CRANFIELD UNIVERSITY

ANURAG TEWARI

Adaptive tension, self-organization and emergence: A complex system perspective of supply chain disruptions

School of Management
PhD Programme

Doctor of Philosophy
Academic Year: 2016 - 17

Supervisor: Professor Liz Varga
March, 2017

CRANFIELD UNIVERSITY

SCHOOL OF MANAGEMENT
PhD Thesis

DOCTOR OF PHILOSOPHY

Academic Year 2016 - 17

ANURAG TEWARI

Adaptive tension, self-organization and emergence: A complex system perspective of supply chain disruptions

Supervisor: Professor Liz Varga
March 2017

This thesis is submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

ABSTRACT

The purpose of this thesis was to explore how microstate human interactions produce macro level self-organization and emergence in a supply disruption scenario, as well as discover factors and typical human behaviour that bring about disruptions. This study argues that the complex adaptive system's view of complexity is most suited scholarly foundation for this research enquiry. Drawing on the dissipative structure based explanation of emergence and self-organization in a complex adaptive system, this thesis further argues that an energy gradient between the ongoing and designed system conditions, known as adaptive tension, causes supply chains to self-organize and emerge.

This study adopts a critical realist ontology operationalized by a qualitative case research and grounded theory based analysis. The data was collected using repertory grid interviews of 22 supply chain executives from 21 firms. In all 167 cases of supply disruptions were investigated.

Findings illustrate that agent behaviours like loss of trust, over ambitious pursuit, use of power and privilege, conspiring against best practices and heedless performance were contributing to disruption. Impacted by these behaviours, supply chains demonstrated impaired disruption management capabilities and increased disruption probability. It was also discovered that some of these system patterns and microstate agent behaviours pushed the supply chains to a zone of emergent complexity where these networks self-organized and emerged into new structures or embraced changes in prevailing processes or goals. A conceptual model was developed to explain the transition from micro agent behaviour to system level self-organization and emergence. The model described alternate pathways of a supply chain under adaptive tension.

The research makes three primary research contributions. Firstly, based upon the theoretical model, this research presents a conceptualization of supply chain emergence and self-organization from dissipative structures and adaptive tension based view of complexity. Secondly, it formally introduces and validates the role of behavioural and cognitive element of human actions in a supply chain scenario. Lastly, it affirms the complex adaptive system based conceptualization of supply chain networks. These contributions succeed in providing organizations with an explanation for observed deviations in their operations performance using a behavioural aspect of human agents.

Keywords:

Complex adaptive system, micro to macro, dissipating structures, adaptive gradient, agent behaviours

ACKNOWLEDGEMENTS

Undertaking this PhD has been a life-changing experience for me and it would not have been possible without the support and guidance that I received from many people.

Firstly, I am grateful to my supervisor and mentor in Cranfield, Professor Liz Varga, for her continuous academic guidance, moral support, patience and for giving me the freedom to explore. Moreover, her 'quick-response' despite her busy work schedules, has always been a big support and encouragement during difficult times of my PhD. I am extremely fortunate to have had this opportunity to be guided by her. Without her constructive criticism and feedback, this PhD would not have been achievable. Professor Liz Varga has been an inspiration to work with sincerity and dedication. Thank you!

My sincere thanks are due to Professor David Denyer for his discussions, questions and insightful comments which helped me in conceptualizing and understanding the debates within my research. He introduced me to the philosophy of critical realism and I am indebted for this as it has immensely contributed towards my research.

I would also like to thank my colleagues at Cranfield and appreciate their willingness to share their academic knowledge and experience with me.

I gratefully appreciate the support of the individuals who willingly participated and shared the information for this research (the names cannot be mentioned here for confidentiality purposes).

