and the grey boxes are the streams of literature excluded from the review.

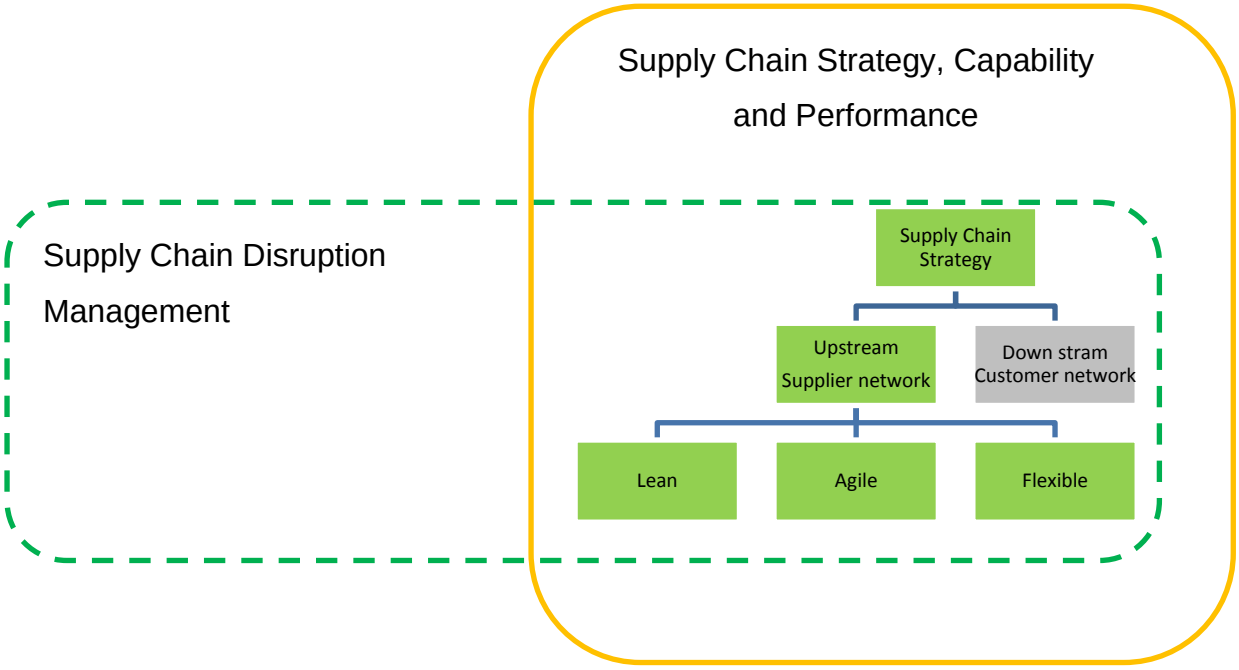

Figure 2-4 The streams in supply chain strategy, capability and performance literature

2.4 Summary

The chapter presented definitions of constructs relevant to this review, like SCV, SCRel and SCRob. The chapter also discussed the literature streams informing my review questions. With a review focus on understanding the construct of resilience and robustness for events of upstream supply chain disruptions, two literature streams were chosen for the review; vulnerability/resilience/robustness studies and supply chain strategy/ capability/ performance literature.

3 METHODOLOGY

3.1 Introduction

Disasters and catastrophes are beyond human control. Every system, how so ever robust it may be, is destined to fail (Christopher and Lee, 2004; Craighead et al., 2007; Perrow, 1984; Perrow, 1999) and this will include the modern supply chain. Acknowledging these arguments, it can be stated that the existing vulnerability in global supply chains presents an opportunity to investigate methods and approaches that may improve the ability of supply networks to bounce back from such unavoidable interceptions. The first step in the direction of discovering such methods and approaches on the phenomenon is to turn to the existing body of knowledge and perform a literature review of it.

3.2 Systematic Literature Review as a Choice of Methodology

There are many approaches to undertake a literature review, such as the traditional narrative literature review, but for the purpose of this thesis, I propose to adopt the method of Systematic Literature Review. Systematic literature review is a very rigorous scientific approach to select appropriate literature, evaluate its contribution, synthesise relevant findings and systematically report the results. As it is based on a clearly stated review protocol, the method succeeds in providing an audit trail of reviewers decisions on procedures, methods and rationale for his inferences and conclusions (Cook et al., 1997; Tranfield et al., 2003). In comparison with other literature review methodologies, the systematic literature review prioritizes evidence by both relevance and quality and thus succeeds to provide a very rigorous and encompassing account of the literature (Tranfield et al., 2003). It is a good

technique to acquire collective knowledge of a given phenomenon or field, its subfields and related constructs (Tranfield et al., 2003).

Based upon the framework suggested by Tranfield et al. (2003), the process to systematic literature review can be divided into four phases; planning, selecting, appraising and reporting.

The planning phase of the review is based upon the development of a systematic review protocol. The protocol states a clearly articulated review question, the motivation for conducting the review and a description of selected databases keywords and search strings. The motivation for the review and the review questions are presented in the previous chapters.

This chapter presents the methodology for the next two stages of systematic review that are selecting and appraising. The following sections describe the decision process and enablers for completing these two steps of the systematic review. The section starts with a description of the systematic review panel followed by a description of selected databases, keywords, search strings and details about the standardised quality appraisal criterion used to evaluate the usefulness of a literary contribution.

3.3 Systematic Review Panel

The process of systematic literature review is a very detailed methodology that requires guidance and direction from process and subject experts. For a reviewer, setting up of a dedicated panel of experienced mentors aids the quality and validity of the study. The panel can help a reviewer to refine his review question and strengthen the design of his review methodology by clearly defining the inclusion or exclusion criterion and refining the quality appraisal decision matrix. During my review, I was supported by a panel of

both subject and methodology experts. Table 3.1 presents their credentials and respective roles of these experts in my review process.

Table 3-1: Review Panel

Person	**Title/Organisation**	**Role**
Dr Liz Varga	Principal Research Fellow, Director of Complex Systems Research Centre	Supervisor: Provided literature recommendations and gave feedback on a draft of the review
Dr David Denyer	Professor of Organizational Change	Internal Advisor: Provided feedback on refining the review questions and positioning of the research.
Dr. Stephanie Hussels	Lecturer in Entrepreneurship Cranfield School of Management	Panel Chair and Methodology expert: Provided support on the Systematic review
Ms Heather Woodfield	Information Specialist for Social Sciences, Kings Norton Library, Cranfield University	Literature search expert: Provided support on the search methodology (search strings in particular)

3.4 Search Strategy

The strategy for my literature search starts with the identification of keywords and setting up of search strings. The strings are modified to suit respective databases that have been identified for the search process. Further, the scope of the search is widened to accommodate specific journals relevant to the review question, publication recommended by panel and cross-references discovered

during the review of papers. The subsections below provide the details of keywords, selected databases and search strings

3.4.1 Keyword

There are four major themes that emerge from the review question; resilience, network structure, network strategy and supply chain. The first three of these are constructs while the last one can be considered as a context. For each of these themes some related keywords have been populated. These keywords include synonyms and antonyms of the construct and also related constructs, referred as 'soft terms'. Table 3-2 below presents these keywords followed by search strings formed out of these keywords.

Table 3-2: Keywords and constructs

Construct	C1 Resilience	C2 Network Structure	C3 Network Strategy	C4 Supply chain
Keywords	**Synonyms: Resilience Robustness, Risk Mitigation, Disaster preparedness, attack tolerance, Network Survivability** **Antonyms: Vulnerability, Network Failure, Disruption, Targeted attack**	**Structure, Tier, Cluster Configuration, graph theory, Topology, Architecture, Nodes, Dyads, Triads, scale free network, random network, Centrality, nested network/systems, Structural holes, Network ties, strong ties, weak ties, vertical integration , horizontal integration**	**Network strategy, Interdependence, network effects, strategic network, efficiency, agility, flexibility, reconfiguration ability, reliability, centralized, decentralized , multiple sourcing, dual sourcing, supplier reduction**	**Supply Chain, logistics, supply network, supplier, buyer, procurement,** **Inter firm, inter organization**
Search string	**"resilience" or "Robust*" or "Risk Mitigation" or "Disaster preparedness" or "Vulnerability" or**	**"Structure" or "Tier" or "Cluster" or "Configuration" or "graph theory" or "Topolog*" or "Architecture" or "Nodes" or "Dyads" or "Triads" or "Centrality" or**	**"Network strategy*" or "Interdependence" "strategic network*" or "efficiency" or "agility" or**	**"Supply Chain*" or "logistic*" or "supply network*" or "supplier*" or**

	"Network Failure*" or "Disruption*" **Soft terms: or "attack tolerance" or "Network Survivability" or "Targeted attack*"**	**"nested network" or "vertical integration"** **Soft terms: "scale free network" or "random network" or "nested system*" or "Structural holes" or " Network ties" or "strong ties" or " weak ties" "horizontal integration"**	**"flexibility" or "reconfiguration" or "reliability" or "centralized" or "decentralized" or "multiple sourcing" "dual sourcing" or "supplier reduction"** **Soft terms: "network effects"**	**"buyer*" or "procurement" or "inter firm" or "inter-firm" or "inter organi*ation" or "inter-organi*ation"**

Using the logical operator 'AND', a set of combined search strings can be formed by these individual strings.

String 1: C1 and C4 (Resilience/Robustness /Vulnerability and Supply chain)

("resilience" or "Robust*" or "Risk Mitigation" or "Disaster preparedness" or "Vulnerability" or "Network Failure*" or "Disruption*")and **("Supply Chain*" or "logistic*" or "supply network*" or "supplier" or "buyer" or "procurement" or "inter firm" or "inter-firm" or "inter organi*ation" or "inter-organi*ation")**

String 2: C2 AND C4 (Structure and Supply Chain)

("Structure" or "Tier" or "Cluster" or "Configuration" or "graph theory" or "Topolog*" or "Architecture" or "Nodes" or "Dyads" or "Triads" or "scale free network" or "random network" or "Centrality" or "nested network" or "nested system*" or "Structural holes" or " Network ties" or "strong ties" or " weak ties" or "vertical integration" or "horizontal integration") and **("Supply Chain*" or "logistic*" or "supply network*" or "supplier" or "buyer" or "procurement" or "inter firm" or "inter-firm" or "inter organi*ation" or "inter-organi*ation")**

String 3: C3 AND C4 (Network Strategy and Supply Chain)

("Network strategy*" or "Interdependence" or "strategic network*" or "efficiency" or "agility" or "flexibility" or "reconfiguration" or "reliability" or "centralized" or "decentralized" or "multiple sourcing" or "dual sourcing" or

"supplier reduction") and **("Supply Chain*" or "logistic*" or "supply network*" or "supplier" or "buyer" or "procurement" or "inter firm" or "inter-firm" or "inter organi*ation" or "inter-organi*ation")**

String 4: C1 and C2 (Resilience and Structure)

("resilience" or "Robust*" or "Risk Mitigation" or "Disaster preparedness" or "Vulnerability" or "Network Failure*" or "Disruption*") and **("Structure" or "Tier" or "Cluster" or "Configuration" or "graph theory" or "Topolog*" or "Architecture" or "Nodes" or "Dyads" or "Triads" or "scale free network" or "random network" or "Centrality" or "nested network" or "nested system*" or "Structural holes" or " Network ties" or "strong ties" or " weak ties" or "vertical integration" or "horizontal integration")**

String 5: C1 and C3 (Resilience and Network Strategy)

("resilience" or "Robust*" or "Risk Mitigation" or "Disaster preparedness" or "Vulnerability" or "Network Failure*" or "Disruption*")and **("Network strategy*" or "Interdependence" or "strategic network*" or "efficiency" or "agility" or "flexibility" or "reconfiguration" or "reliability" or "centralized" or "decentralized" or "multiple sourcing" or "dual sourcing" or "supplier reduction")**

3.4.2 Database

The literature search was conducted using three electronic databases; Business Source Complete (EBSCO), ABI Inform Global PROQUEST and SCOPUS. Considering the fact that SCOPUS is a vast interdisciplinary search database, the search in SCOPUS was restricted to Business Management and decision Science. Table 3-3 presents the details of these databases.

Table 3-3: Databases included for the review

SNo.	Data Base	Description	Explanation
1	Business Source Complete (EBSCO)	A very comprehensive database of many top-rated business and management journals	It is the main data base for the systematic review as it has all reputable business journal
2	ABI Inform Global PROQUEST	A electronic database of approximately 2,500 international business periodicals	It's the second most important data source for the review
4	SCOPUS (Social Sciences)	database covering all areas of science, technology and humanities. It has listing of prominent conference proceedings	Provides a very different set of articles from prominent conferences

3.4.3 Search Results

The search of peer reviewed titles yielded a total of 3334 results. The search results were directly imported to 'Refworks', a citation management software. There were many titles common among various databases and various search strings. Duplicate among databases and within search strings were removed in two stages; firstly by applying the inbuilt tool of Refworks and secondly by manually sorting the closely related duplicates. After removal of all duplicates the total number of articles left was 2077; Table 3-4 provides details.

Table 3-4: Search results summary for each step

Database	string 1	string 2	string 3	string 4	string 5	Total
EBSCO	178	241	383	120	130	1052
ABI ProQ	144	211	309	69	70	803
SCOPUS	226	437	501	161	154	1479
Total before duplicate removal	548	889	1193	350	354	3334
Total after Individual string duplicate removal	459	795	1033	333	325	2945
Total after combined string duplicate removal						2843
Total after manual duplicate removal						2077

3.5 Selection Criterion

The title search in peer reviewed journals returned a very high number of articles. The selection of relevant articles was done in two stages: The first stage was a broad screening was done by evaluating titles, followed by a detailed review of abstracts and full text. After this at the second stage the remaining articles were evaluated using a quality appraisal process, to give a final list of articles. All relevant cross references discovered during the reading of the final set of articles were also subjected to the same process.

3.5.1 Selection Criterion for Titles

The inclusion and exclusion criterion followed for the titles is listed in the Table-3-5.

Table 3-5: Inclusion and exclusion criterion for titles

Criterion	Inclusion	Exclusion	Rationale
Relevance for review question	Titles addressing the following : Supply chain, resilience, structure, strategy, vulnerability, risk mitigation, risk management	studies that only refer to supply chain risk and not its mitigation or management.	answer review question
Language	English	all except for English	English is considered as the universal language for academic publications
Type of publication	scholarly articles (empirical, conceptual & practitioner) Conference papers available through electronic databases	non-scholarly articles, general press articles, and working papers, reports, theses, books, book chapters	To ensure a good quality for the review only peer reviewed articles were considered and working papers thesis were excluded

In the initial phase of title selection only peer reviewed articles were selected. The rationale for it is embedded in the fact that most of the good working papers, findings from quality thesis and good conference articles, often get published into quality journals at a later stage. Also, apart from the working papers and thesis from Cranfield University, it is difficult to get access to most working papers, conference papers and thesis. There are no dedicated electronic databases for these working papers and thesis and this creates difficulty in searching these papers and thesis in a systematic and reliable manner. For the same reason books and book chapters were also excluded from the first stage of

title selection. The exclusion of non-scholarly articles and general press articles was done to ensure a sufficient level of contribution quality for this systematic review as general press and non-scholarly articles are often of low quality.

3.5.2 Selection Criterion for Abstract

The articles left after title filtering were further filtered on the basis of their abstracts. The criterion for abstract filtering is provided below in Table 3-6.

Table 3-6: : Inclusion and exclusion criterion for abstracts

Criterion	Inclusion	Exclusion	Rationale
Relevance for review question	Literature that argues about risk/disaster/crisis management or risk/disaster/crisis mitigation. It may include literature on resilience, robustness, vulnerability or reliability	Any Literature that provides only taxonomical or theoretical discussion of supply chain risk, disaster or crises.	This research is looking to establish causal relationship among constructs and is not exploring any taxonomical classification of risk and crises.
Scientific Field	social sciences, in particular marketing and innovation	natural sciences, computer sciences, engineering	the review question relates to these fields

3.5.3 Selection Criterion for Full Text

The articles short listed on the basis of their extract are put to a full text selection criterion. By reading the full paper, the relevance to my review question is assessed using the criterion mentioned in the Table 3-7.

Table 3-7: : Inclusion and exclusion criterion for full text

Criterion	Inclusion	Exclusion	Rationale
Review question relating to the field of enquiry that is, resilience, vulnerability or robustness	Literature that argues about risk/disaster/crisis management or risk/disaster/crisis mitigation. It may include literature on resilience, robustness, vulnerability or reliability	Any Literature that provides only taxonomical or theoretical discussion of supply chain risk, disaster or crises.	This research is looking to establish causal relationship among constructs and is not exploring any taxonomical classification of risk and crises.
Review question relating to mechanisms for risk mitigation or resilience	papers that relates resilience or supply chain performance to distinctive capabilities of supply chains like • Efficiency • Agility • Flexibility • reconfiguration ability	All other mechanism for risk mitigation like Product categorization or reducing portfolio complexity, Inventory, demand planning, postponement, collaboration, decision making, technology etc.	The criterion mentioned in the inclusion list are found to be influenced by the network structure whereas items in the exclusion list are not.
Review question relating structure of supply network	Papers that relate supply chain structural constructs like • Number of possible connecti ons • Positioning of a node in a network • Size of the network vertical and	Any other aspect of structure.	The study is focused on the physical structure of network connections in a supply chain

	horizontal • Centrality • Structural holes • Network ties, strong or weak to resilience, vulnerability, robustness or reliability		

3.5.4 Quality Appraisal of Short Listed Articles

Until this stage all the articles were excluded or included according to their relevance to the objectives of this review but none of the articles were evaluated on their quality of contribution. Using a predefined set of quality criterion, this stage excludes and includes articles on the basis of the quality and exact alignment of their research question or objectives and the quality of their contribution. The table 3-8 presents the criterion and their weightage for evaluating the relevance and contribution of an article.

Table 3-8 Quality appraisal criterion

SNo	
Citation	
Author: Title:	
	Quality Score (1 lowest to 5 highest)
Is the research question/ objective of the paper rightly aligned with the objectives of my review	
Is the research question / objective adequately established	
Does the paper presents a good summary of relevant literature	
Does the paper presents a clear picture of the methodology of data collection, sampling and method of analysis	
Are the findings clearly reported	
Does the discussion clearly answers the research question and objectives set by the author	
What is the quality of the contribution to theory and is it clearly mentioned	
Total Score	
Was the paper selected (If the total score is more than 21)	
Additional comments if not selected	

1= Not at all, 2= To a limited extent, 3= At an acceptable level, 4=Significantly, 5= Completely

On the basis of this quality appraisal 13 papers were excluded from the group of articles shortlisted after full text review. Appendix B presents the detailed quality appraisal for all these 13 papers.

3.6 Selected Articles

From the initial keyword search, the articles obtained after removing duplicates was 2077. These articles were put through a process of title screening, abstract screening, full text screening and then selection using the process of quality appraisal. The final list of articles so obtained is extracted for relevant data, and doing so some important cross references are discovered. These cross references are also put through quality criterion and the qualifying ones are included for the review. Table 3-8 gives details of the number of articles for each stage.

Table 3-9 Number of articles review in each of the screening process

Screening Criterion adopted on	Number of articles screened
Title	2077
Abstracts	263
Full Text	165
Full Text Quality Appraisal	51
Selected for inclusion	38
Selected from Cross reference	5
Total article reviewed	43

3.7 Data Extraction For Selected Articles

The data from the shortlisted articles is extracted using a standard approach. The details to the approach are listed in Table 3-8.

Table 3-10: Data extraction form

Ref no
Ref Id in Refwork:
Citation
Title:
Author(s):
Journal / Source:
Year:
Key words:
Study Background
Research Question(s)/Objectives:
Primary Research Focus:
Grounding Literature:
Methodology
Method:
Data Description:
Data collection instrument:
Sector:
Unit of analysis:
Analytical approach:
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings
Key prepositions and arguments:
Limitations and Scope for further research:
Synthesis/ Key contribution to review question

3.8 Data Synthesis

The objective of the review is to discover the structural aspects of supply network resilience and the dimensions of strategies that may alter resilience by influencing the network structure and this is achieved by the synthesis of the prepositions, findings and arguments from the selected articles. The definition of supply chain resilience and allied concepts like vulnerability, robustness, risk

mitigation etc are discussed in the Chapter two. Most of these definitions are extracted from the articles discovered during the review process. The extracted data from the selected group of articles is synthesized and characterized in a manner that conveniently helps answers my review questions.

3.9 Summary

The chapter presented the methodological approach used for this systematic review. The advantages for using systematic review methodology over other conventional literature methods were also discussed. The process of the review was presented with details about each step of the review. Starting from the first step of key word formation to the step of exclusion and inclusion criterion for each individual article, a detailed audit trail for each step and the formats used for decision making were presented. In the last step the methods and schemes used for extracting knowledge from the selected articles is provided.

4 DESCRIPTIVE ACCOUNT OF THE LITERATURE

This chapter presents a descriptive account of the literature selected for this review. It includes the characteristics of journals, the chronological distribution of the articles, the country of origin, the key authors, the research focus and unit of analysis adopted by the authors, the sector investigated, and information on geographical locations.

The method of database search, cross-referencing and panel recommendations was used for the selection of these articles. The descriptive statistics are presented both in figure and percentages.

4.1 Chronological Distribution

The bar chart in Figure 4-1 presents a description of percentage of articles published by year. As per the chosen search strings, the time span of articles came out to be 14 years, with the earliest article dating back to year 1998 and the latest contribution was from year 2013. The figure shows that the maximum percentage of published articles is from the year 2009 and 2012. The statistics reveal that year 2007 and 2008 has a drop in the number of resilience/ robustness and vulnerability publications.

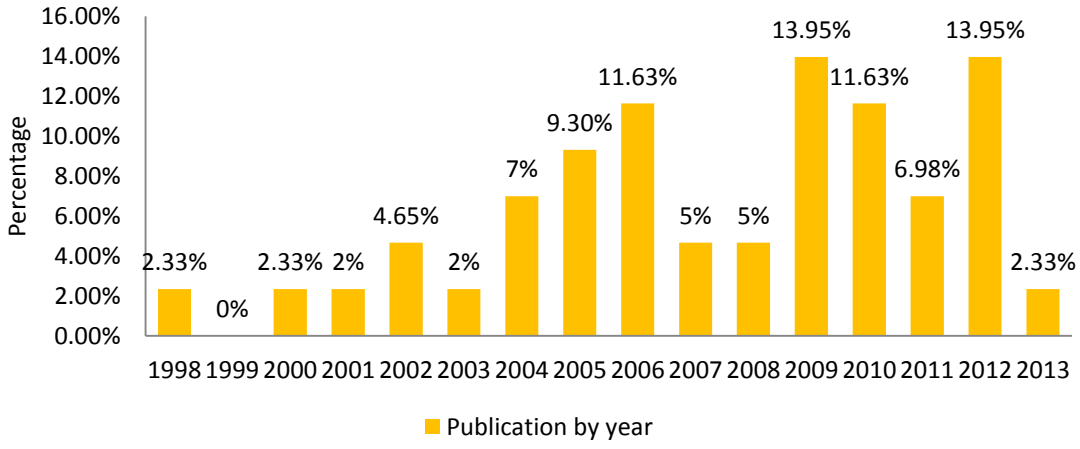

Figure 4-1 Percentage distribution of the number of articles by year

4.2 Journal Characteristics

Table 4-1 Journal names, their ranking and the selected articles frequency from each

Journal Name	Occurrence	Ranking*
IJ of Production Research	5	3*
IJ of Physical distribution and Logistics Management	7	3*
Journal of Purchasing and Supply Management	1	2*
IJ of Logistics Research and Application	3	2*
I J of Production Economics	4	3*
Production and Operations Management	1	3*
IJ of Logistics Mgt	4	3*
J of Marketing Channels	1	non ranked
Production Planning & Control	1	2*
J of Business Logistics	3	3*
Supply Chain Mgt : IJ	3	3*
Information Knowledge System and management	1	non ranked
J of Applied Business Research	1	non ranked
Decision Science	1	4*
IEEE	1	non ranked
Computers & Industrial Engineering	1	non ranked
Management Science	1	4*
J Operations Mgt	2	4*
MIT Sloan Management Review	2	non ranked

Abbreviation: 'I' International, 'J' Journal, 'Mgt' Management

The figure 4-2 represents a bar chart depicting a percentage of articles by journal ranking.

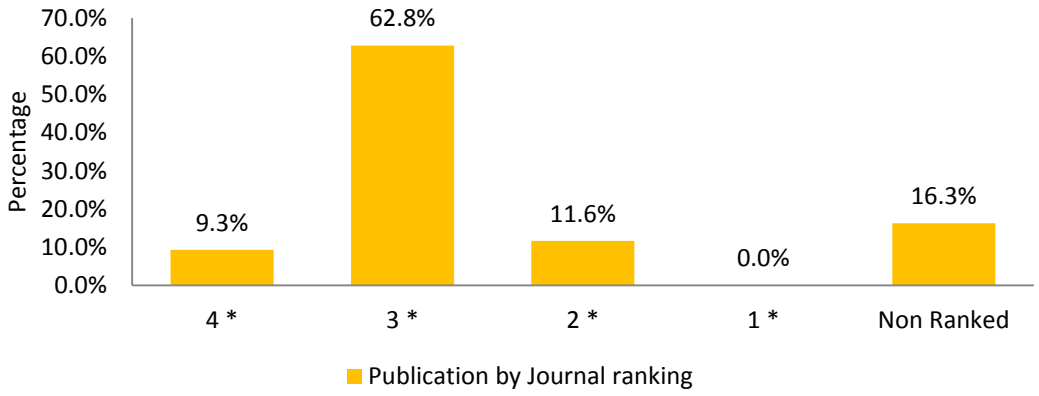

Figure 4-2 Percentage distribution of number of articles by journal rank

Table 4-1 depicts that the reviewed articles were from 19 different journals. The maximum number of articles, seven, were from 'International Journal of Physical distribution and Logistics Management'. From figure 4-1 it is evident that most of the articles, 62.8%, were from 3 star ranking journals. The ranking is based upon Cranfield University journal ranking document 2012-13. A high number of articles are from non-ranked journals as they are either from conference proceedings or from specific Business School publications, like MIT Sloan Management Review.

A classification of journals by research focus indicates that the research into areas like vulnerability and risk mitigation are represented more with 'International Journal of Production Research' and 'International Journal of Production Economics'. Whereas, 'International Journal of Logistics Management' and 'Journal of Business Logistics' have more focus on resilience.

4.3 Key Authors and Countries of Origin

The authors like Brian Tomlin, Claudia Colicchia , Craighead, Christopher, Christopher Tang, George Zsidisin, Göran Svensson , Helen Peck, Jennifer Blackhurst, Martin Christopher, Nikrouz Neshat, Uta Jüttner, Stephan Wagner and Timothy Pettit have published more than one article either as first or joint author.

The number of articles by the location of its originating universities, research institutes or authors is presented in the Figure 4-3 .

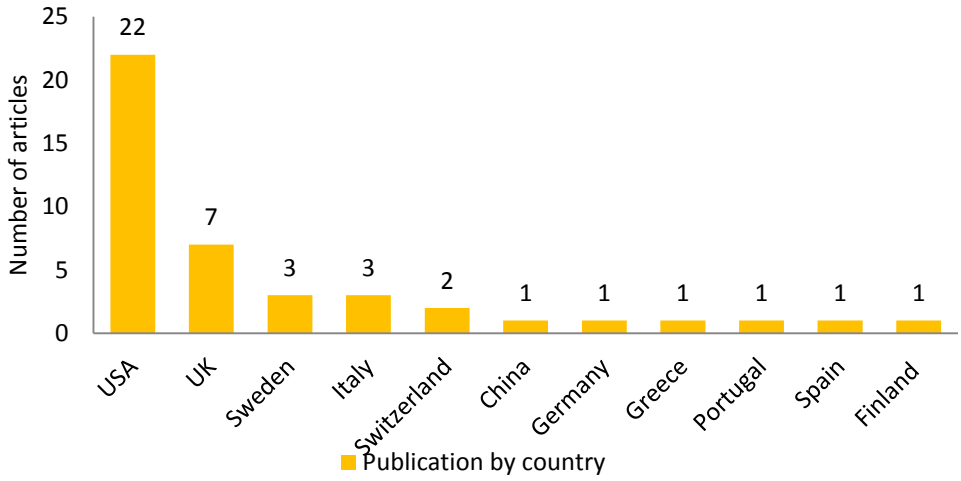

Figure 4-3 Articles by country

The figure reveals that maximum contribution comes from USA and UK. A figure depicting the numbers in percentage is presented in Figure 4-4.

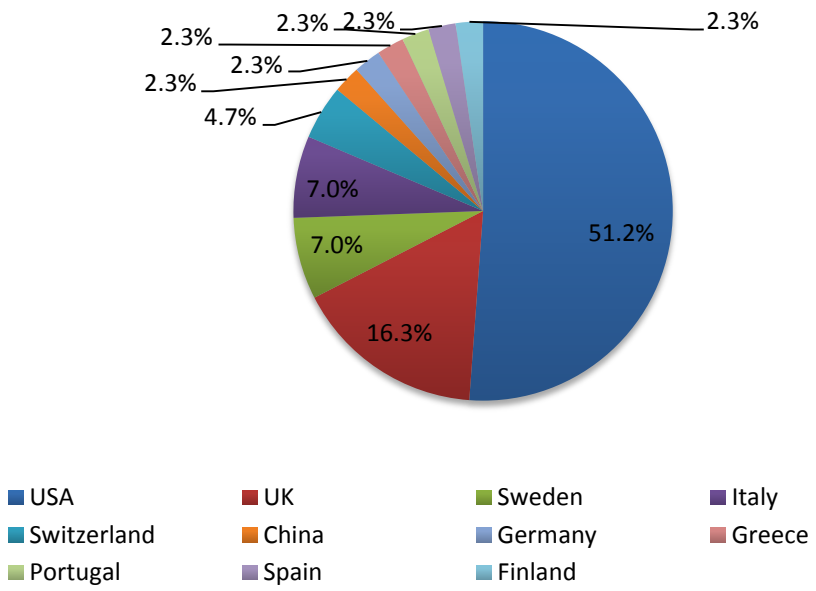

Figure 4-4 The percentage of articles by the country of its origin

The percentage of articles originating from USA is 51.2%. A reason for this could be that supply chains of US are heavily dependent upon global sourcing and thus have high vulnerability. Another reason could be embedded in the fact that US supply chains have been a witness to many severe and historic disruption events like terrorist attack of 9/11, hurricane Katarina, longshoremen union strike at a U.S. West Coast etc and this has led to many private and government sector research to build resilient supply chains. A similar reason could be cited for UK, which is also highly dependent upon resources originating outside UK, and similar to the USA, the UK has also seen some worst supply chain disruptions due to epidemics like mad cow disease and the volcanic ash over Europe.

Most of the journals from the USA have their focus on risk management, risk mitigation and resilience. Journals from UK are more into disruption and resilience while the remaining journals have taken vulnerability as their main research focus.

4.4 Theoretical Foundations/ Grounding Literature Adopted

The Table 4-2 illustrates the theoretical foundations of the reviewed articles. Among the theoretical foundations the 'graph theory' perspective has been the guiding theory to most of the articles followed by systems theory and others. The Table 4-2 presents a chronological evolution of these theoretical foundations in an ascending order by time.

Table 4-2 Theoretical Foundations of Articles

Study	Theoretical Foundations
(Albino et al., 1998)	Production and Operations
(Svensson, 2000)	Channel Theory and Marketing Theory
(Svensson, 2002a)	Contingency Theory, Channel Theory,
(Svensson, 2002c)	JIT, Marketing theory
(Hallikas et al., 2004)	Business Networks, Transaction Cost economics
(Blackhurst et al., 2005)	Resource dependency theory
(Kleindorfer and Saad, 2005)	Industrial Risk Management
(Peck, 2005)	Systems Theory
(Zsidisin et al., 2005)	Systems theory, Institutional theory
(Choi and Krause, 2006)	Buyer supplier relationship, supplier management, Complexity
(Tomlin, 2006)	Strategic management and supply chain management
(Wagner and Bode, 2006)	Normal accident theory
(Meepetchdee and Shah, 2007)	Graph Theory
(Ponomarov and Holcomb, 2009)	Supply chain Management and Interdisciplinary
(Wagner and Neshat, 2010)	Graph Theory
(Yang et al., 2010)	Social network analysis and Graph theory
(Greening and Rutherford, 2011)	Network theory, Social network theory and supply chain management
(Nair and Vidal, 2011)	Network theory and Graph theory
(Adenso-Diaz et al., 2012)	Supply Chain
(Goetschalckx et al., 2012)	Systems engineering approach
(Wagner and Neshat, 2012)	Normal Accident Theory and High-Reliability Theory
(Pettit et al., 2013)	Systems Theory

Most of the selected papers adopted the graph theory as a theoretical foundation; among them were Nair and Vidal (2011), Wagner and Neshat (2010), Meepetchdee and Shah (2007), Yang et al. (2010). Second most cited theoretical foundation is 'systems theory'. This has been used by Peck (2005), Pettit et al. (2013), Zsidisin et al. (2005). The research by Wagner is highly influenced by 'Normal accident theory' whereas Svensson has chosen concepts of Just in Time, marketing and Channel Theory. The theoretical foundation of 'Resource dependency theory' and 'Social network theory' have been mentioned once each.

4.5 Types of Articles and Methods Used

The knowledge of adopted methodology can highlight available methodological choices and also methodological gaps. Most of the articles have used an empirical method of enquiry using qualitative, quantitative and simulated data. There are a few concept based papers aimed at building theory and there are three articles that present a literature synthesis of the field and its definitions. The unit of analysis would also inform the usefulness of a chosen methodology. Table 4-3 gives a list of methodology used and unit of analysis for each paper.

Table 4-3Articles by methodology and unit of analysis

Research paper	Methodology	Unit of Analysis
(Adenso-Diaz et al., 2012)	Empirical with Simulation followed by statistical analysis	Two tiers including focal firm
(Albino et al., 1998)	Model and simulation applied on an industrial case study	Focal and Tier 1
(Blackhurst et al., 2005)	Empirical using mixed methodologies of interview, focus group and case study	First tier and focal firm, horizontal study
(Braunscheidel and Suresh, 2009)	Empirical	Firm level
(Carvalho et al., 2012)	Simulation and case study validation	Focal firm, Tier 1 and Tier 2
(Choi and Krause, 2006)	Theoretical	N/A
(Chopra and Sodhi, 2004)	Theoretical	N/A
(Christopher and Peck, 2004)	Theoretical	N/A

(Colicchia and Strozzi, 2012)	Systematic Literature Review	N/A
(Colicchia et al., 2010)	Simulation	Tier 1 and Transport
(Craighead et al., 2007)	Empirical	Network
(Goetschalckx et al., 2012)	A normative optimization based symbolic mathematical model	Focal Firm
(Greening and Rutherford, 2011)	Literature review	Dyadic and Network level
(Hallikas et al., 2004)	Empirical case study	Focal firm
(Jüttner and Maklan, 2011)	Empirical case study	Firm Level
(Jüttner et al., 2003)	Empirical	Focal firm
(Kleindorfer and Saad, 2005)	Empirical	Firm level (specific manufacturing plant)
(Manuj and Mentzer, 2008a)	Grounded theory with empirical validation from a Focus group	Network
(Meepetchdee and Shah, 2007)	Mathematical model and case study	Focal firm
(Nair and Vidal, 2011)	Simulation	Network
(Oke and Gopalakrishnan, 2009)	Empirical using a Case research approach	Firm level
(Peck, 2005)	Empirical based upon a single case study	Network level both horizontal and vertical
(Peck, 2006)	A literature review paper	N/A
(Pettit et al., 2010)	Grounded theory using a theoretical with empirical validation from a Focus group	Firm level
(Pettit et al., 2013)	Grounded Theory on a case study	Focal Firm and Tier 1
(Ponis, 2012)	Literature review	N/A
(Ponomarov and Holcomb, 2009)	Literature review	N/A
(Sheffi and Rice, 2005)	Theoretical	N/A
(Sheffi, 2001)	Theoretical	N/A
(Skipper and Hanna, 2009)	Empirical	Focal Firm
(Stecke and Kumar, 2009)	Empirical using statistics	Global level catastrophes
(Svensson, 2000)	Empirical/ inductive	Focal firm
(Svensson, 2002a)	E (Inductive and deductive))	Focal firm
(Svensson, 2002c)	E (Inductive)	Focal firm
(Tang, 2006)	Theoretical	N/A
(Tang and Tomlin, 2008)	Mathematical model	Focal Firm
(Tomlin, 2006)	Model simulation	Focal firm and Tier 1
(Wagner and Bode, 2006)	Empirical	Focal firm
(Wagner and Neshat, 2010)	Empirical	Firm
(Wagner and Neshat, 2012)	Empirical	Firm Level
(Yang et al., 2010)	Simulation	Network
(Zsidisin and Wagner, 2010)	Empirical	Focal firm, Tier 1
(Zsidisin et al., 2005)	Grounded theory with empirical case study	Focal firm

Majority of articles focusing on vulnerability, risk mitigation and resilience are empirical. The method of analysis by articles is presented in Figure 4 – 5 .

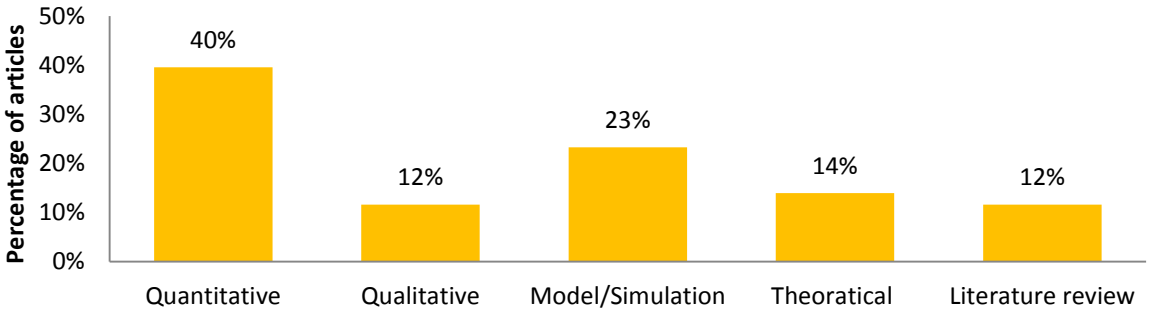

Figure 4-5 Percentage of articles by method of analysis

4.5 Sector and Industries Investigated

The industries investigated in the studies are mention in the Table 4 – 4

Table 4-4 Sectors and Industries investigated

Study	Industries
(Adenso-Diaz et al., 2012)	N/A
(Albino et al., 1998)	Furniture
(Blackhurst et al., 2005)	Primary focus on Automotive and validation on multiple sectors
(Braunscheidel and Suresh, 2009)	Multiple sectors
(Carvalho et al., 2012)	Automotive
(Choi and Krause, 2006)	N/A
(Chopra and Sodhi, 2004)	N/A
(Christopher and Peck, 2004)	Multiple
(Colicchia and Strozzi, 2012)	N/A
(Colicchia et al., 2010)	Transport
(Craighead et al., 2007)	industrial, consumer and service industries
(Goetschalckx et al., 2012)	Manufacturing supply chain
(Greening and Rutherford, 2011)	N/A
(Hallikas et al., 2004)	Electronics and Metal
(Jüttner and Maklan, 2011)	Electrical, timber and chemical
(Jüttner et al., 2003)	U.S-based automobile manufacturer and multiple sectors
(Kleindorfer and Saad, 2005)	Chemical Industry
(Manuj and Mentzer, 2008a)	Global manufacturing from multiple sectors
(Meepetchdee and Shah, 2007)	N/A

(Nair and Vidal, 2011)	N/A
(Oke and Gopalakrishnan, 2009)	Retail
(Peck, 2005)	Defence aircraft, food and drink, Personal care, Health care, automotive, Electronics, Oil, Transport, Packaging
(Peck, 2006)	N/A
(Pettit et al., 2010)	Retail Sector
(Pettit et al., 2013)	Firms with global manufacturing and service firms
(Ponis, 2012)	N/A
(Ponomarov and Holcomb, 2009)	N/A
(Sheffi and Rice, 2005)	N/A
(Sheffi, 2001)	N/A
(Skipper and Hanna, 2009)	Multiple
(Stecke and Kumar, 2009)	Manufacturing
(Svensson, 2000)	Automotive, retail, furniture and real estate
(Svensson, 2002a)	Semi structured interviews. Mail survey, Likert scale
(Svensson, 2002c)	Automotive/ retail/furniture/real estate
(Tang, 2006)	Multiple
(Tang and Tomlin, 2008)	Manufacturing
(Tomlin, 2006)	N/A
(Wagner and Bode, 2006)	Multiple
(Wagner and Neshat, 2010)	Multiple
(Wagner and Neshat, 2012)	Multiple
(Yang et al., 2010)	Automotive
(Zsidisin and Wagner, 2010)	Building, construction, aircraft, equipment and material handling
(Zsidisin et al., 2005)	Aerospace and electronics

It can be observed that most of the research is from multiple sectors followed next by research in the automotive sector and aerospace sector.

5 THEMATIC FINDINGS

5.1 Introduction

This chapter presents a detailed analysis of the findings from the reviewed articles. Before an analysis of thematic contribution, it would be useful to understand the conceptual differences between closely related constructs like vulnerability, resilience, robustness and risk management. The chapter begins with a discussion of these differences followed by a discussion of the findings thematically categorized into three main themes; as presented in Table 5-1.

Table 5-1 Literature Review Classification Framework

SNo	Grouping	Content Covered	Rationale
1	The vulnerability drivers	Structure drivers and strategy drivers	Explores the supply chain characteristics that contribute to vulnerability
2	Strategies to tackle vulnerability and strengthen resilience	Nature of intervention design and Strategic objective based on disruptive event time frame. Strategies of redundancy, risk mitigation and contingency planning.	It presents These strategies focus on achieving objectives of reducing impact, reducing occurrence and reducing recovery time.
3	structural dimensions of supply chains and its relevance to resilience studies	Meaning and measurement of structure. Moderating aspect of structure on resilience.	This will specifically focus on structural aspects of resilience ,robustness and vulnerability and would be simultaneously tackles with the other two groups

5.2 Redefining SCV, SCRes, SCRM and SCRob

5.2.1 Differentiation Between Vulnerability and Risk

The accepted definition of SCV relates the concept to the likelihood and consequences arising out of a disruptive event (Christopher and Peck, 2004; Svensson, 2002a; Svensson, 2002b). However, the classical definition of risk also presents a similar definition for risk based upon probability of happening and significance of loss (Mitchell, 1995). Mitchell (1995) defined risk as

'Risk of any particular type of loss is a combination of the probability of loss and the significance of that loss to the organisation or individual''.

(Mitchell, 1995: pp116)

Although, the two definitions of Risk and SCV seem to be closely aligned, yet there is a fundamental difference between the two constructs. Turning to the dictionary definition, from the 'Concise Oxford Dictionary', we can find that although the definition of both terms are very similar, yet risk is a noun whereas vulnerability is an adjective (Soanes et al., 2004). Thus, we can infer that risk can be seen as a characteristic of a supply network whereas vulnerability is a latent condition (Jüttner and Maklan, 2011).

5.2.2 Comparing SCRob and SCRes

On comparison of robustness with resilience, it can be observed that the definitions of both constructs have a conceptual similarity. The only difference is in the adaptive nature of resilience which is not an intrinsic property of a robust system. Adaptation signifies that the system can evolve into a new structure (Ponomarov and Holcomb, 2009; Christopher and Peck, 2004) thus on getting exposed to a disruption a resilient system will transform into another structure. Asbjornslett and Rausand (1999) argue that robustness refers to a

system retaining its original structure while resilience implies that the system reconfigures to a new state.

5.2.3 The Interplay of Resilience, Vulnerability and Risk Management

In supply chain context risk management is the process of mitigating risk (Hallikas et al., 2004; Manuj and Mentzer, 2008a; Manuj and Mentzer, 2008b)(Hallikas et al., 2004; Manuj and Mentzer, 2008b). Manuj and Mentzer, (2008b) present it in a model, Figure 5-1.

Figure 5-1 Risk management process

Adopted from (Manuj and Mentzer, 2008b)

Hallikas et al. (2004) also propose a similar approach. The authors suggest that the process of risk management has the following stages: identification of risk, assessment of risk, strategies and actions to address it and monitor it. Jüttner et al. (2003) propose a definition for the construct. The authors define SCRM as

"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:pp 201)

Thus we can say that the definition of the construct has two dimensions; first the discovery of the risk and second addressing the risk. If we juxtapose it with the definitions of vulnerability and resilience then the discovery aspect will have a relationship with the construct of SCV while the management aspect will be in principle closer to resilience. Jüttner and Maklan (2011) propose a model relating the three constructs, Figure 5-2

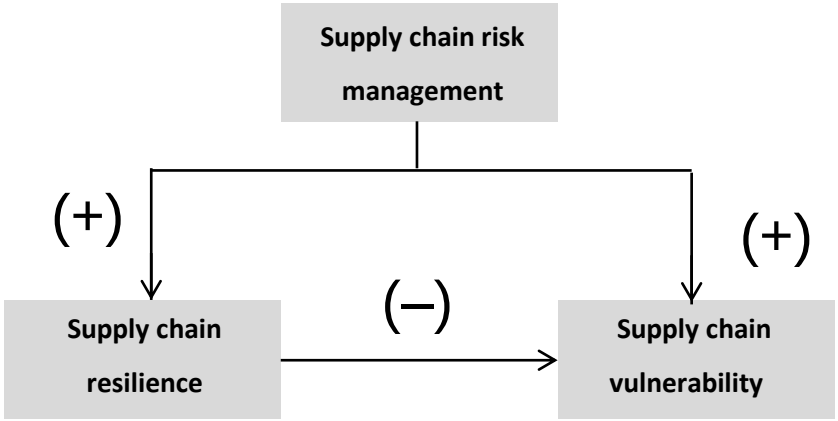

Figure 5-2 Model relating supply chain vulnerability, resilience and risk management

Jüttner and Maklan (2011) argue that SCRM initiatives are aimed both at reducing the probability of disruption, by managing vulnerability, and improving the ability of the system to bounce back, by influencing resilience.

5.3 The Vulnerability Drivers

Supply chain disruption research is a growing body of literature (Stecke and Kumar, 2009; Chopra and Sodhi, 2004; Kleindorfer and Saad, 2005; Craighead et al., 2007; Papadakis, 2003). Within this domain of disruption research, the construct of vulnerability has been evolving complementary with other constructs like risk and resilience. In comparison to the domain of supply chain risk, the domain of vulnerability lacks clarity of definition, measurement and conceptualization (Wagner and Neshat, 2012). However, the SCV literature does suggests many such supply chain characteristics that can be argued to contribute to SCV. These are often referred as vulnerability drivers. These drivers can be categorised thematically into two themes;

- Structural drivers of vulnerability
- Strategy drivers of vulnerability

The next section presents a discussion of vulnerability drivers within each theme.

5.3.1 Structural Drivers of Vulnerability

In contrast to a conventional linear supply chain structure, a network perspective of supply chains is a powerful theoretical foundation to understand the relative positioning of a firm in an extended array of network relationships (Borgatti and Li, 2009). The structural aspect of a network is also particularly useful to evaluate network risk and vulnerability (Craighead et al., 2007).

The argument of network positioning is embedded in the larger domain of network structure related studies that use concepts of graph theory to model and investigate real world networks (Newman, 2009). Many SCV authors have adopted this network structure perspective to model logistics flows and supply chain relationships (Wagner and Bode, 2006; Adenso-Diaz et al., 2012; Adenso-

Diaz et al., 2012; Craighead et al., 2007; Ackermann and Müller, 2007). Supply chain network structure has also been argued as a key contributing factor to SCV drivers. Yang et al. (2010), define structural drivers of SCV as the supply chain characteristics originating out of the linkage, relationship and network structure of the participating actors. The prominent structural drivers of vulnerability are; structural complexity of the network, network density, coherence and connectivity of nodes etc (Adenso-Diaz et al., 2012; Nair and Vidal, 2011; Craighead et al., 2007). These structural drivers are argued to be a result of supply chain disintegration, globalization and the increasing supply network complexity (Wagner and Neshat, 2010).

Table-5-2, presents the list of articles that propose structural drivers of vulnerability.