Finally, I would like to thank my mother, father, sister and especially my wife and two little daughters, who have always been by my side in this journey of my research, living every moment of it and making it possible for me to successfully complete what I started.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

SCD	Supply chain disruption
SCV	Supply chain vulnerability
SCRes	Supply chain resilience
SCRob	Supply chain robustness
CAS	Complex adaptive system
HRO	High reliability organization

One comes away from "Complexity" both intellectually excited by ideas and emotionally involved with the people struggling to formulate them. This is a deep tale of science in the making."

Douglas R. Hofstadter; author of Gödel, Escher, Bach: An Eternal Golden Braid

1 INTRODUCTION

1.1 The problem landscape

Over recent years, a vibrant stream of supply chain research has focused on causes, consequences and mitigation strategies of supply chain disruptions (SCD) (Tang, 2006b; Craighead *et al.*, 2007; Wu, Blackhurst and O'grady, 2007; Kleindorfer and Saad, 2009; Oke and Gopalakrishnan, 2009; Stecke and Kumar, 2009). Whilst contributions from the SCD research have credibly established the influence of a firm's operational characteristics, supply chain strategy or its positioning in the extended supply network, on the risk and disruption performance of these supply chains (Thadakamaila, 2004; Meepetchdee and Shah, 2007; Zhao *et al.*, 2011; Bode and Wagner, 2015); there remains a general lack of understanding about the bottom up aspect of the phenomenon. In particular, the existing supply chain risk and disruption research is yet to detail or formalize the influence of micro level individual agent behaviours, actions and interactions on the risk and disruption profile of supply chains.

The core argument of this thesis is that micro level contributions have been under-examined and in fact provide greater explanatory relevance to events of SCD. Existing supply chain literature lacks empirical investigation of agent's contributions to system level macro supply chain outcomes such as events of disruption. In SCD settings, the micro to macro causation argument is neither adequately tested nor sufficiently grounded in any existing theory. This thesis argues that in order to gain a holistic understanding of the causes and consequences of SCD events, there is a need to look beyond the operational and structural decisions of a supply network into micro decisions and interactions transpiring at an agent level.

1.2 Motivation for the study

The premise that micro agent interactions can have macro consequences is not a new abstraction in organizational studies. Reason (1997) argues that humans are at the centre of the design, operations and maintenance of organizational systems and their contribution to the system's performance cannot be ignored.

The field of neo-institutional theory also has repeatedly argued the importance of grounding explanations of macro level social or organizational phenomenon on micro level processes and mechanisms (George *et al.*, 2006; DiMaggio, 2010). Recent advancement in behavioural supply chain research also acknowledges the same (Gino and Pisano, 2008; Tokar, 2010). Gino and Pisano (2008) argue that most of the existing normative models of supply chains, with their rational and complying human agent assumption, conflicts with operational realities. These normative representation of supply chain activities will continue to lack rationality and predictive accuracy unless behavioural aspects of human actor are included in these models (Gino and Pisano, 2008; Tokar, 2010). Motivated by evidence and theoretical support in other literatures about the agent contribution to a phenomenon, this thesis argues that aspects of human behaviours, actions and interactions have a potential to influence the supply network and a study of it is a worthwhile endeavour to gain a better understanding of SCD events.

1.3 Rationale

This thesis adopts a complex systems view of supply chains and bounds its investigation of the SCD to this theoretical foundation. The complexity paradigm has been argued to be the most appropriate theoretical foundation to evaluate the impact of micro system components or micro agent behaviours on system level macro outcomes (Gell-Mann, 1994; Dooley, 1996; Levin, 1998; Holland, 2006). The complexity paradigm argues that open systems maintained at a distance from equilibrium show traits of adaptation, self-organization and emergence driven by microstate interactions among its participating agents (Prigogine and Stengers, 1984; Kauffman, 1993; Gell-Mann, 1994; Holland, 2006). Within the complexity domain, the studies that tend to focus on system level

emergent behaviours originating from the actions, interactions, and connectedness of multiple diverse system agents, are preferably tackled using the Complex Adaptive System (CAS) perspective (Kauffman, 1993; Gell-Mann, 1994; Holland, 2006), a subset of the wider interdisciplinary field of complex systems.