Table 5-2: Structural drivers of vulnerability

SNo	SCV driver	Authors
1	Tight coupling in supply chain nodes	(Albino et al., 1998; Wagner and Neshat, 2012; Peck, 2005; Greening and Rutherford, 2011)
2	Complexity of network, lack of visibility and lack of predictive capacity	(Adenso-Diaz et al., 2012; Stecke and Kumar, 2009; Jüttner et al., 2003; Wagner and Neshat, 2012; Craighead et al., 2007; Wagner and Neshat, 2010; Meepetchdee and Shah, 2007; Yang et al., 2010; Greening and Rutherford, 2011; Blackhurst et al., 2005)
3	Connectedness and coherence of connectivity	(Pettit et al., 2010; Yang et al., 2010; Greening and Rutherford, 2011)
4	Supplier concentration or network density	(Adenso-Diaz et al., 2012; Sheffi and Rice, 2005; Craighead et al., 2007; Yang et al., 2010; Greening and Rutherford, 2011)
5	Supplier Network structure	(Adenso-Diaz et al., 2012; Jüttner et al., 2003; Wagner and Neshat, 2010)
6	Overall environment of supplier clusters (Geographic, economic, political, social etc)	(Chopra and Sodhi, 2004; Peck, 2005)
7	Power relationship between supply chain actors	(Zsidisin and Wagner, 2010; Peck, 2005; Blackhurst et al., 2005)
8	Infrastructural nodes and links dependency	(Wagner and Neshat, 2012; Peck, 2005; Peck, 2006)

(i) Supply Chain Complexity: Supply chain complexity is attributed as one of the prominent structural vulnerability driver. For this systematic review, I deliberately abstain from defining supply chain complexity, as this can be found in (Choi et al., 2001; Pathak et al., 2007; Surana et al., 2005). However, from within the pool of articles selected for this systematic review, I would particularly like to mention the definition of complexity given by Craighead et al. (2007) as it uses graph theory elements to approach supply chain complexity. The authors define complexity of supply chain to be

"the sum of two components—the total number of nodes (Nnodes) and the total number of forward (Nforward), backward (Nbackward), and within-tier materials flows (Nwithin-tier) within a given supply chain"

(Craighead et al., 2007:pp 140)

From a horizontal and vertical investigation of multiple supply chains, Peck (2005) proposed that complexity and industry structure are key contributors to vulnerability. In supply chains with higher structural complexity, the likelihood of disruption exposure becomes higher (Stecke and Kumar, 2009). This higher disruption likelihood, or vulnerability in the supply chain, could be attributed to a lack of visibility originating due to the structural complexity (Blackhurst et al., 2005) . The argument regarding lack of visibility is also supported by Jüttner et al. (2003), the author argues that complexity of the network creates a 'chaos effect' that makes the network difficult to understand, control or visualize. Wagner and Neshat (2012) attribute structural complexity to higher interactivity among supply chain actors. The authors argue that higher interactivity

along with tight coupling of network increases vulnerability. Craighead et al. (2007) have also grounded their disruption research on the principles of network structure and complexity. Extending the structural vulnerability framework proposed by Craighead et al. (2007), Adenso-Diaz et al. (2012) have successfully validated that structural complexity has a significant bearing on network vulnerability.

(ii) Tight Coupling in Nodes: The nature of coupling among the nodes also has an influence on SCV. It is argued that tightly coupled network structures are more vulnerable to disruption (Albino et al., 1998; Wagner and Neshat, 2012) . Drawing a parallel between events of supply chain disruption and Normal accident Theory, Wagner and Bode (2006) argue that systems with tight coupling among network nodes are bound to fail. Infrastructure dependency: Many prominent supply chain disruptions from the last decade have provided sufficient validation to the claim that tight coupling leads to vulnerability (Pettit et al., 2010; Sheffi, 2001; Sheffi and Rice, 2005). However in most of these disruptions, like the terrorist attack of 9/11, Tsunami in Japan, hurricane Katarina, US West coast port strike or the volcanic ash over Europe, there was another prominent vulnerability factor that contributed to the severity of disruption. It was the coupling between infrastructure and supply chains. SCV researches have acknowledged these infrastructure dependencies to be a significant source of SCV (Wagner and Neshat, 2012; Peck, 2005; Peck, 2006).

(iii) Supplier Concentration or Network Density: Another prominent source of vulnerability is embedded in supplier concentration often measured in graph theory as network density (Craighead et al., 2007). Geographical proximity of suppliers can be very devastating for supply chains (Chopra and Sodhi, 2004; Sheffi and Rice, 2005). Craighead et al. (2007) were

among the first researchers to provide a graph theory based empirical validation for the argument. Building on the framework of Craighead et al. (2007) , Adenso-Diaz et al. (2012) (Adenso-Diaz et al., 2012) also tested the network density for supply chain reliability. Using a simulation model, the authors validated that network density leads to a high supply chain vulnerability.

Vulnerability literature mentions some more drivers of vulnerability such as connectivity or the degree of interdependence and reliance upon critical sources or nodes (Pettit et al., 2010), power relationship among network actors (Blackhurst et al., 2005; Peck, 2005; Zsidisin and Wagner, 2010) etc. We can conclude that the structural aspect of the supply chain has a significant bearing on supply chain vulnerability. This aspect needs further investigation using real world supply network data.

5.3.2 Strategy Drivers of Vulnerability

Managerial decision making process in organizations is largely influenced by the scientific management ideology (Peck, 2005) and the function of supply chain management is not an exception. The positivistic ontology based control and optimization techniques used by supply chain managers are often grounded in the stable world assumption (Monahan et al., 2003). However, there are many documented cases of supply chain disruptions, caused by the unpredictable and dynamic nature of modern business environment, which instigates us to look beyond this stable world assumption. Still, as a part of a 'calculated risk 'approach, as proposed by Svensson (2002a); pp. 119, organizations and decision makers chose supply chain strategies that have a severe tradeoff with SC. Table 5-3 presents a list of vulnerability drivers originating from these organizational strategies targeted at achieving higher efficiency and control.

Table 5-3: Strategy drivers of vulnerability

SNo	SCV driver	Authors
1	Small supplier base	(Wagner and Bode, 2006; Adenso-Diaz et al., 2012; Stecke and Kumar, 2009; Tang, 2006; Chopra and Sodhi, 2004; Jüttner et al., 2003; Sheffi and Rice, 2005; Svensson, 2002c; Wagner and Neshat, 2010; Tang and Tomlin, 2008)
2	Global sourcing	(Wagner and Bode, 2006; Stecke and Kumar, 2009; Chopra and Sodhi, 2004; Jüttner et al., 2003; Svensson, 2002c; Wagner and Neshat, 2010; Blackhurst et al., 2005; Manuj and Mentzer, 2008a)
3	Specialized suppliers or products or source criticality	(Pettit et al., 2010; Wagner and Bode, 2006; Adenso-Diaz et al., 2012; Peck, 2005; Svensson, 2002c)
4	Lean and over efficiency initiatives	(Jüttner et al., 2003; Peck, 2005; Wagner and Neshat, 2010; Meepetchdee and Shah, 2007)
5	Outsourcing and fragmented ownership	(Stecke and Kumar, 2009; Jüttner et al., 2003; Peck, 2005)
6	Time and sequencing constrains designed in the system	(Pettit et al., 2010; Svensson, 2000; Blackhurst et al., 2005; Tomlin, 2006)
7	Stable world and controllable supply chain assumption	(Peck, 2005; Peck, 2006)
8	Resource limit of supplier base	(Pettit et al., 2010; Adenso-Diaz et al., 2012)
9	Overall environment of supplier clusters (Geographic, economic, political, social etc)	(Chopra and Sodhi, 2004; Peck, 2005)

(i) *Small Supplier Base:* Strategically choosing to operate with a small supplier base or single sourcing, an extreme case of small supplier base, is considered to be a cost saving strategy as the cost of partnership and coordination are low (Tang, 2006). However, this proves to be a prominent

SCV driver. To argue the inherent vulnerability of this strategy, (Stecke and Kumar, 2009) mention the example of UPF Thompson, a small chassis manufacturer for Landrover, which became insolvent leading to a sudden and severe disruption in the Landrover supply chain. From Table 5-3, we can infer that many other supply chain researchers have acknowledged it as a prominent SCV driver. Svensson (2002c) views vulnerability to have two dimensions; time and relationship, and according to the author the strategy of having limited suppliers scores high on both the dimensions. The rationale behind reducing supplier base is often motivated by efficiency initiatives and this leads to more integrated and vulnerable supply chains (Jüttner et al., 2003). Working with a single supplier or a very few suppliers might not always be a bad strategy; the issue is about aligning it with your companies procurement strategy (Sheffi and Rice, 2005). If a single supplier is chosen, then a firm should have a high collaboration and close working association with the supplier, otherwise it will prove to be a vulnerability driver (Sheffi and Rice, 2005). Wagner and Bode (2006) also acknowledge the argument of a few highly aligned suppliers, yet the authors argue high level of trust, close collaboration and joint working can only absorb some risk, and as a strategy single sourcing or small supplier base will contribute towards supply chain vulnerability. Wagner and Neshat (2010) have also recognized supplier dependencies, arising out of a small supplier base or a single supplier, are major contributors to supply side vulnerability. The percentage of single sources within supply chain could act as an indicator of vulnerability (Chopra and Sodhi, 2004). In their graph theory based simulation, Adenso-Diaz et al (2012) have empirically measured this vulnerability by a factor called 'source criticality', which for a supply chain refers to the average number

of suppliers for each product. The results of the Adenso-Diaz et al. (2012) simulation are indicative that small supplier base as a strategy indeed leads to vulnerability.'

(i) *Specialized Suppliers:* A very unique product in a supply chain could be a cause of disruption concern (Pettit et al., 2010; Svensson, 2000). Pettit et al. 2010) cite the example from the year 2007 of the earthquake damage caused to Riken Corp, a specialized piston ring manufacturer of Toyota, resulting in shutdown of 12 Toyota production lines and delay in production of 55000 vehicles. A unique product or supplier creates a source criticality and severe supplier dependency (Adenso-Diaz et al., 2012) . Wagner and Bode (2006) have also recognized supplier dependency to be a key vulnerability driver.

(ii) *Global Sourcing:* Global sourcing as a cost reduction approach indeed has quite a few advantages but on the down side the strategy increases the likelihood of a disruption (Jüttner et al., 2003; Christopher and Lee, 2004; Blackhurst et al., 2005). Negative supply chain consequences like supply chain complexity and lack of network visibility could be attributed to the strategy of global sourcing (Blackhurst et al., 2005). Due to the global stretch of supply chains, the product flow and changing dynamic capacity in remote locations becomes difficult to track (Blackhurst et al., 2005). Globalization also poses problems in clearly understanding and predicting the system wide impacts of disruption (Blackhurst et al., 2005). Global supply chains are argued to be slow and less responsive, a characteristic often referred as 'supply chain inertia' (Juttner 2003). Another downside of global sourcing is that network uncertainties become more pronounced, escalating the likelihood of disruption (Manuj and Mentzer, 2008a). Thus, it can be concluded that global operations expose firms to more complex,

uncertain and hard to predict risks, making the network susceptible to disruption.

(iii) *Lean and Over Efficiency Initiative:* Lean and over efficient supply chains are more fragile and less equipped to handle disruptions (Chopra and Sodhi, 2004; Zsidisin and Wagner, 2010). SCV researchers argue that cost effective lean strategies like offshoring, outsourcing, Just in time (JIT) etc are based upon the assumption of a stable world with high integrity and accuracy of data sharing; which in reality puts enormous pressure on supply chains making them prone to disruption (Wagner and Bode, 2006; Zsidisin and Wagner, 2010; Craighead et al., 2007).

Literature also indicates some other drivers like outsourcing that may give rise to a notion of fragmented ownership and lack of willingness among supply chain actors to own responsibility for problems (Stecke and Kumar, 2009; Jüttner et al., 2003; Peck, 2005). Vulnerability is also found to manifest out of strict time constraints in processes like the Just in Time(JIT) or Just in Sequence(JIS) manufacturing.

5.4 Strategies to Tackle SCV and Strengthen SCRes

In the supply chain literature, there has been a recent surge in the publications of risk management and risk mitigation best practices, guidelines and recommendations, aimed at reducing vulnerability and increasing resilience (Chopra and Sodhi, 2004; Zsidisin and Wagner, 2010; Martha and Subbakrishna, 2002; Rice and Caniato, 2003). However, most of these research SCV and SCRes literature remains to be normative and taxonomical (Wagner and Neshat, 2010) aimed largely at identifying supply chain characteristics and drivers that may lead to vulnerability (Ponomarov and Holcomb, 2009).

From a review of the literature on sources and drivers of SCV and SCRes, one can draw an obvious inference that lessor the risk drivers in a supply network, less vulnerable or more resilient the supply chains would be (Zsidisin and Wagner, 2010). Accepting this premise, SCRes and SCV researchers propose many strategies to tackle these drivers of vulnerability such as flexibility, redundancy, agility, visibility, and slack. However, most of such recommendations are fragmented, contextual and often conflicting. Where some authors propose redundancy as a key strategy (Sheffi and Rice, 2005), others argue that redundancy is incapable to mitigate extended supply chain risk, instead firms should adopt flexible practices (Zsidisin and Wagner, 2010).

For the purpose of this systematic review, to provide an order to these fragmented recommendations, I propose to group the SCRes strategies into two dimensions;

- Dimension of disruptive event time frame and
- Dimension of the intervention design

A discussion of these dimensions is provided below.

5.4.1 Strategies Based on Disruptive Event Time Frame

The first dimension of disruptive event time frame refers to strategies influencing different phases of disaster. The crisis and disaster management literature proposes that every disaster has an incubation period of an extended period of time, and during this time many minor causes, preconditions and subsidiary factors accumulate to ultimately result into a severe disaster (Turner, 1994). Similarly, supply chain disruptions can also be argued to have a time dependent incubation period. This time dependency is supported by the Time

vs performance graph of a supply chain under disruption, presented by Sheffi and Rice (2005), Figure 5-3.

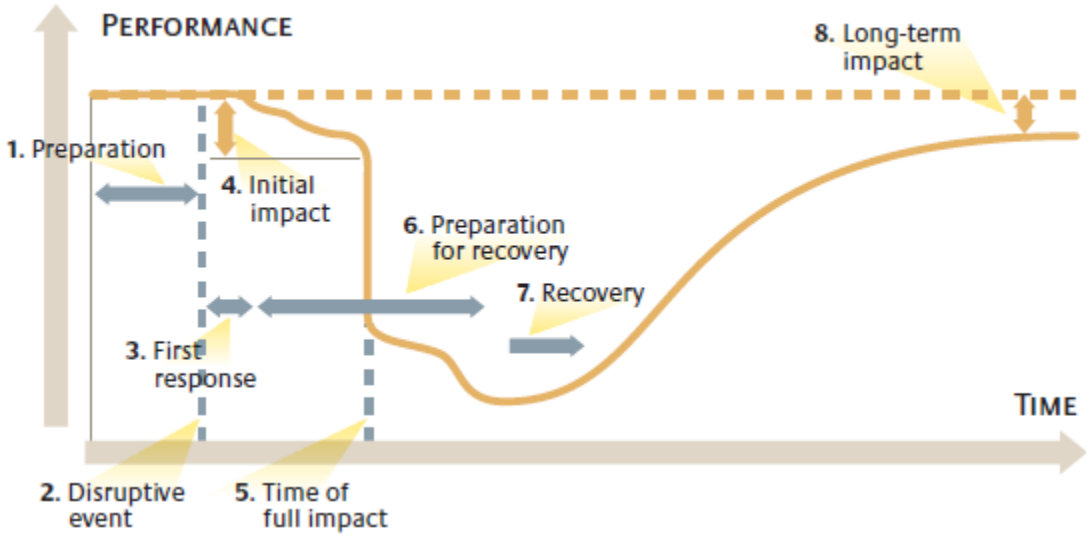

Figure 5-3: Phases of performance vs time in a supply chain disruption

Adopted from: (Sheffi and Rice, 2005)

The eight phases of the disaster proposed by the author can be simplified to represent three time phases; before the event, during the event and after the event. It can be argued that these different time phases can be influenced by different supply chain strategies. For the purpose of this study these strategies, effective for a given time phase, are given a thematic nomenclature;

- Strategies effective to reduce occurrence probability (Time before the event)
- Strategies effective to reduce the event Impact (Time during the event).
- Strategies effective to reduce recovery time (Time of system recovery)

5.4.2 Intervention Design

The number of articles dealing with strategies to improve robustness or resilience is very limited. Accept four articles, (Adenso-Diaz et al., 2012; Craighead et al., 2007), both dealing with structural aspects and (Skipper and Hanna, 2009; Tang and Tomlin, 2008) both dealing with flexibility strategy, none other presents any individual analysis of a specific resilience or robustness strategy. The majority of papers offer a broad set of recommendations. However, within these broad set of recommendations, a few authors, like (Stecke and Kumar, 2009; Colicchia et al., 2010), have grouped these strategies into themes. Stecke and Kumar (2009) have put these strategies into three themes; 'Proactive', 'Advance warning' and 'Coping strategies'. Colicchia et al. (2010) also uses a three theme framework; 'Operational buffer', 'Mitigation' and 'Contingency strategies'.

I too propose a three theme framework for my categorization of resilience or robustness strategies. My categorization focus upon what aspects of organization or network are to be modified to achieve resilience. These are '*Structure aspects', 'Operations aspects' and 'Organizational strategy aspects*.' The strategy and organizational aspects differ on the time frame of the intervention design, operational aspect will correspond to short or medium term influences at local or operational level while strategic changes would require organizational level strategic changes in the way the business is conducted.

5.4.3 The Thematic Classification of Resilience Strategies

The literature proposes many strategies to enhance resilience and robustness of a supply chain network. The resilience recommendations found in this review are listed by the three theme categorization in the Figure5-4. The strategies

within each theme are further divided by the dimension of disruptive event time frame.

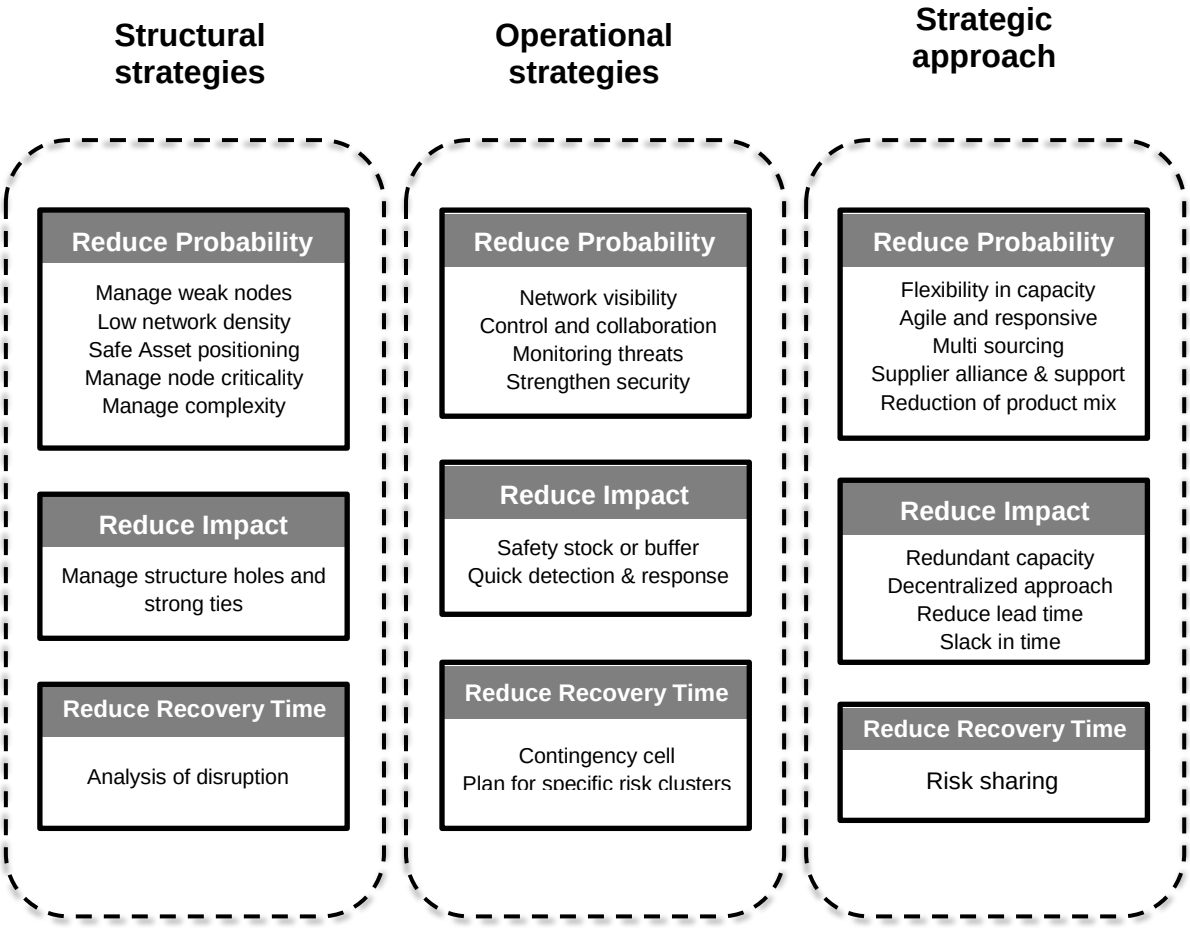

Figure 5-4 Thematic classification of resilience or robustness strategies

A discussion of these suggested strategic interventions is presented in the next section

5.4.4 Structural Strategies for Influencing Resilience

Supply chain topology and network perspective of risk and resilience studies is an evolving research theme. The field builds on graph theory based resilience and attack tolerance research of real world complex networks (Nair and Vidal, 2011; Thadakamaila et al., 2004). Graph theory based network characteristics like clustering coefficient, maximum distance between two node, size of the

largest connected cluster, average path length etc are now been researched from a supply chain resilience perspective(Adenso-Diaz et al., 2012; Nair and Vidal, 2011; Wagner and Neshat, 2010).There could be managerial interventions designed to influence aspects of structural resilience. Table 5-4 presents these strategies.

Table 5-4 Structural strategies for influencing resilience

	Proposed modification	Empirical studies	Theoretical or conceptual studies
Reducing occurrence probability	Manage weak nodes /links	(Kleindorfer and Saad, 2005; Oke and Gopalakrishnan, 2009)	(Tang, 2006; Chopra and Sodhi, 2004)
	Design low network density	(Nair and Vidal, 2011; Craighead et al., 2007)	(Greening and Rutherford, 2011)
	Intelligent structural positioning of safety stock		(Tang, 2006; Chopra and Sodhi, 2004)
	Reduce node criticality, network complexity, cluster complexity	(Adenso-Diaz et al., 2012; Craighead et al., 2007)	
Reducing disruption impact	Better connectedness among network nodes with fewer network structural holes dependent and strong ties		(Greening and Rutherford, 2011)
Reducing recovery time	Predictive analysis of disruption propagation in the network	(Pettit et al., 2010; Blackhurst et al., 2005)	
	supply chain reconfiguration	(Pettit et al., 2010; Blackhurst et al., 2005)	

The rationale of using graph theory constructs in a supply chain resilience context is motivated by the argument that supply chains are also networks and can be effectively modelled using graph theory concepts (Nair and Vidal, 2011). In a supply chain context, .the graph theory constructs like nodes and links would refer to supply chain actors and their connections respectively (Craighead et al., 2007). However definition of a supply chain actor will vary according to the unit of analysis; it can signify a buyer or customer or a specific location or warehouse.

Among the structural strategies the strategy of managing weak nodes and reducing supply chain network density are the most recommended ones. Discussing weak nodes and links , Oke and Gopalakrishnan (2009)) propose that the resilience in supply chains can be built by identifying 'vulnerability points' or weak nodes, understanding their influence on the network and then finally drawing contingency strategies to address them. The authors find this strategy to be very useful in tackling catastrophic natural and manmade disasters. Kleindorfer and Saad (2005) also argue that resilience and robustness of the supply chain will be strongly affected by the weakest link of the network. The authors quote that

"One weak partner in the supply chain can prove disastrous for all participants"

(Kleindorfer and Saad, 2005: pp 56)

In their theoretical paper Chopra and Sodhi (2004) also discuss identifying vulnerability points in a network through a process that authors call as 'stress testing'. The authors suggest that using a 'what if' scenario on the network can highlight network vulnerabilities. The authors also suggest that after the identification of vulnerable nodes, positioning assets and resources at these

vulnerable point could further improve resilience. This is yet another structural strategy that proposes an intelligently positioning of resources in the network.

The next strategy is of developing a tool to do a predictive analysis of disruption propagation. Supply chain managers agree to the fact that it is difficult to fully understand the dynamic behaviour of network risk as it requires a thorough understanding of network structure and associated complexities (Jüttner et al., 2003). If this difficulty of predicting the network behaviour can be overcome then it would definitely improve robustness and resilience. This is has been proposed by some SCRes and robustness researchers as a strategy to counter vulnerability.

Blackhurst et al. (2005) and Pettit et al. (2010) are the two prominent works rallying for such a strategy. The idea of stress testing strategy proposed by Chopra and Sodhi (2004) is similar in spirit to the predictive disruption analysis proposed by Blackhurst et al. (2005) and Pettit et al. (2010). Blackhurst et al. (2005) call for a development of network level predictive tool that may help understand the network behaviour. Abstaining from a clear conceptualization of such a tool, the authors suggest that it might have dynamic, intelligent search agents that will monitor network level properties. Pettit et al. (2010) have named this strategy under the theme of 'Anticipation'. The authors argue that monitoring early warning signals can significantly deter network risk and improve resilience.

There is another set of structural strategies that have directly evolved from graph theory based definitions and measures of a network. These include reducing network density, reducing node criticality, reducing network complexity and managing structural holes and weak/strong ties in a network. Craighead et al. (2007) are among the first academicians to empirically test these

strategies followed by Nair and Vidal (2011). In a recent study by Adenso-Diaz et al. (2012), the authors have extended the work of Craighead et al. (2007) by adding more topological dimensions to the research. Apart from these empirical investigations, using a literature survey, Greening and Rutherford (2011) present a very through conceptual round up of these network strategies.

Evaluating the moderating effect of supply chain structure on the severity of disruption Craighead et al. (2007) propose that higher the network density, node criticality and network complexity, the higher the network will be susceptible to sever disruptions.

Craighead et al. (2007) also defines and quantifies these terms like network density, network complexity and node criticality. Defining network density authors quote

"*when nodes within a supply chain are clustered closely together, as may be measured by the average inter-node distance, the particular supply chain can be described as being dense* "

(Craighead et al., 2007:pp 139)

The author argues that firms are more concern about regional clusters getting affected by disruptions rather than a single supplier getting affected. This concern is relates to network density. Craighead et al. (2007) have associated supply chain complexity with the number of nodes in a network. A higher the number of nodes will indicate a higher structural complexity. The authors argue that complex supply chains are more prone to sever disruptions and thus less resilient. Regarding node criticality, Craighead et al. (2007) argue that similar to network density, the relative importance of a node, 'node criticality', also contributes to severity of disruption.

Nair and Vidal (2011) conducted an agent based simulation to investigate the robustness of some standard network topologies. Using scale free network topology and random network topology, Nair and Vidal (2011) reached a conclusion that supply chain with nodes having longer average path length between them re less robust. The authors argue that the measure of average path length characterises the spread of the network by calculating the average of distance between any two nodes. The authors claim that supply chains with shorter average path length will be more responsive and hence more resilient. This argument supports the premise that dense networks are less robust (Nair and Vidal, 2011).

In yet another recent graph theory based research by Adenso-Diaz et al. (2012), the authors used a set of simple assumptions to argue that supply chains with higher complexity, node criticality and flow criticality are less robust. Building upon the prepositions of Craighead et al. (2007), Adenso-Diaz et al. (2012) tested and validated the claims of Craighead et al. (2007).Using a simulation of a multi-tier supply network, Adenso-Diaz et al. (2012), also tested some additional assumptions and empirically proved that source criticality of products, an indicator of the degree of multiple sourcing, is highly important for robustness. The authors also argued that network design features like density and node complexity will have significant bearing on robustness towards severe disruption.

Thus we can infer that structural aspects of resilience and robustness are very crucial strategies. These would require a graph theory based modelling approach. It was also evident that there are not many studies focusing on these aspects and the field has still a lot of research potential.

5.4.5 Operational strategies for influencing resilience

Under the theme of operational modifications, I have included polices which can be operationalized at local level without altering much of the business structure. Table 5-5 presents these.

Table 5-5 Operational strategies for influencing resilience

	Proposed modification	Empirical studies	Theoretical or conceptual studies
Reducing occurrence probability	Better network visibility	(Pettit et al., 2010; Stecke and Kumar, 2009; Jüttner and Maklan, 2011; Blackhurst et al., 2005)	(Ponomarov and Holcomb, 2009; Chopra and Sodhi, 2004)
	Better control and collaboration	(Jüttner and Maklan, 2011; Kleindorfer and Saad, 2005; Pettit et al., 2013; Oke and Gopalakrishnan, 2009)	
	Monitoring and warning capability for threats (weather, economic, political or terrorist)	(Stecke and Kumar, 2009; Craighead et al., 2007)	
	Strengthen security of facilities and communication	(Pettit et al., 2010; Stecke and Kumar, 2009)	
Reducing disruption impact	Quick detection and response to disruption	(Stecke and Kumar, 2009)	(Tang, 2006; Sheffi and Rice, 2005)
	Safety stock or buffer	(Stecke and Kumar, 2009; Jüttner and Maklan, 2011; Peck, 2005)	(Chopra and Sodhi, 2004; Sheffi and Rice, 2005)
Reducing recovery time	An independent recovery and contingency cell/function	(Pettit et al., 2010; Jüttner and Maklan, 2011; Kleindorfer and Saad, 2005; Colicchia et al., 2010; Oke and Gopalakrishnan, 2009)	(Tang, 2006)

The four most cited operational strategies for influencing resilience are improve visibility, better collaboration and control, development of contingency cell and safety stock.

In their empirical study Blackhurst et al. (2005) found that supply chain visibility is a crucial concern for businesses. Based upon their study, the authors argue that visibility can significantly lower the detection and response time to a network disruption. The authors further argue that visibility can positively influence the reduction of number of disruptions and also reduce the severity of their impact.

To reduce supply uncertainty, Stecke and Kumar (2009) recommend having a good visibility of suppliers' operations and a firm's transport operations. The authors found that advance disruption warning capability is improved by supply chain visibility. Chopra and Sodhi (2004) relate the sharing of demand information across the network as a part of visibility.

In an empirical study Pettit et al. (2010) argued that to manage global supply chains with high number of nodes and connections, visibility will be an essential capability. The authors define visibility as

"Knowledge of the status of operating assets and the environment"

(Pettit et al., 2010: pp 12)

In the authors view, formative elements of supply chain visibility are gathering business intelligence, IT systems, knowledge or visibility about asset or people and effective information exchange among network actors.

In another empirical research Jüttner and Maklan (2011) site various authors to arrive to a conclusion that enhanced visibility will positively influence resilience.

The other operational strategies that have gathered academician's attention are better overall collaboration among supply chain actors and formation of an independent contingency response cell within a firm.

In the supply chain context, the concept of collaboration is closely associated with visibility. It is argued that collaboration can only be successful if network actors are willing to share sensitive information (Faisal et al., 2006). Jüttner and Maklan (2011) argue that as a part of collaborative working, a joint contingency and disruption plan developed with the suppliers can improve resilience. For their empirical work, Jüttner and Maklan (2011) have conceptualized collaboration in terms of the dimension of joint decision making among firms. Grounding it in literature, the authors suggest judging the quality, strength and closeness of collaboration by degree of tactical decision making among two supply chain actors such that whether it is at operational level or at strategic level. Quoting the effectiveness of collaboration as a strategy, Jüttner and Maklan, (2011) say

"*Our findings from the case studies seem to suggest that in a crisis situation, the positive collaboration impact on the smooth supply chain functioning predominates.*"

(Jüttner and Maklan, 2011:pp 254)

Oke and Gopalakrishnan (2009) also proposed that planning and collaboration can influence high probability risks.

Thus it can be concluded that collaborative operations among supply chain actors can lead to higher resilience.

Among other strategies, the strategy of operational buffer or inventory is regarded as a classical supply chain strategy. Chopra and Sodhi (2004) argue that inventory can only shield against demand fluctuations and that too by eroding the bottom lines. The authors argue that for reasonably predictive disruptions building an inventory might be a good idea but it has low utility for unknown disruptions. Stecke and Kumar (2009) also recognize that inventory is only food for meeting day to day demand fluctuations.

Arguing against inventories, Sheffi and Rice (2005) suggest that inventory can be detrimental to overall product quality and profitable operations. The authors instead suggest holding strategic inventory Stecke and Kumar (2009) also propose to use inventory in a more strategic manner. The authors propose inventory pooling by efficient product design.

Some other strategies like setting up of independent contingency cell to tackle disruptions, monitoring threats and securing assets and sites has also been suggested in by few authors. Regarding a dedicated contingency cell and well laid down plan to tackle disruption contingency, Kleindorfer and Saad (2005) propose to adopt a high quality contingency plan similar on principle to Six Sigma .

Thus we can say that among operational strategies, visibility and collaboration are proposed to be the most efficient to tackle disruptions and strengthen supply chain resilience or robustness.

5.4.6 Strategic approach for influencing resilience

The policies discussed under the category of strategic modification are broad firm level initiatives that often require a companywide implementation. Table 5-6 presents a list of articles recommending these strategies.

Table 5-6 Strategic approach for influencing resilience

	Proposed modification	Empirical studies	Theoretical or conceptual studies
Reducing occurrence probability	Flexibility in capacity	(Pettit et al., 2010; Stecke and Kumar, 2009; Jüttner and Maklan, 2011; Zsidisin and Wagner, 2010; Pettit et al., 2013; Tomlin, 2006; Braunscheidel and Suresh, 2009; Oke and Gopalakrishnan, 2009; Tang and Tomlin, 2008)	(Ponomarov and Holcomb, 2009; Tang, 2006; Chopra and Sodhi, 2004; Sheffi and Rice, 2005)
	Create agile and responsive supply chain	(Jüttner and Maklan, 2011; Braunscheidel and Suresh, 2009)	(Ponomarov and Holcomb, 2009; Chopra and Sodhi, 2004; Sheffi and Rice, 2005)
	Multi sourcing strategy	(Adenso-Diaz et al., 2012; Stecke and Kumar, 2009; Jüttner and Maklan, 2011; Oke and Gopalakrishnan, 2009)	(Chopra and Sodhi, 2004; Sheffi and Rice, 2005)
	Supplier alliance and support network		(Tang, 2006)
	Reduction of product mix	(Albino et al., 1998)	
Reducing disruption impact	Redundant capacity	(Adenso-Diaz et al., 2012; Stecke and Kumar, 2009; Jüttner and Maklan, 2011; Peck, 2005; Pettit et al., 2013)	(Chopra and Sodhi, 2004; Sheffi and Rice, 2005)
	Decentralized approach	(Jüttner and Maklan, 2011)	(Chopra and Sodhi, 2004)
	Reduce lead time	(Albino et al., 1998)	(Tang, 2006)
	Provide a slack in form of time	(Peck, 2005)	
Reducing recovery time	Risk sharing among supply chain actors	(Jüttner and Maklan, 2011)	(Ponomarov and Holcomb, 2009)

Among the strategic initiatives, the construct of 'flexibility' is the highest cited resilience strategy. In its literal sense, flexibility corresponds to an ability of a material to bend easily without fracturing or breaking (Jüttner and Maklan, 2011). Similarly, supply chain flexibility can be defined as an ability of the supply chain to absorb a risk event without breaking (Skipper and Hanna, 2009). Sheffi and Rice (2005) consider flexibility as an adaptive organic

capability of organizations, which can sense and respond to threats. Jüttner et al. (2003)define flexibility to be opposite of '*Inertia*'. The authors view inertia as a term that signifies lack of responsiveness of a supply chain.

Some supply chain strategies that may contribute to flexibility are postponement, multiple sourcing and localised sourcing Jüttner et al. (2003). Sheffi and Rice (2005) propose flexibility to be practiced in five dimensions: suppliers, conversion process, systems, distribution channel and corporate culture.

Tang and Tomlin (2008) identify five flexibility strategies; flexibility in suppliers via multiple suppliers, flexible supply contracts, flexible manufacturing, flexible product strategy via postponement and flexible pricing. The first three of these strategies influence the supply side while the last two are targeted at demand. Using a very simple set of assumptions Tang and Tomlin (2008) have empirically tested these five flexibility strategies for mitigating supply chain risk. The authors have demonstrated that using multiple suppliers does provide cost saving. Regarding flexible manufacturing, the authors have presented an argument against the general conceptual recommendations of improving flexible manufacturing. The mathematical model used by Tang and Tomlin (2008) suggests that even at low level of manufacturing flexibility, a firm can lower its process risks. The authors quote

"*Therefore, to reduce process risks, it is sufficient to operate a manufacturing system with limited flexibility. This illustrates the power of process flexibility via flexible manufacturing process.*"

(Tang and Tomlin, 2008: pp 20)

Arguing in favour of flexibility Sheffi and Rice (2005) suggests that practicing flexibility has double benefits of better resilience during disruption and better operational efficiency during normal circumstances.

The next most suggested business strategy is of responsive and agile supply chain design and practice. Arguing in favour of responsiveness and agility, Sheffi and Rice (2005) quote;

" company's resilience is a function of its competitive position and the responsiveness of its supply chains"

(Sheffi and Rice, 2005:pp 44)

Strongly advocating in favour of agility, Christopher and Peck (2004) propose that capability of agility in a supply chain is synonymous to resilience. The authors define agility as a capacity to quickly respond to any unexpected event. Some other agility definitions include flexibility to be a subset of it. Consistent with this argument, Jüttner and Maklan (2011) propose that agility signifies a combination of both flexibility and velocity. In line with Jüttner and Maklan (2011), Braunscheidel and Suresh (2009) also consider flexibility to be a vital dimension of agility. Besides flexibility, Braunscheidel and Suresh (2009) suggest many other aspects of agility such as inter and intra organizational integration, cross functional alignment, alignment with key suppliers and buyers. Regarding agility and flexibility Narasimhan et al. (2006) quote

"Agility involves flexibilities of several sorts, and includes the capability to do unplanned, new activities in response to unforeseen shifts in market demands or unique customer requests"

(Narasimhan et al., 2006: pp443)

To improve robustness and resilience, the literature suggest many other strategic modifications such as decentralized decision making approach, risk sharing among network partners and redundant capacity.

From a discussion of these three supply chain resilience strategies; Structural, Operational and Strategic, we can infer that this domain still has many conceptual gaps and definition conflicts. There are some conflicting strategic recommendations like a choice between flexibility, redundancy and agility or velocity. The literature also fails to demonstrate the kind of product and supply chain characteristics for which a particular strategy will be more suitable. In the section below I present the existing debate in the literature addressing flexibility, redundancy and velocity/agility

5.4.7 The Flexibility, Redundancy and Velocity/Agility Debate

Sheffi and Rice (2005) propose flexibility to be a risk mitigation strategy that reduces the occurrence probability, whereas Tang and Tomlin (2008) consider it to be effective in reducing the impact of disruption. Apart from this conceptual disagreement regarding the purpose served by flexibility, the definition and conceptualization of flexibility are also highly contested. Where some researchers propose flexibility to have common elements with other SCRes strategies as redundancy or agility Jüttner et al. (2003) others define and measure it independent of redundancy or agility Zsidisin and Wagner (2010)

Adopting Buckley and Casson (1998) definition of flexibility in a supply chain context Manuj and Mentzer (2008a) propose that in an event of disruption or change, flexibility in supply chain can facilitate a quick , easy and smooth relocation of resources. This conceptualization places flexibility closer to constructs of supply chain responsiveness, velocity or agility. This argument by

Manuj and Mentzer (2008a) resonates with the flexibility conceptualization proposed by Christopher and Peck (2004) and Jüttner and Maklan (2011) as the author also associates flexibility with the response speed or velocity of the network. However, Jüttner and Maklan (2011) disagree including velocity or agility as a component of flexibility, which they suggest are a measure of efficiency rather than of flexibility. Instead, the authors propose redundancy of suppliers or the strategy of multiple sourcing, as a component of supply chain flexibility. The authors quote

"redundancy, as duplications of capacity so that operations can continue following failure, is rather one route to flexibility"

(Jüttner and Maklan, 2011: pp 247)

Tang (2006) and Tang and Tomlin (2008) also approve the shifting of production among multiple suppliers as a part of flexible supply chain strategy. Similarly, Stecke and Kumar (2009) also put the strategy of multiple sourcing as a flexibility improving strategy. However, the authors chose to define redundancy as a construct independent of flexibility, thus further deepening the debate over the appropriateness of including multiple sourcing within the redundancy framework. In their empirical study, Zsidisin and Wagner (2010) also chose to measure flexibility and redundancy as independent variables.

5.5 Summary

From the literature it is evident that SCV and SCRes researchers have conceptual disagreement in the definition and conceptualization of terms like flexibility, redundancy agility, velocity etc. Although from an overview of the literature it can be inferred that redundancy could be visualized as a route to supply chain flexibility but the statement does not implicitly emerge from the present literature.

6 DISCUSSION

6.1 Introduction

The objective of this review was to discover the aspects of supply chain vulnerability, resilience and robustness. For this purpose one review question and three sub questions were defined in the first chapter. As SCV and resilience are being studied at a network level, the review was particularly interested to investigate the structural aspects of SCV and resilience. Since the field of SCV, resilience and robustness is still an evolving domain, thus not many relevant contributions relating to structural aspects could be discovered. The literature in the domain appeared to be fragmented as it fell short of providing a focused conceptualization of strategies and drivers influencing vulnerability, robustness or resilience. It was observed that the literature in the SCV and resilience domain is still in the divergent stage, where new ideas, methodologies, theoretical and ontological assumptions are still being explored. In the sections below the findings from the literature are discussed in relevance to my doctoral research. The first section presents a discussion of the thematic findings in line with the objective of answering the defined review question. This is followed by a discussion of key insights gained from the review and the future potentials of research in the area.

6.2 Answer To The Review Question

One of the key objectives of this review was to answer the research question and sub questions presented in the first chapter. The thematic findings of this review, as presented in the previous chapter, provide the basis to answer the review question and sub questions.

The primary review question of this systematic review is

What are the aspects of upstream supply chain vulnerability and resilience?

This can be answered using the three sub questions

6.2.1 Discussion Of Sub Question 1

The first sub question is

What are the drivers of supply chain vulnerability and resilience?

The Thematic findings chapter presents a comprehensive discussion about the drivers of SCV and resilience. The vulnerability drivers have been presented into two themes

(i) Structural vulnerability drivers

(ii) Strategic vulnerability drivers

Table 5-2 and 5-3 and the following description presents a detailed analysis of eight structural vulnerability drivers and nine strategic vulnerability drivers. Regarding the drivers of resilience, Zsidisin and Wagner (2010) argue that the lesser the vulnerability in the network the more the networks are resilient. Thus, extending this argument it can be inferred that the drivers of vulnerability are the same characteristics that can influence resilience.

6.2.2 Discussion Of Sub Question 2

The second sub question is

Q2. What are the supply network strategies that influence vulnerability or resilience?

The section 5.4 from the chapter of thematic findings presents a thorough discussion of strategies mentioned in the literature that may influence SCV or resilience. The approach to improve vulnerability and resilience has been classified into three themes

(i) Structural interventions

(ii) Operational interventions and

(iii) Strategic interventions

Within each theme the interventions suggested from the literature are presented with a discussion of their conceptualization and operationalization.

6.2.3 Discussion Of Sub Question 3

Q3. What are the structural properties of supply networks that influence resilience, robustness or vulnerability?

The structural properties of supply network have been dealt as individual themes in both the vulnerability drivers, section 5.3.1 and in strategies to improve vulnerability and resilience, section 5.4.4.

On the basis of the literature findings relevant to the three sub questions, we can comment upon the review question of this study. It can be argued that the SCV and resilience has two dimensions; a dimension of causes or drivers and a dimension of approaches or interventions to tackle these drivers. Both of these taken together form the aspects of supply chain vulnerability and resilience. Among these aspects, the aspect of network positioning and structural characteristic of network has not been thoroughly investigated in the present literature. Although many theoretical recommendations regarding structural drivers and interventions have been presented yet, the literature fall shorts on providing an operational validation of these constructs.

6.3 Insights from the Literature

6.3.1 Key insight 1

The resilience and robustness studies in other disciplines, like ecology, sociology and organization science, have reached a level of maturity with clearly defined theoretical and methodological foundations (Ponomarov and Holcomb, 2009). Whereas, the supply chain resilience and robustness studies

have not yet reached on a consensus about the theoretical or methodological approach. Some of the theoretical foundations like social network analysis, systems theory, and graph theory, have conflicting assumptions and ontology. This has proved to be a constraint in the progress of the field. Graph theory draws from simulation of nodes and edges, representing supply chain actors, whereas systems theory perspective use profit maximization and other optimization techniques.

6.3.2 Key Insight 2

There is a rich body of literature on supply chain risk and its drivers. However, the literature on vulnerability is still in the rudimentary stage. Due to its conceptual closeness to risk, the domain of SCV research falls short of generating sufficient contributions to fill all conceptual gaps A large gap exists in demonstrating the moderating effect of individual vulnerability drivers on other vulnerability drivers. There are also very limited network data based vulnerability research demonstrating the joint interaction of vulnerability drivers and supply chain product and network characteristics.

6.3.3 Key Insight 3

Among the suggested resilience strategies, the strategy of adopting manufacturing and operational flexibility and agility are the most recommended. Although, for a very simple set of assumptions Tang and Tomlin (2008) do test the moderating effect of flexibility on risk mitigation, however, there are no studies testing these strategies with supply network data. It is not a surprise as the problem is embedded in the way academicians have defined these constructs. Except the Tang and Tomlin (2008) quantification of manufacturing flexibility as the number of qualified suppliers, all the other existing definitions are conceptual explanations of the phenomenon.

Considering that supply chain flexibility and agility has an independent body of literature, there has not been a sufficient effort to include the knowledge in these existing domains into the context of resilience.

6.3.4 Key insight 4

For evaluating vulnerability or resilience, the literature recognizes the importance of two factors; relative network positioning of firms and the nature of interdependencies among them. However, the structural variables contributing towards these two factors are not dealt in detail.. Although in their extensive simulation study, Adenso-Diaz et al (2012) have succeeded in conceptualizing these factors using structural variables like node complexity, node criticality, flow criticality etc, yet it can be argued that the use of a simple network topology in this study limits the scope of the outcome. It can be further argued that the inherent characteristics of these constructs at a network level can only be captured using a network topology with a multi echelon, multi-tier global supply network structure, having hundreds of different type of nodes and product flows.

6.3.5 Key Insight 5

The early vulnerability and supply chain researchers proposed redundancy of capacity and inventory as one of the key resilience strategies. However, recent work on SCV and SCRes argued against practicing redundancy. The argument in support or against redundancy has not yet been tested using real network data. Most of the recommendations made against redundancy are based upon industrial best practices and managerial perception. However, there could be other factors that may influence the choice, for example Chopra and Sodhi (2004) have suggested product and demand characteristics appropriate for following redundancy ,such as fast moving goods with low forecast risk. Thus

it would useful to closely analyse other product, demand and network characteristic before deciding upon one policy and discounting others.

6.3.6 Key insight 6

Among strategies of improving resilience visibility is also suggested to be a very powerful tool for early disruption detection and for taking a corrective action to reduce impact. However similar to constructs like flexibility or agility this too has gaps in its conceptualization and operational validation. Aspects of its trade off with cost and efficiency are also not appropriately addressed. There is a rich possibility to simultaneously compare the moderating effects of level of technology, supply chain topology along with visibility on disruption handling. Moreover, issues addressing the subjective benefit of visibility for varying supplier and product characteristics or for varying supply chain structural and topological settings are also not yet addressed in the literature.

6.3.7 Key insight 7

It has been recognized that for managers it is very difficult to understand and predict the behaviour of a complex network. To counter this supply chain researchers have suggested for a creation of a unique predictive analysis tool to visualize the disruption propagation in a network. This tool could also serve as stress testing mechanism to identify weak nodes and links and also to simulate 'what if' scenarios. Although there is sufficient support for this sort of initiative tool, yet there has been no effort to create such a tool that may be sufficient to incorporate supply chain characteristics , capture most of the vulnerabilities and be able to provide a meaningful and simple to understand outputs that may assist the human decision making process.

6.3.8 Key insight 8

One of the most advocated characteristic of a resilient supply network is its capacity of adaptation. However, there is not a single empirical study focusing on this aspect of the construct. The reason to it is that literature does not provide any method or quantitative approach to measure adaptation. Although adaptation has been studied in complex network using agent based simulation, still the methodology has not yet been used to measure adaptation in SCV, resilience or robustness context.

6.3.9 Key insight 9

In a very recent study by Adenso-Diaz et al (2012) the aspects of structural robustness were studied using a simple set of network assumptions. The study highlights the contextual relevance of this approach. However, the proposed complexities of network, its nodes and its connecting edges can only be fully exploited by adopting a large scale complex network data of multi echelon, multiple products and with multiple buyer supplier relationships.

Also it is not just the number of nodes that will impact the result but also the relative positioning of each node in the extended supply chain. The impact of clusters, triads and dyads and their relative positioning also requires a thorough evaluation.

Although Adenso-Diaz et al (2012) have used an experiment design with a very high number of permutations, 2^{13} yet the experiment design fails to capture the dimension of relative importance of a node. In the network and graph theory, relative importance of node could be quantified as node with maximum connection or highest weightage. In supply chain context this could be a node with maximum suppliers or buyers and node which provides maximum

number of unique products to the network. But the existing literature has not captured this dimension of node characteristic.

6.4 Future Research Possibilities

The literature review indicates that there are many promising opportunities in the field of upstream supply chain vulnerability resilience and robustness research. The operationalization of constructs, like flexibility, agility and redundancy, requires a much thorough examination. There is a further need to understand aspects of the problem that can be investigated using different theoretical lenses, like systems theory, network / graph theory, social network theory etc.

This section proposes the directions for future research. Table 6-1 presents a list the research gaps observed from the key insights and also proposes future research prospect for each gap.

Table 6-1 Research gaps and future research directions

vulnerability, resilience and robustness themes	Research gap	Proposed research direction
SC Structure	Defining and measuring key structural parameters of SC. The moderating effect of these network variables on SCV and SCRes performance.	Define, quantify and operationalize key terms like weak nodes, structural holes, flow and node complexity, node and flow criticality etc.
	Modelling the complex dynamics behaviour of a supply network.	Adopt complex system methodologies, like agent based modelling, node percolation, error and attack tolerance etc, in supply chain vulnerability context.