Supply chains have also been progressively argued to demonstrate complex system characteristics, typically the characteristics that are common to Complex Adaptive System (CAS) based conceptualization of complexity (Choi, Dooley and Rungtusanatham, 2001; Surana *et al.*, 2005; Datta, Christopher and Allen, 2007; Pathak *et al.*, 2007; Nair, Narasimhan and Choi, 2009; Pathak, Dilts and Mahadevan, 2009). In the existing complexity debate there are two popular conceptualizations of CAS; one that emerged from thermodynamics and chemical kinematics and advocates the emergence of a complex system from the formation and dissolution of self-organizing dissipating structures generated from the existence of a critical level of potentials/gradients also known as adaptive tension (Prigogine and Stengers, 1984; McKelvey, 1999b; Lichtenstein *et al.*, 2007). While the other field that draws on advancements in complexity from the field of evolutionary biology and suggest that system's tend to demonstrate self-organizing and co-evolutionary emergent behaviours as a result of schemas, internal models and agent mechanisms that shape agent interactions and force the system to move among multiple possible fitness landscapes (Kauffman, 1993).

Most of the existing supply chain complexity researchers draw on the fitness landscape metaphor of complexity and argue system behaviours based upon internal models and schemas of the interacting supply chain agents (Choi, Dooley and Rungtusanatham, 2001; Surana *et al.*, 2005; Datta, Christopher and Allen, 2007; Pathak *et al.*, 2007; Nair, Narasimhan and Choi, 2009; Pathak, Dilts and Mahadevan, 2009). There are numerous supply networks studies that propose CAS as the most appropriate framework for a bottom up investigation of supply networks. These studies argue that aggregated micro interactions can influence macro level system outcomes and that evolution and self-organization of supply networks is governed by a few dominant generative agent mechanisms produced by a collective influence of these micro agent behaviours, actions and interactions (Choi, Dooley and Rungtusanatham, 2001; Surana *et al.*, 2005; Datta,

Christopher and Allen, 2007; Pathak *et al.*, 2007; Nair, Narasimhan and Choi, 2009; Pathak, Dilts and Mahadevan, 2009). Proponents of CAS in supply chains further argue that a study of these mechanisms can provide explanatory relevance to various complex and evolutionary supply chain phenomenon and behaviours; the approach is specially touted for being able to provide structurally realistic and more accurate representation of supply networks (Choi, Dooley and Rungtusanatham, 2001; Surana *et al.*, 2005; Datta, Christopher and Allen, 2007; Pathak *et al.*, 2007; Nair, Narasimhan and Choi, 2009; Pathak, Dilts and Mahadevan, 2009).

However, none of the existing studies provide the mechanism that can explain the transformation of micro level interactions into system level outcomes. Drawing on the dissipative systems theory of CAS, this thesis argues that the accumulation of adaptive tension is a crucial intermediary mechanism that links micro state agent interactions to system wide self-organization and emergence. This thesis avoids the bias of adopting one conceptualization of CAS over other and focuses on the core arguments of complexity that is in an open system, at a distance from equilibrium, a diverse array of microstate agent's interactions can create adaptive tensions leading to self-organizing and emergent system behaviours at the edge of chaos. Using this framework of complexity, this thesis proposes that supply chains are a CAS that are under a constant flux and dynamic operating environment. Typically for events of SCD that are a departure from optimal operating conditions, it is expected to observe adaptive, self-organizing emergent system behaviours. However, despite having a strong theoretical support for the argument (McKelvey, 1999b, 2004; Lichtenstein *et al.*, 2007), in supply chain literature, and specially for SCD events, it has been challenging to demonstrate evolutionary and self-organizing behaviours originating from the microstate interaction of participating system components and agents. Where the complexity literature on leadership (Lichtenstein and Plowman, 2009), entrepreneurship (McKelvey, 2004) or new product development (Mccarthy *et al.*, 2006) have come up with clear conceptualizations of adaptive tension, self-organization or emergence with respect to their field; these constructs have not yet been clearly defined for a supply chain scenario.