	Process of supply network adaptation and response of a network to events of disruption.	Design experiments to particularly demonstrate adaptability n supply networks. Use them to investigate resilience and vulnerability in networks.
	Impact of disruptive events on industrial clusters and hubs of products and suppliers.	Choose the unit of network analysis to represent important supply chain clusters and nodes with high degree of importance both from critical and unique product perspective and important or unique supplier perspective.
SC Operations Strategy	Aspects and formative elements of supply chain visibility.	Moderating effect of collaboration, trust and opportunistic behaviour on the relationship of visibility and vulnerability.
	Redundancy or buffer; right quantity, location and product characteristics of safety stock.	Segmentation of product type for creating an inventory buffer and the right quantity, stock policy and location of such a buffer to influence vulnerability, resilience and robustness.
SC Strategy	Flexibility, velocity and agility in influencing vulnerability, resilience or robustness.	Operationalization of flexibility and agility. Methods to quantify and measure these in a network setting and experiments to

	discover their moderating influence on other vulnerability drivers.

'SC' refers to supply chain

The table 6-1 presents the gaps and future research directions grouped by the thematic framework of this review. Along with these research directions, there is an opportunity of jointly examining these individual themes. Flexibility, agility, collaboration, visibility and redundancy can all be examined by using any of the structural, operational or strategic lens. There would be varying theoretical and ontological assumptions for each case and this also can be a very promising area for future research.

6.5 Implications for My Doctoral research

The review of literature and proposed directions of future research has implications for my doctoral research. For my doctoral research, I propose to form a research question combining elements from all the three themes; structural, operational and strategic. The research question for my doctoral research would be;

What will be the moderating effect of flexible and agile supply chain strategy on critical supply chain nodes and links?

The answer of this research question will achieve the following objectives;

1. To clearly define a critical or weak supply chain node and link.
2. Devise methods and experiments to identify these critical and weak supply chain links.

3. For defined set of assumptions, evaluate the impact of flexible and agile supply chain strategies on the robustness and resilience of these nodes.

6.6 Contribution of this Review

This review is first to address the issue of SCV, SCRel and SCRob. The review provides an extensive overview of the present extant of the vulnerability, robustness research and it proposes a thematic framework to further extend the knowledge in this filed. The directions of future research suggested in the review will help address conceptual and theoretical gaps in the domain.

7 CONCLUSION

The objective of this review was to investigate the extent of literature in domain of supply chain vulnerability, robustness and resilience and to present a structured conceptualization of the research knowledge. Using a structured literature review approach, this review presented various theoretical and methodological underpinning of the resilience and vulnerability literature. The review findings are discussed within a framework of four aspects. Firstly, the review clarified the existing definition ambiguities of related constructs like vulnerability, risk, resilience, risk management and robustness, by addressing their similarities and dissimilarities. Secondly, the review presented the supply chain characteristics, also termed as supply chain drivers, which lead to vulnerability in the supply networks. Thirdly, the review presented strategies and best practices that may help supply chains to become more robust or resilient. Lastly, on the basis of key insights gained from the literature findings, the review suggested avenues for future research.

The next section presents the limitations and critique of this review followed by a note on my personal learning during the process.

7.1 Limitations of the Review

This literature review has three major limitations. First, the review is based upon a very small number of articles. This limits the validity of claims and findings. Second, the quality criterion adopted for the inclusion and exclusion of articles was subjective to my judgement and thus had an associated bias. Third, the findings and articles did not accurately fit into my framework of thematic categorization. Due to blurred definitions of terms and constructs, an article could be reasoned to be a part of other theme and also there could be

various other thematic frameworks that could have been used. The categorization offered by me had a level of subjectivity associated with it. Lastly, although a very high number of titles were reviewed for the process and data was collected from a very broad set of databases, yet it cannot be claimed with conviction that all relevant articles have been discovered.

7.2 Personal Learning

As it would have been mentioned a hundred times earlier that the process of systematic literature review is more punishing then you can actually imagine, I would candidly accept that I was wrong to underestimate the claim. Finally, at the end of this arduous journey I too would accept that it required more academic rigour than any other study I have ever undertaken.

For me, the initial process of literature review from title selection to data extraction, seemed to be very mechanical and not at all challenging, though time consuming. But when I sat to pen down the findings from the selected group of articles, the process became a scary ride. As I started to dig deep into articles, evaluating the interplay of arguments and trying to fit them in a logical and rational framework, the task started to challenge my mental faculties. After days of reading, regressing, reading and regressing again, there were times when I felt I knew everything and then there were days when I felt all that I knew was gone and I have to start all over again. It was only after many rounds of reading the articles over and over again, a holistic picture of the domain started to take shape in my subconscious and it was at this stage that I felt confident to write. But to reach at this level of awareness, it took months.

On the personal front, the vigour of the process taught me how to balance my family and work in a better manner; though my partner felt that the vigour and

tension reflected on my demeanour, and this is one thing that I need to improve in the personal front.

At the end of this systematic review process I can claim with confidence that I have gained sufficient knowledge of my research domain and related fields.

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APPENDICES

Appendix A List of Included Articles

1	(Adenso-Diaz et al., 2012)
2	(Albino et al., 1998)
3	(Blackhurst et al., 2005)
4	(Braunscheidel and Suresh, 2009)
5	(Carvalho et al., 2012)
6	(Choi and Krause, 2006)
7	(Chopra and Sodhi, 2004)
8	(Christopher and Peck, 2004)
9	(Colicchia and Strozzi, 2012)
10	(Colicchia et al., 2010)
11	(Craighead et al., 2007)
12	(Goetschalckx et al., 2012)
13	(Greening and Rutherford, 2011)
14	(Hallikas et al., 2004)
15	(Jüttner and Maklan, 2011)
16	(Jüttner et al., 2003)
17	(Kleindorfer and Saad, 2005)
18	(Manuj and Mentzer, 2008a)
19	(Meepetchdee and Shah, 2007)
20	(Nair and Vidal, 2011)
21	(Oke and Gopalakrishnan, 2009)
22	(Peck, 2005)
23	(Peck, 2006)
24	(Pettit et al., 2010)
25	(Pettit et al., 2013)
26	(Ponis, 2012)
27	(Ponomarov and Holcomb, 2009)
28	(Sheffi and Rice, 2005)
29	(Sheffi, 2001)
30	(Skipper and Hanna, 2009)
31	(Stecke and Kumar, 2009)
32	(Svensson, 2000)
33	(Svensson, 2002a)

34	(Svensson, 2002c)
35	(Tang, 2006)
36	(Tang and Tomlin, 2008)
37	(Tomlin, 2006)
38	(Wagner and Bode, 2006)
39	(Wagner and Neshat, 2010)
40	(Wagner and Neshat, 2012)
41	(Yang et al., 2010)
42	(Zsidisin and Wagner, 2010)
43	(Zsidisin et al., 2005)

Appendix B Quality Appraisal form of rejected articles

Full text quality appraisal was done using predefined weightage (scored from 1 to 5) for seven parameters in an article. Only the articles that had a net score more than 21 were selected for the final inclusion. There were 13 articles that did not meet the quality appraisal criterion. The table below presents details of these 13 articles . that were excluded from the review.

SNo 1	
Citation Baghalian, A., Rezapour, S. and Farahani, R. Z. (2013), "Robust supply chain network design with service level against disruptions and demand uncertainties: A real-life case", *European Journal of Operational Research,* vol. 227, no. 1, pp. 199-215.	
Author: (Baghalian et al., 2013) Title: Robust supply chain network design with service level against disruptions and demand uncertainties: A real-life case	
	Quality Score (1 lowest to 5 highest)
Is the research question/ objective of the paper rightly aligned with the objectives of my review	4
Is the research question / objective adequately established	3
Does the paper presents a good summary of relevant literature	3
Does the paper presents a clear picture of the methodology of data collection, sampling and method of analysis	2
Are the findings clearly reported	2
Does the discussion clearly answers the research question and objectives set by the author	2
What is the quality of the contribution to theory and is it clearly mentioned	2
Total Score	18

Was the paper selected (if the score is more than 21)	No
Additional comments if not selected Although it is a 3 tier multi echelon model but the third tier is the manufacturing unit and has no consideration of supplier disruption and most importantly it looks at a reactive response to disruption rather than a proactive one	

SNo 2	
Citation Barroso, A. P., Machado, V. H. and Cruz Machado, V. (2009), "Identifying vulnerabilities in the supply chain", *IEEM 2009 - IEEE International Conference on Industrial Engineering and Engineering Management,* pp. 1444.	
Author: (Barroso et al., 2009) Title: Identifying vulnerabilities in the supply chain	
	Quality Score (1 lowest to 5 highest)
Is the research question/ objective of the paper rightly aligned with the objectives of my review	2
Is the research question / objective adequately established	3
Does the paper presents a good summary of relevant literature	2
Does the paper presents a clear picture of the methodology of data collection, sampling and method of analysis	2
Are the findings clearly reported	2
Does the discussion clearly answers the research question and objectives set by the author	2

What is the quality of the contribution to theory and is it clearly mentioned	2
Total score	15
Was the paper selected (if the score is more than 21)	No
Additional comments if not selected	

SNo 3	
Citation Blos, M. F., Hui-Ming Wee and Yang, J. (2010), "Analysing the external supply chain risk driver competitiveness: A risk mitigation framework and business continuity plan", *Journal of Business Continuity & Emergency Planning,* vol. 4, no. 4, pp. 368-374.	
Author: (Blos et al., 2010) Title: Analysing the external supply chain risk driver competitiveness: a risk mitigation framework and business continuity plan	
	Quality Score (1 lowest to 5 highest)
Is the research question/ objective of the paper rightly aligned with the objectives of my review	3
Is the research question / objective adequately established	2
Does the paper presents a good summary of relevant literature	1
Does the paper presents a clear picture of the methodology of data collection, sampling and method of analysis	1

Are the findings clearly reported	1
Does the discussion clearly answers the research question and objectives set by the author	1
What is the quality of the contribution to theory and is it clearly mentioned	1
Total score	10
Was the paper selected (if the score is more than 21)	No
Additional comments if not selected	

SNo 4	
Citation Deane, J. K., Ragsdale, C. T., Rakes, T. R. and Rees, L. P. (2009), "Managing supply chain risk and disruption from IT security incidents", *Operations Management Research,* vol. 2, no. 1, pp. 4-12.	
Author: (Deane et al., 2009) Title: Managing supply chain risk and disruption from IT security incidents	
	Quality Score (1 lowest to 5 highest)
Is the research question/ objective of the paper rightly aligned with the objectives of my review	2
Is the research question / objective adequately established	4

Does the paper presents a good summary of relevant literature	2
Does the paper presents a clear picture of the methodology of data collection, sampling and method of analysis	3
Are the findings clearly reported	3
Does the discussion clearly answers the research question and objectives set by the author	4
What is the quality of the contribution to theory and is it clearly mentioned	3
Total score	21
Was the paper selected (if the score is more than 21)	No
Additional comments if not selected Only IT threats of the network were considered	

SNo 5	
Citation Dillon, R. L. and Mazzola, J. B. (2010), "Management of disruption risk in global supply chains", *IBM Journal of Research & Development,* vol. 54, no. 3, pp. 10:1-10:9.	
Author: (Dillon and Mazzola, 2010) Title: Management of disruption risk in global supply chains	
	Quality Score (1 lowest to 5

	highest)
Is the research question/ objective of the paper rightly aligned with the objectives of my review	3
Is the research question / objective adequately established	3
Does the paper presents a good summary of relevant literature	3
Does the paper presents a clear picture of the methodology of data collection, sampling and method of analysis	4
Are the findings clearly reported	3
Does the discussion clearly answers the research question and objectives set by the author	2
What is the quality of the contribution to theory and is it clearly mentioned	2
Total score	20
Was the paper selected (if the score is more than 21)	No
Additional comments if not selected	

SNo 6
Citation Faisal, M. N., Banwet, D. K. and Shankar, R. (2006), "Supply Chain Risk Mitigation: Modeling the Enablers", *Business Process Management Journal,* vol. 12, no. 4, pp. 535-552.

Author:(Faisal et al., 2006) Title: Supply chain risk mitigation: modeling the enablers	
	Quality Score (1 lowest to 5 highest)
Is the research question/ objective of the paper rightly aligned with the objectives of my review	1
Is the research question / objective adequately established	3
Does the paper presents a good summary of relevant literature	2
Does the paper presents a clear picture of the methodology of data collection, sampling and method of analysis	2
Are the findings clearly reported	3
Does the discussion clearly answers the research question and objectives set by the author	2
What is the quality of the contribution to theory and is it clearly mentioned	3
Total score	16
Was the paper selected (if the score is more than 21)	No
Additional comments if not selected Not a robust method, based on perception of only two academics	

SNo 7	
Citation Hale, T. and Moberg, C. R. (2005), "Improving supply chain disaster preparedness: A decision process for secure site location", *International Journal of Physical Distribution & Logistics Management,* vol. 35, no. 3, pp. 195-207	
Author:(Hale and Moberg, 2005) Title: Improving supply chain disaster preparedness: A decision process for secure site location	
	Quality Score (1 lowest to 5 highest)
Is the research question/ objective of the paper rightly aligned with the objectives of my review	3
Is the research question / objective adequately established	3
Does the paper presents a good summary of relevant literature	3
Does the paper presents a clear picture of the methodology of data collection, sampling and method of analysis	3
Are the findings clearly reported	2
Does the discussion clearly answers the research question and objectives set by the author	2
What is the quality of the contribution to theory and is it clearly mentioned	2
Total score	20
Was the paper selected	No

(if the score is more than 21)	
Additional comments if not selected Inventory and redundancy has been used as a policy but the article fails to provide a clear rationale for leaving out any other mechanism of securing valuable supply chain resources. The location optimization method is not the most appropriate of methodologies to answer the research question of the article.	

SNo 8	
Citation Huatuco, L. H., Burgess, T. F. and Shaw, N. E. (2010), "Entropic-related complexity for re-engineering a robust supply chain: a case study", *Production Planning & Control,* vol. 21, no. 8, pp. 724-735.	
Author: (Huatuco et al., 2010) Title: Entropic-related complexity for re-engineering a robust supply chain: a case study	
	Quality Score (1 lowest to 5 highest)
Is the research question/ objective of the paper rightly aligned with the objectives of my review	3
Is the research question / objective adequately established	3
Does the paper presents a good summary of relevant literature	2
Does the paper presents a clear picture of the methodology of data collection, sampling and method of analysis	3
Are the findings clearly reported	3
Does the discussion clearly answers the research question and objectives	2

set by the author	
What is the quality of the contribution to theory and is it clearly mentioned	2
Total score	18
Was the paper selected (if the score is more than 21)	No
Additional comments if not selected	

SNo 9	
Citation Klibi, W., Martel, A. and Guitouni, A. (2010), "The design of robust value-creating supply chain networks: A critical review", *European Journal of Operational Research,* vol. 203, no. 2, pp. 283-293.	
Author: (Klibi et al., 2010) Title: The design of robust value-creating supply chain networks: A critical review	
	Quality Score (1 lowest to 5 highest)
Is the research question/ objective of the paper rightly aligned with the objectives of my review	2
Is the research question / objective adequately established	3
Does the paper presents a good summary of relevant literature	2
Does the paper presents a clear picture of the methodology of data	2

collection, sampling and method of analysis	
Are the findings clearly reported	2
Does the discussion clearly answers the research question and objectives set by the author	2
What is the quality of the contribution to theory and is it clearly mentioned	2
Total score	15
Was the paper selected (if the score is more than 21)	No
Additional comments if not selected	

SNo 10	
Citation Klibi, W. and Martel, A. (2012), "Modeling approaches for the design of resilient supply networks under disruptions", *International Journal of Production Economics,* vol. 135, no. 2, pp. 882-898.	
Author: (Klibi and Martel, 2012) Title: Modeling approaches for the design of resilient supply networks under disruptions	
	Quality Score (1 lowest to 5 highest)
Is the research question/ objective of the paper rightly aligned with the objectives of my review	2
Is the research question / objective adequately established	3

Does the paper presents a good summary of relevant literature	2
Does the paper presents a clear picture of the methodology of data collection, sampling and method of analysis	3
Are the findings clearly reported	3
Does the discussion clearly answers the research question and objectives set by the author	2
What is the quality of the contribution to theory and is it clearly mentioned	3
Total score	18
Was the paper selected (if the score is more than 21)	No
Additional comments if not selected Only transport network is considered	

SNo 11	
Citation Shukla, A., Lalit, V. A. and Venkatasubramanian, V. (2011), "Optimizing efficiency-robustness trade-offs in supply chain design under uncertainty due to disruptions", *International Journal of Physical Distribution & Logistics Management,* vol. 41, no. 6, pp. 623-647.	
Author: (Shukla et al., 2011) Title: Optimizing efficiency-robustness trade-offs in supply chain design under uncertainty due to disruptions	
	Quality Score (1 lowest to 5

	highest)
Is the research question/ objective of the paper rightly aligned with the objectives of my review	2
Is the research question / objective adequately established	3
Does the paper presents a good summary of relevant literature	2
Does the paper presents a clear picture of the methodology of data collection, sampling and method of analysis	3
Are the findings clearly reported	3
Does the discussion clearly answers the research question and objectives set by the author	2
What is the quality of the contribution to theory and is it clearly mentioned	3
Total score	18
Was the paper selected (if the score is more than 21)	No
Additional comments if not selected Deals only with demand side	

SNo 12
Citation Vieira, G. E. and Lemos, R. (2009), "Understanding supply chain robustness", *2009 IEEE/INFORMS International Conference on Service Operations, Logistics and Informatics, SOLI 2009,* pp. 157.

Author: (Vieira and Lemos, 2009) Title: Understanding supply chain robustness	
	Quality Score (1 lowest to 5 highest)
Is the research question/ objective of the paper rightly aligned with the objectives of my review	2
Is the research question / objective adequately established	3
Does the paper presents a good summary of relevant literature	3
Does the paper presents a clear picture of the methodology of data collection, sampling and method of analysis	3
Are the findings clearly reported	2
Does the discussion clearly answers the research question and objectives set by the author	2
What is the quality of the contribution to theory and is it clearly mentioned	3
Total score	20
Was the paper selected (if the score is more than 21)	No
Additional comments if not selected More focus on demand fluctuations	

SNo 13	
Citation Wen, L., Xu, L. and Wang, L. (2013), "Research on the robustness of the directed complex supply chain network", *Journal of Information and Computational Science,* vol. 10, no. 2, pp. 563-570.	
Author: (Wen et al., 2013) Title: Research on the Robustness of the Directed Complex Supply Chain Network	
	Quality Score (1 lowest to 5 highest)
Is the research question/ objective of the paper rightly aligned with the objectives of my review	4
Is the research question / objective adequately established	3
Does the paper presents a good summary of relevant literature	3
Does the paper presents a clear picture of the methodology of data collection, sampling and method of analysis	2
Are the findings clearly reported	2
Does the discussion clearly answers the research question and objectives set by the author	2
What is the quality of the contribution to theory and is it clearly mentioned	2
Total score	18
Was the paper selected (if the score is more than 21)	No
Additional comments if not selected structures were not studied only attack methods were simulated (random or directed)	

Appendix C Methodology of Analysis

1	(Adenso-Diaz et al., 2012)	Simulation
2	(Albino et al., 1998)	Simulation
3	(Blackhurst et al., 2005)	Quantitative
4	(Braunscheidel and Suresh, 2009)	Quantitative
5	(Carvalho et al., 2012)	Simulation and case study validation
6	(Choi and Krause, 2006)	Theoretical
7	(Chopra and Sodhi, 2004)	Theoretical
8	(Christopher and Lee, 2004)	Theoretical
9	(Colicchia and Strozzi, 2012)	Simulation
10	(Colicchia et al., 2010)	Systematic Literature Review
11	(Craighead et al., 2007)	Qualitative
12	(Goetschalckx et al., 2012)	Simulation
13	(Greening and Rutherford, 2011)	Literature review
14	(Hallikas et al., 2004)	Qualitative
15	(Jüttner and Maklan, 2011)	Qualitative
16	(Jüttner et al., 2003)	Qualitative
17	(Kleindorfer and Saad, 2005)	Quantitative
18	(Manuj and Mentzer, 2008)	Quantitative
19	(Meepetchdee and Shah, 2007)	Model simulation
20	(Nair and Vidal, 2011)	Simulation
21	(Oke and Gopalakrishnan, 2009)	Quantitative
22	(Peck, 2005)	Quantitative
23	(Peck, 2006)	A literature review paper Theory
24	(Pettit et al., 2010)	Quantitative
25	(Pettit et al., 2013)	Quantitative
26	(Ponis, 2012)	Literature review
27	(Ponomarov and Holcomb, 2009)	Literature review
28	(Sheffi and Rice, 2005)	Theoretical
29	(Sheffi, 2001)	Theoretical
30	(Skipper and Hanna, 2009)	Quantitative
31	(Stecke and Kumar, 2009)	Quantitative
32	(Svensson, 2000)	Quantitative
33	(Svensson, 2002a)	Quantitative
34	(Svensson, 2002b)	Quantitative
35	(Tang, 2006)	Theoretical

36	(Tang and Tomlin, 2008)	Model
37	(Tomlin, 2006)	Model
38	(Wagner and Bode, 2006)	Quantitative
39	(Wagner and Neshat, 2010)	Quantitative
40	(Wagner and Neshat, 2012)	Quantitative
41	(Yang et al., 2010)	Simulation
42	(Zsidisin and Wagner, 2010)	Quantitative
43	(Zsidisin et al., 2005)	Qualitative

Appendix D Individual Data Extraction Sheet

Citation details
Reference Number 1
Citation
Title: The impact of supply network characteristics on reliability
Author(s): Adenso-Diaz, Belarmino; Mena, Carlos; García-Carbajal Santiago; Liechty, Merrill
Journal / Source: Supply Chain Management: An Int. J.
Year: 2012
Key words: Supply network risk management, Supply network design, Network design, Risk management, Simulation methods, Supply chain management
Study Background
Research Question(s)/Objectives: 1. What is the impact of different supply network design factors on the reliability of networks? 2. How are these factors interrelated?
Primary Research Focus: Reliability
Grounding Literature: Supply Chain
Methodology
Method: Empirical with Simulation followed by statistical analysis
Data Description: 2^{13} full-factorial design with 81,920 supply chain structures
Data collection instrument: multi-factorial Design of Experiments (DOE)
Sector:
Unit of analysis: Two tiers including focal firm
Analytical approach: ANOVA
Measure of resilience/robustness/ vulnerability: Truth tables for all possible structure configuration

Contribution
Key Findings: 1. The factors that may define how supply chain structure will influence reliability are Node complexity, Suppliers Complexity, Sources Criticality, Density, Node Criticality, Flow Complexity Node Reliability Flow Reliability. 2. Supply network reliability is positively related to Sources Criticality, Flow Reliability, Node Reliability and Flow Complexity. 3. There is significant interaction between the pairs Node complexity and Source criticality, between Node complexity and Node Reliability, and between Node complexity and Flow Complexity. 4. Lower level of Node complexity and supplier complexity or Node complexity and Node criticality leads to a higher network reliability 5. Network density is the second strongest factor , negatively associated with reliability, indicating that the higher geographical clustering between nodes the lower the network reliability. 6. Flow complexity has a positive effect on reliability, indicating that the higher the interconnectedness of network higher the reliability. 7. Results show that three factors (Node Complexity, Density and Node Criticality) decrease the reliability of the network while a fourth factor, Flow Complexity, helps to increase reliability. 8. Two network design factors associated with the supply of raw materials were included in the study: -Supplier Complexity and Sources Criticality. On the one hand, Supplier Complexity was found to have a strong negative effect on network reliability. 9. The interaction between both supplier related factors, Supplier Complexity and Sources Criticality, suggests that the contribution of the interaction between these variables is positive for reliability, but comparatively small in relation to other factors in the study.
Key prepositions and arguments: 1. Network design features such as high density or high node complexity will lead to lower reliability, not only because these factors affect reliability independently but also because they have strong interactions. 2. For node and flow complexity, authors argue that even though increasing the number of nodes in a network would reduce its reliability, increasing the number of connections would help to mitigate some of the negative effects. This dual role of complexity is often not recognised in practice. 3. In the new factors of reliability that the authors considered, the authors argue that sources criticality had the strongest positive effect on network reliability. 4. This provide evidence in favour of **multiple-sourcing**. 5. Network design elements, such as node complexity and sources criticality, were found to be considerably more important for overall network reliability than the reliabilities of these network element. 6. The design of supply networks is central to their reliability, and that **simplicity and redundancy** appear to be the two most critical factors when designing reliable supply networks
Limitations and Scope for further research: The definition of factors and method of their estimation is the biggest limitation of the study,
Synthesis/ Key contribution to review question In the structural aspects of reliability, the authors provide sufficient proof for reducing complexity, node criticality and supplier criticality. Another observation, important to my research is that the authors provide convincing evidence to support multiple sourcing, redundancy and decreasing network complexity.

Citation details
Reference Number 2
Citation
Title: Vulnerability of production systems with multi-supplier network: a case study
Author(s): Albino, V ; Garavelli, AC; Okogbaa, OG
Journal / Source: Int. J. of Production Research
Year: 1998
Key words: N/A

Study Background
Research Question(s)/Objectives: What are the effects of process uncertainty and product mix on a production system performance?
Primary Research Focus: Vulnerability of production systems to unexpected and unavoidable disruptions
Grounding Literature: Operations management
Methodology
Method: Model and simulation applied on an industrial case study
Data Description: N/A
Data collection instrument: Simulation results
Sector: Furniture
Unit of analysis: Focal firm and Tier 1 suppliers
Analytical approach: Algebra using variable plots
Measure of resilience/robustness/ vulnerability: Vulnerability calculated by back order frequency
Contribution
Key Findings: 1. System is vulnerable to throughput time variability. 2. If a very low through put variability is not guaranteed for the system , then the system shows a very high sensitivity to disruption for higher product mix.
Key prepositions and arguments: 1. Adoption of safety stock and reduction in product mix can improve performance.
Limitations and Scope for further research: Not mentioned
Synthesis/ Key contribution to review question
1. Vulnerability could be measured in back order quantity 2. Tight coupling between network nodes can lead to vulnerability

Citation details
Reference Number 3
Citation
Title: An empirically derived agenda of critical research issues for managing supply-chain disruptions
Author(s): Blackhurst , J.;Craighead, C. W.;Elkins, D. ;Handfield, R. B
Journal / Source: Int. J. Production Research
Year: 2005
Key words: Supply-chain management; Sourcing; Supply-chain disruptions; Supply-chain uncertainty; Empirical research; Supply-chain risk
Study Background
Research Question(s)/Objectives:
Primary Research Focus: Recovery and resilience
Grounding Literature: Resource dependency theory

Methodology
Method: Empirical using mixed methodologies of interview, focus group and case study
Data Description: Interview with focal firm and Ist tier suppliers, Focus group with 10 to 14 supply chain executives from various industry and sectors
Data collection instrument: Semi structured interviews and focus group
Sector: Case study of automotive supply chain and focus group of Multiple industries and sectors
Unit of analysis: First tier and focal firm, horizontal study
Analytical approach: Qualitative data analysis
Measure of resilience/robustness/ vulnerability: N/A
Contribution
Key Findings: The risk mitigation can be achieved by 1. Disruption discovery: Better visibility in the network 2. Capacity: ability to measure capacity at remote international locations or at various supply chain nodes. 3. Predictive analysis: Need for independent search agents and dynamic risk indices for every node. 4. Disruption recovery: To develop capacity to quickly reconfigure supply chains. 5. Reachability analysis: To have a clear view on system wide impact of disruption.
Key prepositions and arguments:
Limitations and Scope for further research: Suggested future research 1. Cost Vs benefits of investing in network visibility. 2. Type of supply chains, such as volatile, uncertain, dynamic or complex, for which having better visibility will be more beneficial. 3. Research focusing on the prediction of capacity bottlenecks in global transportation networks. 4. Issues regarding supply chain redesign.
Synthesis/ Key contribution to review question
Classification of vulnerability/ robustness/ resilience: 1. Time dependencies 2. Relationship vulnerability Drivers of Vulnerability: 1. Lack of visibility or method to measure dynamic changes in capacity of nodes, 2. Lack of predictive capacity in a complex system Remedies for vulnerability/ robustness/ resilience: 1. Identification of high probability notes 2. Flexibility and tools that can reconfigure the chain, 3. Tool to understand system wide impact of an event /disruption

Citation details
Reference Number 4
Citation
Title: The organizational antecedents of a firm's supply chain agility for risk mitigation and response
Author(s): Braunscheidel, Michael J.; Suresh, Nallan C.
Journal / Source: J. Operations Mgt.

Year: 2009
Key words: Supply chain management Agility, Flexibility Supply chain integration Disruption risk mitigation and response
Study Background
Research Question(s)/Objectives: To develop an enhanced supply chain agility framework
Primary Research Focus: Risk mitigation and management through enhanced flexibility
Grounding Literature:
Methodology
Method: Empirical
Data Description: After screening sample size was reduced to 2955 respondents, and 303 responses were received. A total of 218 usable responses were analysed (i) *Purchasing:* VP, director, manager; (ii) *manufacturing/operations*: VP, director, plant manager; (iii) *logistics:* VP, director, manager, supply chain manager, material manager; and general managers, presidents and other titles similar to the above. For
Data collection instrument: Seven point likert scale web based survey
Sector: Multiple sectors
Unit of analysis: Firm level
Analytical approach: Statistical using factor analysis and Chi square
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings:
Key prepositions and arguments: 1. agility is of value for both risk mitigation and response. 2. flexibility alone is not enough for agility in the supply chain. Internal and external integration are also necessary to ensure connected and coordinated response to meet unforeseen changes. Secondly,
Limitations and Scope for further research:
Synthesis/ Key contribution to review question 1. A good and clear conceptualization of flexibility and agility

Citation details
Reference Number 5
Citation
Title: Supply chain redesign for resilience using simulation
Author(s): Carvalho, Helena, Barroso, Ana P.;Machado, Virgínia H.;Azevedo, Susana Cruz-Machado,
Journal / Source: Computers & Industrial Engineering
Year: 2012
Key words: Supply chain design Supply chain resilience Case study Simulation

Study Background
Research Question(s)/Objectives: The main objective of the paper is to use simulation as a tool to support the decision making process in supply chain design to create a more resilient supply chain.
Primary Research Focus:
Grounding Literature:
Methodology
Method: Simulation and case study validation
Data Description: Logistics operations managers of automotive sector
Data collection instrument: Semi structured interview, face to face, email and telephone.
Sector: Automotive
Unit of analysis: Focal firm, Tier 1 and Tier 2
Analytical approach:
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. The factor of structural connectivity in a network directly to the Supply chainC design and allows strong capabilities in the areas of collaboration, visibility, and flexibility to be created, contributing to balanced resilience through the management of interrelated operations between multiple tiers of suppliers and customers.
Key prepositions and arguments:
Limitations and Scope for further research:
Synthesis/ Key contribution to review question

Citation details
Reference Number 7
Citation
Title: Managing risk to avoid supply-chain breakdown
Author(s): Chopra, S; Sodhi, MS
Journal / Source: MIT Solan Management Review
Year: 2004
Key words:
Study Background
Research Question(s)/Objectives: To identify types of supply chain risks and their management strategies
Primary Research Focus: Risk Management
Grounding Literature:

Methodology
Method: Theoratical
Data Description: N/A
Data collection instrument: N/A
Sector: N/A
Unit of analysis: Focal firm
Analytical approach:
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. Mitigating strategies for (i)Disruption risk: Inventory and redundant capacity. (ii) Procurement risk: Capacity, inventory, redundancy, flexibility 2. Mitigation approaches: Capacity, redundancy, responsiveness, inventory, flexibility, aggregating demand, increasing capability.
Key prepositions and arguments: 1. Individual supply chain risks are often interconnected. 2. Mitigation of risk by intelligently positioning and sizing the supply chain reserves is key to profitability. 3. Stress testing of supply chain for disruption scenarios can help identify and prioritize risk. 4. Risk can be mitigated by flexible capacity and by geographically scattering customers/ suppliers. 5. Decentralized approach is good for fast moving products. 6. Flexibility is good for short life cycle or slow moving products.
Limitations and Scope for further research: There is no discussion of cost and tradeoffs of efficiency and redundancy or capacity or flexibility.
Synthesis/ Key contribution to review question Some arguments regarding redundancy and flexibility are important for my research and need to be validated and contrasted with other recent empirical works.

Citation details
Reference Number 8
Citation
Title: Building the resilient supply chain
Author(s): Christopher, Martin, Peck, Helen
Journal / Source: I. J. Logistics Mgt.
Year: 2004
Key words:
Study Background
Research Question(s)/Objectives: Agenda for identification and management of supply chain risk and recommendations for improving supply chain resilience.

Primary Research Focus: Resilience
Grounding Literature:
Methodology
Method: Conceptual
Data Description: N/A
Data collection instrument: N/A
Sector: Multiple
Unit of analysis: Network
Analytical approach:
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. Modern supply chains are not simple linear relationships, they are a complex network. 2. The issue of supply chain vulnerability lacks necessary research base, both in government and the private sector, to comprehend the subject and grasp its impact or breadth. 3. Modern supply chains are at greater risk than its mangers or decision makers think it to be. 4. Risk can be categorized into three categories; (i) Internal to the firm: Process, Control (ii) External to the firm but internal to supply chain: Demand, Supply (iii) External to the network: Environmental
Key prepositions and arguments: 1. Resilience should be built into the supply chain. 2. It would require high level of collaboration. 3. Agility is very important, in a way it signifies resilience. 4. Risk management culture can enhance resilience. 5. Identify critical paths in a supply chain (long lead rime, single source, poor visibility, identifiable risk) 6. Rationalise the supply base strategy. While outsourcing cost reduction through supplier consolidation, there is a limit to pursue the strategy. 7. Supply chain design has an analogy with 'Real Option Theory' from investment planning. Re-examine efficiency vs. redundancy tradeoff. 8. Agility in supply chain is the ability to respond rapidly to unpredictable change. 9. The two ingredients of agility are visibility and velocity. 10. Dimensions of velocity are; streamlined process, reduced lead time and reduced non –value added time.
Limitations and Scope for further research: There are other methods of categorizing supply chain risk and authors draw only on the aspect from their empirical results of on-going studies. Cost aspects of redundancy or flexibility are not considered.
Synthesis/ Key contribution to review question The article presents a good overall conceptual explanation of agility, resilience etc.

Citation details
Reference Number 9

Citation
Title: Supply chain risk management: a new methodology for a systematic literature review
Author(s): Colicchia, Claudia; Strozzi, Fernanda
Journal / Source: Supply Chain Mgt : IJ
Year: 2012
Key words:
Study Background
Research Question(s)/Objectives: advance the understanding of SCRM by conducting a focused literature review aiming to investigate the process of knowledge creation, transfer and development from a dynamic perspective.
Primary Research Focus:
Grounding Literature: Network analysis
Methodology
Method: Systematic Literature review
Data Description:
Data collection instrument:
Sector:
Unit of analysis:
Analytical approach:
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: key elements for a robust and resilient supply chain are a strategy and a structure aligned with the actual business context, a dynamic and comprehensive approach to risk management, and, finally, collaboration among all companies operating within the same supply network
Key prepositions and arguments: Research directions for future research are proposed Locating research into SCRM within the more structured study of the supply chain complexity Modelling supply chains considering robustness and resilience Assessing and managing disruption risks Investigating mitigation capabilities, adopting a supply network perspective, i.e. considering the supply chain as an open system interconnected with the environment Evaluating the value of an increased supply chain resilience and robustness
Limitations and Scope for further research:
Synthesis/ Key contribution to review question
A good source of consolidated research on supply chain management

Citation details
Reference Number 10
Citation
Title: Increasing supply chain resilience in a global sourcing context

Author(s): Colicchia, Claudia; Dallari, Fabrizio; Melacini, Marco
Journal / Source: Production Planning & Control: The Management of Operations
Year: 2010
Key words: supply chain risk management; resilience; inbound supply risk analysis; international transportation; global sourcing
Study Background
Research Question(s)/Objectives: How a company (manufacturer or retailer) can increase its supply chain resilience by employing the risk management approaches that have been highlighted in the literature review: mitigation actions and contingency plans.
Primary Research Focus: Risk mitigation and resilience
Grounding Literature:
Methodology
Method: Simulation
Data Description: N/A
Data collection instrument: Monte Carlo Simulation
Sector: Transport
Unit of analysis: Tier 1 and Transport
Analytical approach: Statistics
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. Risk management in supply chain has three approach (i) Operational buffers: (e.g. excess inventory or productive capacity) traditional buffering strategies could decrease operational performances and could negatively impact competitive advantage. (ii) Mitigation: based on the analysis of the processes with the aim of reducing the likelihood of occurrence. (iii) Introducing contingency plans: These can be activated once a negative event occurs. , contingency plans are further divided into: Response plans (immediate reaction to a problem), Recovery plans (actions needed to resume the essential parts of a process or a business) and restoration plans (starting up the whole organisation from scratch
Key prepositions and arguments: 1.Contingency plans are better than mitigation activities. 2. Applying both the contingency planning and mitigation strategies, can reduce the transport lead time considerably.
Limitations and Scope for further research: 1. Cost are not modelled in the model 2. Combining safety and risk it with a cost-evaluation model, could offer a good tool to perform sensitivity analysis
Synthesis/ Key contribution to review question 1. The article focuses on increasing velocity by decreasing lead time of transport.

Citation details

Reference Number 11
Citation
Title: The Severity of Supply Chain Disruptions: Design Characteristics and Mitigation Capabilities
Author(s): Craighead, Christopher W.;Blackhurst, Jennifer; Rungtusanatham, M. Johnny Handfield; Robert B.
Journal / Source: Decision Sciene
Year: 2007
Key words: Business Continuity Planning, Case Studies, Empirical Re- search, Focus Groups, Multimethod Research, Purchasing, Procurement, Sourcing, Supply Chain Design, Supply Chain Disruptions, Supply Chain Management, Supply Risk Management, Supply Chain Uncertainty, Tele- phone Interviews, and Theory Building.
Study Background
Research Question(s)/Objectives: How and why would one supply chain disruption be more severe than another?
Primary Research Focus: Mitigation
Grounding Literature:
Methodology
Method: Empirical
Data Description: 1. U.S-based automobile manufacturer, 2. Top supply chain executives from Nine firms in different sectors, 3. Focus groups
Data collection instrument: Semi structured interviews
Sector: U.S-based automobile manufacturer and multiple sectors
Unit of analysis: Network
Analytical approach: Qualitative
Measure of resilience/robustness/ vulnerability: N/A
Contribution
Key Findings: 1. The severity of a supply chain disruption within a supply chain appears to be positively related to supply chain density. 2. Firms are more concerned with regional disruptions that affect a cluster of suppliers than with a disruption affecting any specific supplier. 3. A more complex supply chain would have a larger number of nodes and flows than one that is relatively less complex. 4. Supply chain complexity and the severity of a supply chain disruption also appear to be positively related. 5. The severity of a supply chain disruption also appears to be positively related to node criticality. 6. The severity of a supply chain disruption, therefore, appears to be negatively related to the warning capability present in the supply chain
Key prepositions and arguments: 1. An unplanned event that disrupts one or more dense portions of a supply chain would be more likely to be severe than the same supply chain disruption affecting relatively less dense portions of the same supply chain. 2. An unplanned event that disrupts one or more complex portions of a supply chain would be more likely to be severe than the same supply chain disruption affecting relatively less complex portions of the supply chain. 3. An unplanned event disrupting a supply chain with many critical nodes would be more likely to be severe than the same supply chain disruption occurring within a supply chain with few critical nodes. 4. An unplanned event that disrupts a supply chain with the capability to proactively and/or reactively respond quickly and effectively to correcting the disruptive event is less likely to be severe than the same supply chain

disruption affecting a supply chain with little or no capability to recover. 5. An unplanned event that disrupts a supply chain with the capability to quickly detect and disseminate pertinent information pertaining to the disruptive event is less likely to be severe than the same supply chain disruption affecting a supply chain with little or no capability to warn.
Limitations and Scope for further research: 1. Future research can test and validate the six propositions against other forms of data and research designs (e.g., large-scale studies utilizing the critical incident technique to systematically investigate differ- ences between a supply chain disruption that is severe versus one that is not severe, simulation-based studies involving varying the levels of the three design character- istics and the two mitigation capabilities, and longitudinal field research tracking a supply chain disruption as it unfolds over time
Synthesis/ Key contribution to review question 1. The paper derives six propositions relating the severity of supply chain disruptions to the supply chain design characteristics of density, complexity, and node criticality and to the supply chain mitigation capabilities of recovery and warning. These will serve as a starting point for my research.

Citation details
Reference Number 12
Citation
Title: Robust global supply network design
Author(s): Goetschalckx, Marc; Huang, Edward; Mital, Pratik;
Journal / Source: Information, Knowledge, Systems Mgt.
Year: 2012
Key words: Supply chain and network design, robust systems design, risk-based design, modeling-based decision support, supply chain risk management
Study Background
Research Question(s)/Objectives: How to design and plan the activities of the global supply network in advance to minimize the impact of possible future disruptions?
Primary Research Focus: Risk mitigation
Grounding Literature: Systems engineering approach
Methodology
Method: A normative optimization based symbolic mathematical model
Data Description:
Data collection instrument:
Sector: Manufacturing supply chain
Unit of analysis:
Analytical approach: Simulation modelling
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. Implementing the best supply network configuration for the most likely values of the uncertain parameters is

not an efficient configuration. 2. To realize a higher expected profit the supply network must accept higher variability of the profit
Key prepositions and arguments: 1. The network structure configuration with highest expected performance also has the highest risk. 2. Selecting a supply chain configuration with an appropriate robustness is one of the principal risk mitigation policy.
Limitations and Scope for further research: This was a optimization based study and had a positivistic ontology, which is not consistent with the highly uncertain and dynamic environment of modern supply chains.
Synthesis/ Key contribution to review question 1. Robustness can be traded off with performance and the paper defines some benchmarking mechanisms to do so. 2. It highlights the potential of structural configuration in achieving mitigating disruption risk.

Citation details
Reference Number 13
Citation
Title: Disruptions and supply networks: a multi-level, multi-theoretical relational perspective
Author(s): Greening, Phil; Rutherford, Christine
Journal / Source: Int. J. of Logistics
Year: 2011
Key words: Supply chain management, Social networks
Study Background
Research Question(s)/Objectives: 1. How can supply chain disruption be viewed through the lens of network- related theories? What is required to consider in terms of change/adaptation to ensure business continuity in the context of a supply network disruption?
Primary Research Focus: Disruption and resilience
Grounding Literature: Network theory, Social network theory and supply chain management
Methodology
Method: Literature review
Data Description:
Data collection instrument:
Sector:
Unit of analysis: Dyadic and Network level
Analytical approach:
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. There is reasonable agreement in the literature regarding the nature of disruptions, they are: difficult to predict,

rare, have significant impact and result in discontinuities. 2. Much of the extant literature is focused on the mitigation of risk, implicitly assuming that sources of risk can be identified, and bases mitigation strategies on organisational preparedness 3. Understanding network formation is fundamental to understanding network behaviour. Actors. 4. In networks containing a focal buyer and many suppliers, the propensity for supplier opportunism was negatively related to its embeddedness, its perceived embeddedness and the connectedness. 5. In a network embeddedness, structural differentiation (a reasonable proxy for network maturity) and interdependence all influence what relationships the various actors form. 6. The ability of a firm to react to external changes is dependent on its awareness of its position in the network, without this awareness a firm cannot comprehend its embeddedness, and therefore the network imposed inertia in its reaction to events outside the dyad. 7. The interaction between network actors gives the network a set of characteristics, which can be used to predict its behaviour as it evolves. 8. Network attributes like Density that reflects the concentration of ties within a network m holes reflect the lack of connection between clusters , weak ties the relative strength of relationships , equivalence the similarity of organizations structural position ,will determine the way that networks respond to disruption
Key prepositions and arguments: 1. The time taken for a network to recover will be greater in dense networks, compared to the time taken for less dense networks to recover. 2. The impact of a disruption will be greater in less dense networks than in more dense networks. 3. Disruptions in dense networks will result in greater instability across the network during the recovery phase. 4. Networks with a higher proportion of holes, and associated high dependency ties, will experience greater disruptive impact on those networks with fewer holes. 5. Networks with a high proportion of holes, and associated high dependency ties, will take longer to recover from a disruptive impact than those networks with fewer holes. 6. Disruptions in structurally evolving networks will have greater impact than in mature networks with proportionately less holes. 7. Nodes whose shortest connecting path to a disruptive event is via a weak tie will be impacted less than a node whose shortest connecting path is through a greater number of strong ties. 8. Nodes whose shortest connecting path to a disruptive event is via a weak tie will recover more quickly than a node whose shortest connecting path is through a greater number of strong ties. 9. Disruptions connected to powerful nodes (described by centrality) will result in less impact and then accelerated recovery period when compared to disruptions connected to less powerful nodes
Limitations and Scope for further research: Lack of empirical validation for prepositions.
Synthesis/ Key contribution to review question
All findings and propositions are aligned to my research question.

Citation details
Reference Number 14
Citation
Title: Risk management processes in supplier networks
Author(s): Hallikas, Jukka; Karvonen, Iris; Pulkkinen, Urho; Virolainen, Veli-Matti Tuominen, Markku
Journal / Source: International Journal of Production Economics
Year: 2004
Key words:
Study Background
Research Question(s)/Objectives: What kinds of risks arise from network collaboration? (2) How do the risk management processes operate in network collaboration?

Primary Research Focus: Risk Management
Grounding Literature:
Methodology
Method: Empirical case study
Data Description: Electronic and Metal industry
Data collection instrument:
Sector:
Unit of analysis:
Analytical approach: Qualitative
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: A typical risk management process of an enterprise consists of ;risk identification, risk assessment, decision and implementation of risk management actions, risk monitoring. risk management strategy include; risk transfer, risk taking, risk elimination, *risk reduction, further analysis of individual risks
Key prepositions and arguments: Companies become more dependent on each other and thus risk transfer and sharing occur in networks. The primary purpose of network co-operation is to bring benefits to both the original equipment manufacturer (OEM) and the suppliers. This is, however, likely to increase dependency between the organizations.
Limitations and Scope for further research:
Synthesis/ Key contribution to review question

Citation details
Reference Number 15
Citation
Title: Supply chain resilience in the global financial crisis: an empirical study
Author(s): Jüttner, Uta; Maklan, Stan
Journal / Source: Supply Chain Magt: An Int. J.
Year: 2009
Key words: Supply chain resilience, Supply chain vulnerability, Supply chain risk management, Supply chain disruptions, Financial risk, World
Study Background
Research Question(s)/Objectives: 1. To define the conceptual domain of Supply chain resilience. 2. To conceptualise the linkage between supply chain resilience, risk mitigation and vulnerability. 3. To explore the proposed relationships empirically between: (i) supply chain risk effect as well as knowledge management; (ii) the four formative supply chain capabilities “flexibility”, “velocity”, “visibility” and “collaboration”; and

(iii) The vulnerability of supply chains in the context of a major manifest supply chain risk event: the global financial crisis.
Primary Research Focus:
Grounding Literature:
Methodology
Method: Empirical case study
Data Description: A cabling supplier , a speciality chemical supplier and a wood timber wholesaler. There were 28 interview and five workshop with participants from all organizational hierarchies starting from the owner/ Directors to line mangers.
Data collection instrument: Interviews and workshops
Sector: Electrical, timber and chemical
Unit of analysis: Firm level
Analytical approach: Content analysis and qualitative data analysis
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. There are four supply chain resilience capabilities; Flexibility, velocity, visibility and collaboration. 2. There are three supply chain risk mitigation strategies and they influence various resilience capabilities; (i) Sharing risk: positive influence on flexibility, visibility and collaboration. Examples to this strategy are index based pricing, joint business continuity plans, outsourcing agreements. (ii) Hedging risk: positive influence on flexibility and velocity. Examples to the strategy are regional distribution centres or warehouses, decentralized supply chain management , dual or multiple sourcing. (iii) Knowledge management: positive influence on visibility. Examples to the strategy are Formalized supplier risk management process, human resource dedicated to risk management.
Key prepositions and arguments: 1. Many companies ignore or tolerate the presence of low probability high impact risk. 2. Flexibility and visibility are very important dynamic supply chain capabilities that can not only contain supply chain disruptions but, moreover, generate competitive advantage also in normal, routine operating times. 3. To adopt a centralised supply chain planning with decentralised local capacity could be led to resilience and competitive advantage. 4. Having slack in resource and capability is also very important.
Limitations and Scope for further research: 1. Findings suggest that a more refined relationship between Supply chain risk and resilience and a tighter specification of research propositions should be investigated through further empirical research. 2. Behavioural antecedents of resilience is also important for future research. Limitations are 1. No systematic empirical measure of resilience was used for before and after recession scenario. 2. It only takes recession as one risk event but there could be other aspects.
Synthesis/ Key contribution to review question
1. Flexibility , velocity and visibility are highly relevant to the supply chain structure and suggests a closer evaluation. 2. Multi sourcing and decentralized strategies also have structural antecedents.