Considering this as an opportunity to contribute, this thesis sets out to present a supply chain centric conceptualization of adaptive tension generated by micro agent behaviours and interactions and in turn seeks to validate the occurrence of emergence and self-organization in a SCD scenario. This thesis proposes that events of supply chain disruption (SCD) provide the best opportunity to study adaptive tension, self-organization and emergence in supply chains as these are the circumstances where the system is perturbed from operational equilibrium and into the realm of chaos.

This thesis also argues that the complex and highly interdependent nature of supply networks obscures an individual's ability to discern mechanisms responsible for a phenomenon, and thus, despite having abundance of contextual and tacit knowledge, managers often find it hard to conceptualize, articulate or express their views on complex and unexplored supply chain issues. This thesis proposes to use a systematic interview technique of Repertory Grid (Rep Grids), with its theoretical foundation in psychology, that helps overcome these issues related to difficulty in understanding or articulation and provides an opportunity to discover deeper conceptualization and analysis of the phenomenon under discussion.

1.4 Research outline and aims

People are at the core of operations and supply chain processes. Organizations can gain from an improved awareness about the impact of aggregated actions of individuals on diverse operational aspects. The most pertinent question from a practitioner perspective is that how do individual actions, behaviours and interactions reflect on complex organizational outcomes. The aim of this research is to investigate the bottom up influence of micro agent interactions on macro supply chain outcomes. While the 'why' aspect of the phenomenon will be of more importance and interest to academicians. The research question for this doctoral research is

Research question 1:

How do micro level agent behaviours, actions and interactions influence macro level self-organization and emergence in a supply chain disruption scenario?

Research question 2:

What are the factors and micro state agent behaviours that influence events of supply chain disruption?

This research question will be investigated using an appropriate research design, presented in next section.

1.4.1 Approach and research design

The ontological and epistemological position of this thesis can best be characterized as a version of critical realism that, in accordance with Bhaskar (1978), explores supply chain disruptions as open stratified systems with a laminated system of layered ontology for taxonomically defining or identifying the sites of engagement relevant to the phenomenon. Bhaskar (1978), suggests the existence of three domains to a phenomenon; a domain of 'Empirical' which involves the observed events and experiences of participants; a domain of actual which accounts for the 'Actual' events that transpired and finally the domain of 'Real' where reside the mechanisms and causal forces that bring about these changes in actual. From a complexity perspective this thesis argues that microstate behaviours, actions and interactions of agents, the observed self-organizing structures and observable patterns of system emergence are in the domain of empirical and actual, such that the participating agents can perceive and comment about them. While the development of causal gradients such as adaptive tension in the system maintained at a distance from equilibrium could be argued to be the mechanisms that bring about the changes observed in the domain of empirical and actual such as self-organization and system emergence. A detailed discussion of it is provided latter in the thesis.

The research design adopts a qualitative research strategy which is operationalized using a Repertory Grid data collection tool. Analytical framework of the thesis is a critical realist version of grounded theory analysis, known as 'Retroductive Grounded Theory'. Table 1 presents an overview of the research and relevant decisions informing the enquiry.

1.5 Overview of findings and contribution

A summary of research contributions is presented in this section. A detailed discussion of contributions is provided in the chapter of conclusion.

Primary contributions

- presents the conceptualization of supply chain emergence and self-organization from dissipative structures and adaptive tension based view of complexity.

- formalizes the agent perspective in SCD events and empirically validating it in a field based case study by presenting a set of agent behaviours contributing to the departure of supply chain from normal operating conditions and influencing network disruptions.
- presents a model that can be used to explain the possible future pathways of a supply chain under crisis.
- affirms the complex adaptive system based conceptualization of supply chain networks by validating the claim that agent schemas and internal mechanism have an explanatory relevance for systemic phenomenon.