Citation details
Reference Number 16
Citation
Title: Supply chain risk management: outlining an agenda for future research
Author(s): Jüttner, Uta; Peck, Helen; Christopher, Martin
Journal / Source: Int. J. Logistics Research and Applications
Year: 2003
Key words:
Study Background
Research Question(s)/Objectives: purpose of this paper is to delineate the domain of risk management in supply chains, to provide an operational definition and to outline an agenda directing future research
Primary Research Focus: risk management
Grounding Literature:
Methodology
Method: Empirical
Data Description: Managers from supply chain
Data collection instrument: Semi structured interviews
Sector: industrial, consumer and service industries (see
Unit of analysis: Focal firm
Analytical approach: Qualitative
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. Critical aspects of risk management are (a) assessing the risk sources for the supply chain; (b) identifying the risk concept of the supply chain by defining the most relevant risk consequences; (c) tracking the risk drivers in the supply chain strategy; and (d) mitigating risks in the supply chain. 2. Main sources of risk are Network, Environmental and organizational. 3. network-related risk sources: lack of ownership, chaos and inertia. 4. implementing a supply chain-wide risk assessment is a complex and difficult task. 5. network-related risks are an important and so far neglected source of risk. visibility and control appear to be thinning beyond the next tier of related organisation. 6. Network-related risk sources, however, cannot be dealt with through ‘‘tried and trusted’’ risk assessment tools. Instead, identifying network risks requires a thorough understanding of the supply network’s structure, flows, operational dynamics and complexities. 7. Managers are insensitive towards low probability and high impact risk. 8. Supply chain-wide risk management on the other hand is not yet recognised as a key element in business continuity planning.
Key prepositions and arguments: 1. The factors that have increased risk are (a) a focus on efficiency rather than effectiveness; (b) the globalisation of supply chains; (c) focused factories and centralised distribution; (d) the trend to outsourcing; and (e) the reduction of the supplier base. 2. Some of the other risk drivers like the reduction of the supplier base and the trend towards efficiency rather than effectiveness lead to more integrated supply chains

3. risk mitigating strategies in supply chains have to be investigated in conjunction with the risk drivers.
Limitations and Scope for further research: 1. Assessing the risks sources for the supply chain. 2. Developing more practical approaches to guide the risk assessment process in supply networks 3. Identifying the risk drivers of the supply chain strategy. 4. Developing approaches helping managers to track the vulnerabilities of their supply chain strategies. 5. Handling trade-off decisions was a highly relevant issue. 6. Sheffi (2002) as: (1) repeatability versus unpredictability, i.e. trading the benefits of repeatable processes against the cost of a lack of flexibility; (2) the lowest bidder versus the known supplier; (3) centralisation versus dispersion decisions in pro- duction and distribution; (4) collaboration versus secrecy, i.e. while sharing more information on, for example, the results of risk audits would better place organi- sations to manage supply chain risks, it could also deter potential customers or weaken the bargaining position; and (5) redundancy versus efficiency, i.e. 7. Four critical aspect of management concept are: (1) assessing the risks sources for the supply chain; (2) defining the supply chain risk concept and adverse consequences; (3) identifying the risk drivers in the supply chain strategy; and (4) mitigating risks for the supply chain.
Synthesis/ Key contribution to review question The managerial view presented in the article is highly relevant for the formulation of future supply chain resilience strategies

Citation details
Reference Number 17
Citation
Title: Managing Disruption Risks in Supply Chains
Author(s): Kleindorfer, Paul R.; Saad, Germaine H.
Journal / Source: Production and Operations Management
Year: 2009
Key words: disruptive risks; operational risks; supply chain management
Study Background
Research Question(s)/Objectives: How to effectively manage disruption risk in supply chain operations? Objectives: 1. Develop a conceptual framework that reflects the effective integration of the joint activities of risk assessment and risk mitigation. 2. Provide strategic directions, actions, and necessary conditions that help advance cost-effective mitigation practices
Primary Research Focus: Risk Management
Grounding Literature: Industrial Risk Management
Methodology
Method: Empirical
Data Description: Empirical results on hazards and disasters from US chemical industry. Risk Management Programs for Chemical Accidental Release Prevention" data between 1995 and 2000
Data collection instrument: Agency
Sector: Chemical industry
Unit of analysis: Firm level (specific manufacturing plant)
Analytical approach: Statistical nonparametric using Pearson chi-square or Wilcoxon rank test

Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. There are two fundamental approaches to manage supply chain risk; First practices that can reduce the severity and frequency of risk at firm and network level, Second strategies that will increase the capacity of supply chain participants to sustain or absorb risk. 2. For implementing risk mitigation strategies, internal supply chain integration and optimization must precede any inter-firm interfaces. 3. Similar to the concept of hedging in finance, the sourcing of product and services should have multi dimension diversification. 4. For risk management we should target the weakest link in the supply chain
Key prepositions and arguments: 1. High quality contingency approaches, similar in spirit to six sigma, must be used and continually audited. 2. The approach used, should be aligned (fit) with characteristics and needs of the underlying decision environment. 3. For risk mitigation, there should be a good coordination between partners. This can be enhanced by Trust, information, continuing profitability etc
Limitations and Scope for further research:
Synthesis/ Key contribution to review question: The article suggests 1. supplier and logistics diversification. 2. Identification of the most vulnerable node in the network

Citation details
Reference Number 18
Citation
Title: Global supply chain risk management strategies
Author(s): Manuj, Ila; Mentzer, John T.
Journal / Source: International Journal of Physical Distribution & Logistics Management
Year: 2008
Key words:
Study Background
Research Question(s)/Objectives: To develop a definition of supply chain risk. definition of risk management in a global supply chain context Explore three moderators in the process of risk management, namely team composition, supply chain complexity management, and inter-organizational learning.
Primary Research Focus: Risk Management
Grounding Literature:
Methodology
Method: grounded theory methodology. Grounded theory is a qualitative research methodology
Data Description: 14 interview with mangers from supply chain of 8 companies

Data collection instrument: Semi structured interview
Sector: manufacturing companies, including home appliances, electronic component suppliers, pharmaceuticals and over-the-counter products, office products, heavy equipment, and consumer goods
Unit of analysis: Firm
Analytical approach: Quantitative
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: There are two moderators of the strategy implementation-performance relationship – complexity and inter-organizational learning. literature does not sufficiently address implementation issues after strategy selection, and
Key prepositions and arguments: Factors influencing risk management strategy, namely temporal focus, supply chain flexibility, and supply chain environment
Limitations and Scope for further research: sample consists exclusively of managers involved in making and executing supply chain decisions for their firms
Synthesis/ Key contribution to review question
The interplay of strategy and implementation is good for my doctoral research

Citation details
Reference Number 19
Citation
Title: Logistical network design with robustness and complexity considerations
Author(s): Meepetchdee, Yongyut; Shah, Nilay
Journal / Source: Int. J. Physical Distribution & Logistics Management
Year: 2007
Key words:
Study Background
Research Question(s)/Objectives: 1. To develop a complexity measure for logistics network. 2. To develop a framework for designing logistical networks with desired levels of robustness. 3. Explore relationships of logistical network efficiency, robustness, and complexity.
Primary Research Focus: Robustness and structural complexity
Grounding Literature: Graph Theory
Methodology
Method: Mathematical model and case study
Data Description:
Data collection instrument:
Sector:
Unit of analysis: Focal firm

Analytical approach: Mathematical model
Measure of resilience/robustness/ vulnerability: Logistical network robustness is the ratio of the extent to which the network is able to fulfil demand when deleting component j
Contribution
Key Findings: 1. The objectives of design for efficiency and design for robustness are often in conflict. 2. Characteristic of network topology is that, for many real-world networks such as the internet, protein interaction networks, etc. the plot of degree of vertex (k_i) versus its probability $p(k_i)$ is often found to be a power law distribution. 3. robust logistical networks in this paper typically follow the power-law degree distribution, a well-known topological property of scale-free networks, and exhibit small APL.
Key prepositions and arguments: 1. efficiency of logistical network be measured by conventional supply chain optimisation objectives such as costs, customer delays, etc. 2. Mathematically defined logistics network robustness. 3. Defined logistical network complexity and normalised efficiency. 4. Supply chain managers have to trade-off robustness with both complexity and efficiency.
Limitations and Scope for further research: Directions for future work are identifying other aspects of robustness and complexity, conditions for the emergence of topological robustness versus redundancy robustness, using supply contracts to influence topological robustness, and more realistic supply chain network.
Synthesis/ Key contribution to review question 1. Has demonstrated different logistical network structures based on various trade-offs between efficiency and robustness including network complexity measurement. 2. The paper demonstrates a good use of graph theory for some standard topologies.

Citation details
Reference Number 20
Citation
Title: Supply network topology and robustness against disruptions – an investigation using multi-agent model
Author(s): Nair, Anand;Vidal, José M.
Journal / Source: International Journal of Production Research
Year: 2011
Key words:
Study Background
Research Question(s)/Objectives: To examine how supply network topology is associated with its robustness in the event of disruptions.
Primary Research Focus: Robustness
Grounding Literature: Network and graph theory
Methodology
Method: Simulation
Data Description: 10 network topologies representing random networks and 10 network topologies representing scale-free networks.
Data collection instrument:

Sector:
Unit of analysis: Network
Analytical approach: Agent based modelling and statistics
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: In the presence of disruptions, the robustness of the supply network is negatively associated with its average path length. In the presence of disruptions, the robustness of the supply network is negatively associated with its clustering coefficient In the presence of disruptions, the robustness of the supply network is positively associated with the size of its largest connected component. In the presence of disruptions, the robustness of the supply network is positively associated with the maximum distance in its largest connected component
Key prepositions and arguments:
Limitations and Scope for further research:
Synthesis/ Key contribution to review question The graph theory perspective of error or attck tolerance is very important for my work. The paper defines good modelling approach to incorporate netwrk complexity

Citation details
Reference Number 21
Citation
Title: Managing disruptions in supply chains: A case study of a retail supply chain
Author(s): Oke, Adegoke; Gopalakrishnan, Mohan
Journal / Source: Int. J. Production Economics
Year: 2009
Key words: Supply chain risks, Disruption, Case study, Retail
Study Background
Research Question(s)/Objectives: 1. What are the different types of risks or potential risks in a retail supply chain? What are the mitigation strategies required to manage these risks? 2. Which of these are generic and which are specific to a particular type of risk?
Primary Research Focus: Risk mitigation
Grounding Literature:
Methodology
Method: Empirical using a Case research approach
Data Description: 1. Six participants from the focal firm including Vice-President of Supply chain, two purchasing managers, two store managers and a distribution centre supervisor. 2. Two supply chain mangers from vendors.

Data collection instrument: Semi structured interviews
Sector: Retail
Unit of analysis: Firm level
Analytical approach: Qualitative
Measure of resilience/robustness/ vulnerability: N/A
Contribution
Key Findings: 1. Supply chain risk can be categorized as High likelihood, low impact, Low likelihood, high impact and Medium likelihood, moderate impact. 2. High likelihood, low impact, supply side risk are due to imports and climate Strategies to mitigate it is flexible capacity, 3. Low likelihood, high impact supply side risk are due to manmade and natural disasters,. Strategy to mitigate it is contingency planning. 4. Medium likelihood, moderate impact supply side risk are due to socio economic and loss of key suppliers. Strategy to mitigate it is multiple.
Key prepositions and arguments: 1. Better coordination and planning can reduce high likelihood and low impact risk. 2. To cope with low-likelihood high-impact risks there is a need to identify supply chain vulnerability points and to have contingency plans.
Limitations and Scope for further research: Future research should empirically test these propositions
Synthesis/ Key contribution to review question Remedies for vulnerability/ robustness/ resilience: 1. Contingency planning 2. Identification of vulnerable nodes

Citation details
Reference Number 22
Citation
Title: Drivers of supply chain vulnerability: an integrated framework
Author(s): Peck, Helen
Journal / Source: Int. J. of Physical distribution and Logistics Mgt.
Year: 2005
Key words: Supply chain management, Risk management, United Kingdom
Study Background
Research Question(s)/Objectives: How can the supply chain networks of United Kingdom can be made more resilient?
Primary Research Focus: Vulnerability of a nation's supply networks
Grounding Literature: Systems Theory
Methodology

Method: Empirical based upon a single case study
Data Description: 47 Managers in Five Tier of supply network of a defence aircraft manufacturer and cross validation from 27 senior supply chain mangers from across the industry.
Data collection instrument: Semi structured interview with snow ball sampling
Sector: Defence aircraft, food and drink, Personal care, Health care, automotive, Electronics, Oil, Transport, Packaging
Unit of analysis: Network level both horizontal and vertical
Analytical approach: Qualitative
Measure of resilience/robustness/ vulnerability: N/A
Contribution
Key Findings: Drivers of Vulnerability: They have four levels 1. Level 1-Value stream / Product or process: Irregular demand patterns, measures introduced to reduce costs, changes and upgrades to product specifications, customer determined network reconfiguration, effort to create a seamless Lean supply chain. that is stable an controllable. 2. Level 2- Asset and infrastructure dependencies: Infrastructure nodes and links and myopic view of mangers for only looking at their company infrastructure or link, specially a single firm or single site. Nodes of communication and transportation. 3. Level 3- Organizational and inter-organizational networks: Organizational networks and nodes, their trading relationship and power dependencies as links. Opportunism and fragmented ownership due to outsourcing. 4. Level 4- The Environment: Over all global environment; economic, geographical, metrological and political
Key prepositions and arguments: 1. Slack in the system, whether in the form of inventory, capacity, capability and even time is necessary 2. Constant awareness and vigilance at network level s required.
Limitations and Scope for further research: Limitations were 1. Multi tier investigation across sector was not performed. This was only done for the defence sector. Further research on 1. Integration of supply chain risk and conventional risk management concepts and taxonomies. 2. Established definitions and taxonomies of risk in relation to respective units or levels of analysis.
Synthesis/ Key contribution to review question
1. Need for evaluation of organizational and infrastructure dependencies at network level. 2. A need to align functional goals of supply chain with network structure, organizational structure and business strategy. 3. Systems are tightly coupled in a network and we need to provide a sort of slack to upset disruptions. 4. Systems theory can be a good perspective to look at disruptions at network leve;/

Citation details
Reference Number 23
Citation
Title: Reconciling supply chain vulnerability, risk and supply chain management
Author(s): Peck, Helen
Journal / Source: Int. J. of Logistics Research and Application
Year: 2006
Key words: Supply chain management; Risk; Vulnerability; Corporate governance; Security

Study Background
Research Question(s)/Objectives: What is the literature positioning and relationship between terms like resilience, risk management, risk mitigation, supply chain etc in the organizational and business literature?
Primary Research Focus: Resilience, vulnerability and risk mitigation
Grounding Literature:
Methodology
Method: A literature review paper
Data Description: N/A
Data collection instrument: N/A
Sector: N/A
Unit of analysis: N/A
Analytical approach:
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. Supply chain vulnerability as a discipline is informed by several developing interdisciplinary academic fields. 2. Supply chain and supply chain risk are phenomenon that stand independently of the supply chain management or risk management efforts.
Key prepositions and arguments: 1. Manufacturing perspective gives a convenient but incomplete picture of supply chain vulnerability. 2. Manufacturing and operations management perspective are dominant in supply chain research, however their assumptions are not appropriate to correctly model vulnerability. There is a need to consider infrastructure dependencies which is missing from the operations perspective.
Limitations and Scope for further research: Should contingency planning be used where there is no scope for preventive measures or preventive measures have a possibility to fail?
Synthesis/ Key contribution to review question Drivers of Vulnerability: 1. Dependencies within infrastructure network. 2. The hard systems strategy approach or the manager oriented decision approach based upon the paradigm of scientific management. 3. The positioning of the firm's network in the extended world network.

Citation details
Reference Number 24
Citation
Title: Ensuring supply chain resilience: development of a conceptual framework
Author(s): Pettit, TJ; Fiksel, Joseph; Croxton, KL
Journal / Source: J. Business Logistics
Year: 2010
Key words:

Study Background
Research Question(s)/Objectives: To develop a framework for evaluating and improving supply chain resilience.
Primary Research Focus: Resilience
Grounding Literature:
Methodology
Method: Grounded theory using a theoretical with empirical validation from a Focus group
Data Description: Eight focus group with two to four members at Limited Brand inc.
Data collection instrument: semi unstructured interviews and discussions.
Sector:
Unit of analysis: Firm level
Analytical approach: Qualitative
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. Vulnerability drivers are turbulence, deliberate threats, external; pressure, resource limits, sensitivity, connectivity and supplier/ customer disruptions. 2. These vulnerability drivers are to be counterbalanced by resilience drivers that are Flexible sourcing, flexible order fulfilment, supply chain visibility, adaptability, anticipation of risk and threats, high recovery capability, organizational support, security.
Key prepositions and arguments: 1. The author suggested 12 supply chain capabilities and 40 sub factors connected to these main factors that will enhance resilience. 2. The concept of resilience, unlike conventional risk analysis, utilizes strategies that do not require exact quantification, complete enumeration of possibilities, or assumptions of a representative future.
Limitations and Scope for further research: 1. The study was limited due to the fact that the chosen focus groups were from a company that was only outracing and not manufacturing internally. 2. There is a research gap in linking vulnerabilities and threats to the strategies to overcome them.
Synthesis/ Key contribution to review question 1. All the drivers of vulnerability, resilience and supply chain capability are relevant to my research question. 2. 2. Research gap in linking resilience with strategies to counter it.

Citation details
Reference Number 25
Citation
Title: Ensuring Supply Chain Resilience: Development and Implementation of an Assessment Tool
Author(s): Pettit, Timothy J.; Croxton, Keely L.; Fiksel, Joseph
Journal / Source: J. Business Logistics
Year: 2013

Key words: resilience; disruptions; risk management; supply chain management; vulnerabilities
Study Background
Research Question(s)/Objectives: 1. create a measurement for measuring the current level of Supply Chain Resilience. 2. What framework and strategy direction will improve supply chain resilience
Primary Research Focus:
Grounding Literature: Systems Theory
Methodology
Method: Grounded Theory on a case study
Data Description: 83 manufacturing and service firms from Midwest for survey and Seven firms in which focus groups of total 170 participants were run to understand the complex issues relating to disruption and resilience.
Data collection instrument: Online survey of five point Likert scale and focus groups
Sector: Firms with global manufacturing and service firms
Unit of analysis:
Analytical approach: Qualitative
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. Infrastructure and complexity are the greatest vulnerability drivers. 2. To increase resilience there is need for additional emphasis on Collaboration, capacity, flexibility and adaptability. 3. List of Vulnerability factors and linked supply chain capabilities
Key prepositions and arguments: 1. External Pressures and Connectivity are the highest vulnerabilities faced bu global firms.
Limitations and Scope for further research: Future research could address 1. A longitudinal study could explore the results of enhancements to balanced resilience on long-term performance, specifically focusing on the profitability aspect of erosion of profits versus exposure to risk. 2. To deter mine multiple measures at each subfactor level, with the addition of objective measurements where appropriate. 3. To modify the measure for different sector and industries.
Synthesis/ Key contribution to review question The list of resilience capabilities to counter vulnerability has many structural constructs.

Citation details
Reference Number 26
Citation
Title: Supply chain resilience: definition of concept and its formative elements
Author(s): Ponis,
Journal / Source: J. Applied Business Research

Year: 2012
Key words: Supply chain resilience, disruption
Study Background
Research Question(s)/Objectives: What are the existing definitions and constructs in the academic literature regarding supply chain resilience?
Primary Research Focus:
Grounding Literature:
Methodology
Method: Literature review
Data Description:
Data collection instrument:
Sector:
Unit of analysis:
Analytical approach:
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: Resilience is a multi-discipline construct There is a lot of definition and conceptual disparity in the current supply chain resilience literature.
Key prepositions and arguments:
Limitations and Scope for further research:
Synthesis/ Key contribution to review question Provides a good round up of resilience definitions from varied fields

Citation details
Reference Number 27
Citation
Title: Understanding the concept of supply chain resilience
Author(s): Ponomarov, Serhiy Y.; Holcomb, Mary C.
Journal / Source: The Int. J. of Logistics Management
Year: 2009
Key words: Supply chain management, Risk management, Adaptability
Study Background
Research Question(s)/Objectives: 1. What are the antecedents of supply chain resilience from the logistics perspective? What is the link to logistic capabilities? 2. What are some of the outcomes of supply chain resilience? How could it help companies gain a competitive advantage?

Primary Research Focus: Resilience
Grounding Literature: Supply chai Management and Interdisciplinary
Methodology
Method: Literature review
Data Description: N/A
Data collection instrument: N/A
Sector: N/A
Unit of analysis: N/A
Analytical approach: N/A
Measure of resilience/robustness/ vulnerability: N/A
Contribution
Key Findings: 1. The paper provides a through definition of resilience and supply chain resilience. 2. Supply chain resilience aspects in literature are Agility or responsiveness, visibility, flexibility or redundancy, structure of knowledge, reduction of uncertainty or complexity, reengineering, collaboration, integration or operational capabilities. 3. Key supply chain capabilities relating to performance, are delivery speed, reliability, responsiveness , low cost distribution and resilience. 4. From psychological literature the principles of resilience are control, coherence, and connectedness.
Key prepositions and arguments: 1. Cause effect relationship between supply chain constructs influencing resilience are not properly addressed in literature. 2. Dynamic capabilities are difficult to sustain in uncertainty. 3. The better the dynamic integration of logistic capabilities, the greater the supply chain resilience. 4. Strategies enhancing control, coherence and connectedness are; Control- Timelines, postponement Coherence- Flexibility, agility, risk sharing Connectedness- Information sharing and visibility 5. The greater the resilience of the supply chain, the better it maintains control of logistics capabilities when disruptions occur. 6. The greater the resilience of the supply chain, the better it maintains coherence of logistics capabilities when disruptions occur. 7. The greater the resilience of the supply chain, the higher the levels of integration (connectedness) across logistics capabilities when dealing with disruptions. 8. The greater the supply chain resilience, the greater the sustainable competitive advantage. 9. The greater the level of risk sharing in a supply chain (based on continual risk analysis, assessment and top management support) the stronger the relationship between logistics capabilities and supply chain resilience
Limitations and Scope for further research: Limitations are 1. The conceptual model presented by the author is not exhaustive or is just one possible view. Future research 1. The theoretical model can be tested empirically. 2. The links between risks and implications for supply chain management, and the methodologies for managing these key issues are poorly understood. 3. The logistical perspective has yet to be researched. The relationship between logistics capabilities and supply chain resilience is largely unknown. 4. Further conceptualization using different research perspectives would be highly recommended. For instance, knowledge-based theory could help to develop the learning perspective of supply chain resilience. 5. Different risk assessment paradigms, such as probabilistic choice, systems theory and the theory of constraints could also be applied to advance the discussed research topic.

6. Logistics capabilities could be grouped using exploratory factor analysis procedure, measuring specific logistics capabilities and exploring their factor loadings on factors such as connectedness, coherence and control. 7. Link between supply chain risk assessment, top management support, and risk sharing could be researched.
Synthesis/ Key contribution to review question

Citation details
Reference Number 28
Citation
Title: A supply chain view of the resilient enterprise
Author(s): Sheffi, Yossi; Rice, J
Journal / Source: MIT Sloan Management Review
Year: 2005
Key words:
Study Background
Research Question(s)/Objectives: For supply chain disruptions, this study explores the common traits between corporations and supply chains that performed well and distinguishing them from those that did not.
Primary Research Focus: Resilience
Grounding Literature:
Methodology
Method: Theoretical
Data Description: N/A
Data collection instrument: N/A
Sector: Multiple
Unit of analysis: Network level
Analytical approach: N/A
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. Stages of disruption are Preparation, the disruptive event, first response, initial impact, full impact , recovery preparation, recovery, long term impact. 2. Many companies use comprehensive scenario planning to model the dynamics and consequences of high impact risk.
Key prepositions and arguments: 1. Not all companies are impacted by the same event in same manner. 2. Vulnerability assessment involves answering three questions: What can go wrong? What is the likelihood of that happening? What are the consequences if it does happen? 3. Fundamentally companies can improve resilience by either investing on redundancy or flexibility. 4. Redundancy can be in form of safety stock, deliberate use of multiple suppliers, deliberate low capacity utilization. 5. Two important variables determine a company's resilience: the competitive position of the enterprise and the

responsiveness of the supply chain. 6. It is more advantageous to build flexibility rather than adding redundancy. 7. "Flexibility is an organic capability that can sense threats and respond to them quickly". 8. Flexibility has five facets; Supply and procurement, conversion process, distribution channel, systems and corporate culture. 9. Flexibility not only has resilience benefits but also improves operational efficiency.
Limitations and Scope for further research:
Synthesis/ Key contribution to review question The article presents some key arguments in favour of flexibility and against redundancy.

Citation details
Reference Number 29
Citation
Title: Supply chain management under the threat of international terrorism
Author(s): Sheffi, Y
Journal / Source: International Journal of Logistics Management,
Year: 2001
Key words:
Study Background
Research Question(s)/Objectives: evalute the threat to supply chains due to terrorism.
Primary Research Focus: Management of terrorism threat
Grounding Literature:
Methodology
Method: Theoretical
Data Description:
Data collection instrument:
Sector:
Unit of analysis:
Analytical approach:
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: JIT and other lean initiatives fail under disruption from a terrorist attack
Key prepositions and arguments: trade-off decisions was a highly relevant issue (1)repeatability versus unpredictability, i.e. trading the benefits of repeatable processes against the cost of a lack of flexibility; (2) the lowest bidder versus the known supplier; (3) centralisation versus dispersion decisions in pro- duction

and distribution; (4) collaboration versus secrecy, i.e. while sharing more information on, for example, the results of risk audits would better place organi- sations to manage supply chain risks, it could also deter potential customers or weaken the bargaining position; and (5) redundancy versus efficiency, i.e. Location of strategic stcock
Limitations and Scope for further research:
Synthesis/ Key contribution to review question

Citation details
Reference Number 30
Citation
Title: Minimizing supply chain disruption risk through enhanced flexibility
Author(s): Skipper, Joseph B.; Hanna, Joe B.
Journal / Source: International Journal of Physical Distribution & Logistics Management
Year: 2009
Key words:
Study Background
Research Question(s)/Objectives: to examine the issue of supply chain disruptions and the risk exposure they create for individual companies and their supply chain networks
Primary Research Focus: Risk management
Grounding Literature: Contingency Planning
Methodology
Method: empirical study utilizing a survey methodology
Data Description: 400 personnel involved in an advanced contingency planning process seminar for management professionals
Data collection instrument:
Sector:
Unit of analysis:
Analytical approach: Statistics
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: Top management support, resource alignment, information technology usage, and external collaboration provide the largest contributions to flexibility.
Key prepositions and arguments: Flexibility enhances the ability to minimize risk exposure in the event of a supply chain disruption
Limitations and Scope for further research: the multiple regression results produced an R 2 of 0.45, indicating that additional variables of interest may need to be identified and investigated. Sample of the data

Synthesis/ Key contribution to review question

Citation details
Reference Number 31
Citation
Title: Sources of Supply Chain Disruptions, Factors That Breed Vulnerability, and Mitigating Strategies
Author(s): Stecke, Kathryn E.; Kumar, Sanjay
Journal / Source: J. of Marketing Channel
Year: 2009
Key words: supply chain disruption, supply chain efficiency, supply chain vulnerability
Study Background
Research Question(s)/Objectives: 1. What are the risk sources and the mitigation strategies that are suitable for a company? 2. What are the structural properties of modern supply chain that are contribute to vulnerability?
Primary Research Focus: Vulnerability and mitigation stategies
Grounding Literature:
Methodology
Method: Empirical using statistics
Data Description: 1. Past catastrophe and economic losses on trends in the losses and number of disruptions. 2. data on man-made and natural catastrophes and their associated economic losses. 3. Data source include articles, data from agencies and government like Department of State, the Center for Research on the Epidemiology of Disasters, the Federal Emergency Management Agency, the U.S. Department of Commerce, the National Climate Data Center, and the National Counterterrorism Center. 4. Time period of data varied for different items, but it was in between year 1990's to 2005.
Data collection instrument: Manually on article search and on request from government agencies.
Sector: Manufacturing
Unit of analysis: Global level catastrophes and disasters.
Analytical approach: Statistics
Measure of resilience/robustness/ vulnerability: N/A
Contribution
Key Findings: 1. There are four vulnerability causing factors; (i) Increase in the number of exposure points (ii) Increase in distance/time (iii) Decrease in flexibility (iv) Decrease in redundancy 2. These vulnerability factors are related to some supply chain management practices; Globalization, Decentralization, Outsourcing, Sole sourcing, JIT, Product/process complexity, Litigation.
Key prepositions and arguments: 1. The threat posed by a catastrophe depends on company-specific factors such as industry, geographic location, political situation, culture, location of suppliers and customers, economy, and crisis preparedness.

2. Mitigation strategies could be (i) Proactive strategies: Safe location, robust supplier and transport, enforce security, efficient human resource management, secure communication links. (ii) Advance warning strategies: High visibility and coordination, high transport visibility, monitoring the weather forecast, act according to terrorist threat levels, monitor trends(market, customer, product, law, political). (iii) Coping strategies: Multiple facilities with flexible and redundant resources, extra inventory, alternative sourcing arrangement, flexible transportation, maintaining redundant critical components, standardize processes, redesign product to pool risk, influence customer choice, insurance.
Limitations and Scope for further research: Future research areas could be 1. To develop models that help understand and estimate the impact of a catastrophic risk. 2. Design a supply chain risk measure. 3. Models to identify abnormal variations in supply chain and provide forecast on disruption indicators.
Synthesis/ Key contribution to review question All the key findings and arguments are very important for answering my review question.

Citation details
Reference Number 32
Citation
Title: A conceptual framework for the analysis of vulnerability in supply chains
Author(s): Svensson, G
Journal / Source: Int. J. of Physical distribution and Logistics
Year: 2000
Key words: Supply chain, Supply chain management, Logistics, car manufacturer
Study Background
Research Question(s)/ Objectives: To conceptualise a framework for the analysis of vulnerability in supply chains
Primary Research Focus: Vulnerability in the focal firm and first tier supply chain
Grounding Literature: Channel Theory and Marketing Theory
Methodology
Method: Empirical/ inductive
Data Description: Top Executives of the focal firm
Data collection instrument: Personal interviews and questioner through mail
Sector: Automotive, retail, furniture and real estate (pre- made houses)
Unit of analysis: Focal firm
Analytical approach: Non parametric statistics
Measure of resilience/robustness/ vulnerability: N/A
Contribution
Key Findings:
Key prepositions and arguments:

Limitations and Scope for further research:
Synthesis/ Key contribution to review question
Classification of vulnerability: 1. Atomistic vulnerability is limited to a small section of supply chain mostly in Ist tier. 2. Holistic vulnerability refers to a wider systematic vulnerability, often its considered to be severe. Drivers of Vulnerability: Time constraints in the production line, variability of component, very specialized products with single supplier.

Citation details
Reference Number 33
Citation
Title: A conceptual framework of vulnerability in firms' inbound and outbound logistics flows
Author(s): Svensson, G
Journal / Source: Int. J. of Physical distribution and Logistics Mgt.
Year: 2002
Key words: Inbound logistics, Outbound logistics, supply chains
Study Background
Research Question(s)/Objectives: What are the dimensions of vulnerability in an inbound and outbound logistics flow of company,? Where logistics flow is restricted to only Ist tier
Primary Research Focus: Dyadic vulnerability between focal firm and Ist tier
Grounding Literature: Just in Time, Supply Chain and Marketing Theory
Methodology
Method: Empirical/ inductive
Data Description: Top Executives of the focal firm
Data collection instrument: Questioner
Sector: Automotive
Unit of analysis: Dyadic relationship
Analytical approach: Non parametric statistics
Measure of resilience/robustness/ vulnerability: N/A
Contribution
Key Findings:
Key prepositions and arguments:
Limitations and Scope for further research: Porters (1985) concept of value chain is considered that includes inbound and outbound logistics, but the network aspect of supply chain is not considered. The paper only looks at dyadic relationship.
Synthesis/ Key contribution to review question

Citation details
Reference Number 34
Citation
Title: A typology of vulnerability scenarios towards suppliers and customers in supply chains based upon perceived time and relationship dependencies
Author(s): Svensson, G
Journal / Source: Int. J. of Physical distribution and Logistics
Year: 2002
Key words: Supply chain, Motor industry, Surveys , Sweden
Study Background
Research Question(s)/Objectives:
Primary Research Focus:
Grounding Literature: Contingency Theory, Supply Chain, Marketing network, Channel Theory
Methodology
Method: Empirical/ inductive and deductive using Triangular research approach by combining methodologies.
Data Description: 17 Top Executives of the focal firm for interview and 418 executive from 214 firm for mail survey.
Data collection instrument: Mail survey and Likert Scale and semi structured interview
Sector: Automotive
Unit of analysis: Dyadic relationship, horizontal study
Analytical approach: Qualitative and Quantitative. Univariate and bivariate statistics with factor analysis
Measure of resilience/robustness/ vulnerability: N/A
Contribution
Key Findings: 1. The vulnerability has three principle components (i) Source of disturbance: Atomistic and holistic (ii) Category of disturbance: Quantitative and qualitative (iii) Type of logistics flow in terms of complexity, inventory buffer and material: 2. There are two sub groups of contingency planning; System breakdown and product recall.
Key prepositions and arguments: 1. Two components of vulnerability are disturbance and the negative outcomes of the disturbance. 2. Vulnerability can be positioned in the theoretical foundation of contingency planning. 3. The overall theoretical foundation of the vulnerability construct in supply chain is of supply chain management. The theoretical foundation also derives from JIT and other lean business philosophies.
Limitations and Scope for further research: 1. The sample of initial interviews was not a random sample. 2. The questioner was deliberately made using constructs that the supply chain executives could relate to an thus no new dimension was available to be discovered.
Synthesis/ Key contribution to review question
The model of inbound and outbound vulnerability is a useful visual interpretation of supply chain vulnerability.

Citation details
Reference Number 35
Citation
Title: Robust strategies for mitigating supply chain disruptions
Author(s): Tang, Christopher
Journal / Source: Int. J. of Logistics Research and Application
Year: 2006
Key words: Disruption; Supply chain management; Risk management.
Study Background
Research Question(s)/Objectives: What are the supply chain robustness strategies that can help a firm succeed before, during and after a major disruption?
Primary Research Focus: Robustness towards disruption recovery
Grounding Literature:
Methodology
Method: Theoretical
Data Description: N/A
Data collection instrument: N/A
Sector: N/A
Unit of analysis: N/A
Analytical approach: N/A
Measure of resilience/robustness/ vulnerability: N/A
Contribution
Key Findings: Robust supply chain strategy are; Postponement, Strategic stock, flexible supply base, make and buy, economic supply incentives, flexible transportation, revenue management, dynamic assortment planning, silent product rollover.
Key prepositions and arguments: 1. Firms should focus on strategies that can reduce both the likelihood of disruption and also the impact of the disruption. 2. Should use a supply alliance network which may work as a safety net, where all suppliers can help each other. 3. Reduce lead time 4. Have in place recovery planning systems.
Limitations and Scope for further research: Future research could be on 1. An empirical study to examine the underlying reasons why so many firms have recognised the detrimental effect of supply chain disruptions, yet have committed so few resources to mitigating supply chain risks. 2. Develop quantitative models to address How should one measure the effectiveness of a robust strategy? What are the underlying conditions for one robust strategy dominating another robust strategy? What will happen if a firm adopts multiple robust strategies? 3. What are the possible resilience benefits of using RFID systems?
Synthesis/ Key contribution to review question
Classification of disruption/vulnerability: 1. High likelihood low impact event

2. Low likelihood and high impact event Strategies for robustness 1. Strategic stock 2. Flexible supply base 3. Flexible transportation Remedies for vulnerability/ robustness/ resilience: 1. Identification of most susceptible or vulnerable nodes. 2. Contingency planning

Citation details
Reference Number 36
Citation
Title: The power of flexibility for mitigating supply chain risks
Author(s): Tang, Christopher; Tomlin, Brian
Journal / Source: Int. J. Production Economics
Year: 2008
Key words: Supply chain disruptions Risk management Flexibility Resilient supply chains
Study Background
Research Question(s)/Objectives: What are the risk mitigation strategies to handle risks that are inherent to all supply chains, namely, supply, process, and demand risks, specially agility based startegies?
Primary Research Focus:
Grounding Literature:
Methodology
Method: Mathematical model
Data Description:
Data collection instrument:
Sector:
Unit of analysis:
Analytical approach:
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. Flexibility in supply chain could be of many types (i) Flexible supply strategy via multiple suppliers (ii) Flexible supply strategy via flexible supply contracts (iii) Flexible process strategy via flexible manufacturing process (iv) Flexible product strategy via postponement (v) Flexible pricing strategy via responsive pricing
Key prepositions and arguments: 1. Firms do not require to invest on high flexibility, most benefit are achieved at low level of flexibility. 2. When implementing a particular strategy in a particular context, a firm needs to establish a structured evaluation process that includes risk identification, risk assessment, decision analysis, mitigation, and

contingency planning
Limitations and Scope for further research: 1. The cost tradeoff of implementing flexibility are not considered in the model.
Synthesis/ Key contribution to review question This article reconfirms the importance of integrating flexibility in the supply chain network structure.

Citation details
Reference Number 37
Citation
Title: On the Value of Mitigation and Contingency Strategies for Managing Supply Chain Disruption Risks
Author(s): Tomlin, Brian
Journal / Source: Management Science
Year: 2006
Key words:
Study Background
Research Question(s)/Objectives: Using supply side tactics of inventory, sourcing and rerouting, how can we better manage disruption risk?
Primary Research Focus: Managing disruption risk
Grounding Literature: Strategic management and supply chain management
Methodology
Method: Model simulation
Data Description: Based on a infinite horizon periodic inventory review system with one focal firm and two suppliers (a reliable but costly supplier and a cheap but unreliable supplier)
Data collection instrument:
Sector:
Unit of analysis: Focal firm and Tier 1
Analytical approach:
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. Sourcing mitigation is a better strategy than contingency planning for handling rare disruptions. 2. Most of the multiple sourcing based literature assumes identical lead time .
Key prepositions and arguments: 1. Percentage uptime, disruption length, capacity, flexibility and firm characteristics such as risk tolerance, play a key role in determining the firm's optimal disruption management strategy. 2. Inventory management is not a viable strategy for long disruptions. 3. Operations literature has shown importance of mixed flexibility but the authors argue that volume flexibility is a key alternative to inventory.

Limitations and Scope for further research: 1. The study only focuses on Tier1 and is a very big limitation as it fails to capture the network interactions.
Synthesis/ Key contribution to review question 1. The authors recommendation of avoiding inventory and replacing it with flexibility is a key take away from this paper

Citation details
Reference Number 38
Citation
Title: An empirical investigation into supply chain vulnerability
Author(s): Wagner, Stephan M.; Bode, Christoph
Journal / Source: J. Purchasing and Supply Mgt.
Year: 2006
Key words: Supply chain management; Risk management; Supply chain vulnerability; Normal accident theory; Survey
Study Background
Research Question(s)/Objectives: What is the relationship between supply chain characteristics and supply chain vulnerability?
Primary Research Focus: Vulnerability
Grounding Literature: Normal accident theory
Methodology
Method: Empirical
Data Description: cross-sectional survey administered in Germany to a sample of 4946 top-level executives in logistics and supply chain management
Data collection instrument: Questioner based survey
Sector: Multiple sectors
Unit of analysis: Focal firm level
Analytical approach: Quantitative statistics using factor analysis and regression.
Measure of resilience/robustness/ vulnerability: N/A
Contribution
Key Findings: 1. Demand side vulnerability significantly increases with strong customer dependence and strong supplier dependence. 2. Supply side vulnerability increases with single sourcing and global sourcing. 3. Vulnerability to catastrophic risk increases with global sourcing and decreases with supplier consolidation.
Key prepositions and arguments: 1. Since supply chain vulnerability factors explain only a small fraction of the variance in the dependent variable thus this indicates that there will be more factors influencing vulnerability.
Limitations and Scope for further research: Limitation is that the studies were conducted in Germany which being stable both in political and metrological environment, does not capture true vulnerability. Explore more variables contributing to supply chain vulnerability using theories like Normal accident theory or High

reliability theory.
Synthesis/ Key contribution to review question 1. Global sourcing and single sourcing elevates supply chain vulnerability, these have an structural antecedent. 2. Supplier consolidation improves resilience to catastrophic risk, this argument has to be tested as it goes against the graph theory perspective of network vulnerability.

Citation details
Reference Number 39
Citation
Title: Do Perceptions Become Reality? the Moderating Role of Supply Chain Resiliency on Disruption Occurrence
Author(s): Zsidisin, George a.; Wagner, Stephan M.
Journal / Source: J. of Business Logistics
Year: 2010
Key words:
Study Background
Research Question(s)/Objectives: 1. how supply management professionals perceive various sources of risk? 2. how often that risk occurs in the form of supply disruptions? 3. To test the extent to which supply chain resiliency practices moderate disruption frequency
Primary Research Focus: Resilience
Grounding Literature:
Methodology
Method: Empirical
Data Description: Supply chain executives from five firms
Data collection instrument: Online suppler risk audit on a Five point Likert scale
Sector:
Unit of analysis: Focal firm and Tier 1
Analytical approach: Factor analysis, Hierarchical multiple regression , Statistics
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. supply chain risk moves from low to high, disruption occurrence increases if the buying firm has little flexibility, and decreases with high flexibility. 2. If redundancy is pursued on a low level, disruptions occur less frequently when there is high extended supply chain risk, and more frequently in cases of low extended supply chain risk. 3. Extended supply chain risk has a negligible effect under high levels of redundancy (zero slope) 4. High levels of redundancy do not support firms in mitigating extended supply chain risk.
Key prepositions and arguments: 1. Flexibility can help firms to lessen negative consequences from extended supply chain risk. 2. implementation of flexible practices is a more powerful approach to limit the potential negative consequences stemming from extended supply chain risk sources.

3. The redundancy practices, such as having multiple suppliers, holding inventory and creating business continuity plans, may not reduce how often disruptions occur. 4. Instead of building additional redundancy into the supply chain, purchasing professionals may instead consider investing in process improvement tools to strive towards preventing disruptions from occurring in the first place. 5. Depending on the structure of the supply market (e.g., number of suppliers, buyer-supplier power, competition among suppliers on the supply market), these measures to influence individual suppliers might not be effective. 6. it appears that supply chain redundancy has little to no benefits from supplier risk, but can ensure continuity if that risk exists throughout the overall supply market.
Limitations and Scope for further research: 1. five companies in three distinct industries limits the generalizability. 2. The paper investigated the frequency of disruption occurrence and not the actual costs associated with these disruptions. 3. gathered supply disruption data with a survey instrument deployed at one specific point in time. Therefore, we cannot infer what happens over an extended period of time. This can be an important future research agenda.
Synthesis/ Key contribution to review question The article presents arguments against the implementation of redundancy and also limits the applicability of flexibility. These are some key arguments that will influence my research.

Citation details
Reference Number 40
Citation
Title: A comparison of supply chain vulnerability indices for different categories of firms
Author(s): Wagner, Stephan M.; Neshat, Nikrouz
Journal / Source: Int. J. of Production Research
Year: 2012
Key words: supply chain management; risk management; vulnerability; graph theory; empirical research
Study Background
Research Question(s)/Objectives: 1. How can we define the concept of supply chain vulnerability? 2. How can we measure supply chain vulnerability, namely the supply chain vulnerability using an index (SCVI). 3. To compare the supply chain vulnerability of various categories of firms, based on supply chain performance, firm size (number of employees and sales revenues), production type, logistics importance, supply chain risk planning, and supply chain risk management.
Primary Research Focus: Vulnerability
Grounding Literature: Normal Accident Theory and High-Reliability Theory
Methodology
Method: Empirical
Data Description: supply chain management executives in German firms
Data collection instrument: Five point Likert survey
Sector: Multiple
Unit of analysis: Firm level
Analytical approach: Statistical factor analysis

Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. Supply chain vulnerability is an elusive concept that is determined by certain characteristics, supply chain design variables, and the environment in which the supply chain is embedded. 2.
Key prepositions and arguments: 1. The higher the number of employees, the higher the supply chain vulnerability. 2. The higher the sales revenues, the higher the supply chain vulnerability. 3. The higher the supply chain vulnerability, the more emphasis the firm places on logistics. 4.
Limitations and Scope for further research: 1. Self reported data was used. 2. Data was from Germany, which itself is geologically and politically stable. 3. Future research could use secondary data, longitudinal data and multi informants.
Synthesis/ Key contribution to review question 1. Gives a measure of supply chain vulnerability. 2. Relates it to firm's size and span of operations, hinting an antecedent of structure in vulnerability.

Citation details
Reference Number 41
Citation
Title: Assessment and management vulnerability of supply networks structure based on Social network analysis
Author(s): Yang , Zigang, Huang Zhang; Xubo, Zhang
Journal / Source: IEEE
Year: 2010
Key words: Supply network risk, vulnerability, social network analysis
Study Background
Research Question(s)/Objectives: Structural analysis of supply network for management of risk and controlling vulnerability.
Primary Research Focus: Risk management and vulnerability
Grounding Literature: Social network analysis and Graph theory
Methodology
Method: Simulation
Data Description: Examples from an existing data set
Data collection instrument:
Sector: Automotive
Unit of analysis: Network
Analytical approach:

Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. Based on social analysis theory and tools, the article suggest that the closeness and the centrality of stakeholders involved in supply networks represent the complex extent of supply networks.
Key prepositions and arguments: 1. Vulnerability drivers related to supply network structure are related to the factors of linkage and relationship among participants. 2. Vulnerability should be firstly assessed at the level of economy and then at the industry or firm level.
Limitations and Scope for further research: Future research should further develop various methods to assess and manage supply chain vulnerability, and compare alternative methods with social networks analysis to determine the superior approach.
Synthesis/ Key contribution to review question A good methodology to evaluate network structural constructs like Betweenness, Centrality, Cliques etc.

Citation details
Reference Number 42
Citation
Title: Do Perceptions Become Reality? the Moderating Role of Supply Chain Resiliency on Disruption Occurrence
Author(s): Zsidisin, George a.; Wagner, Stephan M.
Journal / Source: J. of Business Logistics
Year: 2010
Key words:
Study Background
Research Question(s)/Objectives: 4. how supply management professionals perceive various sources of risk? 5. how often that risk occurs in the form of supply disruptions? 6. To test the extent to which supply chain resiliency practices moderate disruption frequency
Primary Research Focus: Resilience
Grounding Literature:
Methodology
Method: Empirical
Data Description: Supply chain executives from five firms
Data collection instrument: Online suppler risk audit on a Five point Likert scale
Sector:
Unit of analysis: Focal firm and Tier 1
Analytical approach: Factor analysis, Hierarchical multiple regression , Statistics

Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 5. supply chain risk moves from low to high, disruption occurrence increases if the buying firm has little flexibility, and decreases with high flexibility. 6. If redundancy is pursued on a low level, disruptions occur less frequently when there is high extended supply chain risk, and more frequently in cases of low extended supply chain risk. 7. Extended supply chain risk has a negligible effect under high levels of redundancy (zero slope) 8. High levels of redundancy do not support firms in mitigating extended supply chain risk.
Key prepositions and arguments: 7. Flexibility can help firms to lessen negative consequences from extended supply chain risk. 8. implementation of flexible practices is a more powerful approach to limit the potential negative consequences stemming from extended supply chain risk sources. 9. The redundancy practices, such as having multiple suppliers, holding inventory and creating business continuity plans, may not reduce how often disruptions occur. 10. Instead of building additional redundancy into the supply chain, purchasing professionals may instead consider investing in process improvement tools to strive towards preventing disruptions from occurring in the first place. 11. Depending on the structure of the supply market (e.g., number of suppliers, buyer-supplier power, competition among suppliers on the supply market), these measures to influence individual suppliers might not be effective. 12. it appears that supply chain redundancy has little to no benefits from supplier risk, but can ensure continuity if that risk exists throughout the overall supply market.
Limitations and Scope for further research: 4. five companies in three distinct industries limits the generalizability. 5. The paper investigated the frequency of disruption occurrence and not the actual costs associated with these disruptions. 6. gathered supply disruption data with a survey instrument deployed at one specific point in time. Therefore, we cannot infer what happens over an extended period of time. This can be an important future research agenda.
Synthesis/ Key contribution to review question The article presents arguments against the implementation of redundancy and also limits the applicability of flexibility. These are some key arguments that will influence my research.

Citation details
Reference Number 43
Citation
Title: An institutional theory perspective of business continuity planning for purchasing and supply management
Author(s): Zsidisin , G. a., Melnyk, S. a.; Ragatz, G. L.;
Journal / Source: International Journal of Production Research
Year: 2005
Key words:
Study Background
Research Question(s)/Objectives: 1. To examine how firms manage supply risk when its probability of occurrence is very low, it is difficult to predict, and its impact to the organization is potentially disastrous. 2. To explain why many of these risk management practices are similar.
Primary Research Focus: Business continuity planning

Grounding Literature: Opens system Theory, business continuity planning
Methodology
Method: Case study using a grounded theory methodology (GTM)
Data Description: commodity manager, quality management specialist, vice-president of procurement, risk management specialist, supplier development liaison, risk manager, and others.
Data collection instrument: Semi structured Interviews
Sector:
Unit of analysis: Foal firm
Analytical approach: Qualitative
Measure of resilience/robustness/ vulnerability:
Contribution
Key Findings: 1. BCP system as consisting of four major elements: 1. risk identification; 2. risk assessment; 3. risk ranking; and 4. risk management.
Key prepositions and arguments: 1. Some of the results were not been able to explained using open systems theory thus other theories were tested and frameworks as contingency theory and the resource based view, institutional theory was deemed to be the most appropriate. Institutional theory emphasizes homogeneity; it argues that forces exist both within the firm and the environment that encourage convergent business practices. 2. Over time, more firms will adopt business continuity planning as a formal risk management technique when the probability of risk occur rence is very low, its potential impact is very high, and it is very difficult to predict. 3. Purchasing organizations will adopt BCP in their upstream supply chains in the manner in which regulating bodies, such as the government and influential supply chain partners, direct them to do so. 4. As purchasing organizations garner greater experience in BCP and supply risk management, these firms will look to normative institutions in adopting risk management processes. 5. BCP and supply risk management will evolve toward being embedded in the everyday strategic practices of purchasing organizations
Limitations and Scope for further research:
Synthesis/ Key contribution to review question Defines the contextual use of many theoretical underpinnings in the supply chain risk context

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