Secondary contributions

- establish the role of behavioural and cognitive element of human actions in a supply chain scenario.
- presents a conceptualization and explanation of agent behaviours leading to supply chain resilience and robustness and validates it by using qualitative case data.
- presents a systematic data collection tool of Repertory Grids as a preferred technique to help respondents articulate and discover agent and agency aspect of a supply chain phenomenon.
- presents the utility of having a critical realist research design for investigating complex system phenomenon, particularly the ones that require accounting for an agent perspective. It also proves the utility of abductive reasoning in supply chain theory building.
- operationalise a modified version of grounded theory based inductive, qualitative analysis framework based upon Gioia methodology.

Contribution to practice

- provide organizations with an explanation for observed deviations in their operations performance using a behavioural aspect of human agents. Using the findings of the research, firms and managers will be able to look beyond meagre normative supply chain models and operation procedures into the aspect how these procedures are disposed in an operations environment.

- help organizations to draw interventions and strategies. Being aware of agent behaviours and schemas relevant to SCD, firms will be able to draw better interventions and more robust strategies to tackle events of disruption.

Table 1: Research study overview

Research Question
Research question 1: How do micro level agent behaviours, actions and interactions influence macro level self-organization and emergence in a supply chain disruption scenario? *Research question 2:* What are the factors and micro state agent behaviours that influence events of supply chain disruption?
Ontological Stance
Critical Realism
Research Design
Research strategy: Qualitative; *Sampling Criterion:* Purposive sampling was used to control the degree of variety and similarity among selected cases to get a better control of theoretical categorization within cases; *Sample:* Rep Grid interview with 22 middle managers and senior managers from 21 different firms. The selected participants represented 15 different industrial sectors, varying degree of responsibility, and 6 to 27 years of work experience in both upstream and downstream networks; *Unit of Analysis:* Event of supply chain disruption. In all there were 167 cases of supply chain disruption were investigated; *Unit of Data collection:* An individual manager of a firm in a supply chain network; *Data analysis technique:* Retroductive Grounded theory using Gioia methodology for operationalising and representing Grounded theory findings.

1.6 Structure of the thesis

The core agenda for this research is to explore the influence of individual behaviours and interactions on macro level supply chain phenomenon. Subscribing to the theory of complex systems, this research looks for micro-macro transition from aspect of self-organization and systemic emergence generated by the adaptive tension/gradient linked to individual agent behaviours actions and interactions. The objective of this enquiry requires developing an apt methodology to capture the agent's contribution to SCD and to be able to connect the findings to the theoretical foundation of CAS.

The above research objectives are accomplished using a three phase research enquiry. The Phase I consist of Chapter 2 and Chapter 3 that present a discussion of the relevant literature and a pilot study. The literature section examines the existing body of supply chain and complex system literature. Supply chain literature is used to identify the

organizational drivers of SCD and the proposed organizational response to manage or mitigate effects of a disruptive event. To gain an overarching view on drivers and contextual conditions contributing to an increased disruption probability, literature on supply chain risk and vulnerability were also included. To gain an understanding of the debates and arguments in literature around aspects of managing and mitigating effects of SCD. It was also deemed necessary to include the literature on supply chain resilience and robustness as these constructs reduce the probability or impact of disruptions and thus worth an investigation. The complexity and CAS literature provides with the necessary theoretical foundation to investigate the micro to macro transformational influence. It is in this phase that a preliminary research question is developed which is tested in a pilot study.

The pilot study, presented in Chapter 3, was conducted to test the methodology and research design in a controlled environment. The chapter provides a detailed description of the data collection tool (Rep grids) and produces an exemplary mixed method data analysis based upon the Rep grid data from pilot interviews. Albeit of it being performed at a small scale, with three organizations, the pilot was still an empirical study on its own. The learnings from it were used to inform the main study.

Reflecting upon the results from the pilot helped to improve the framing of the research enquiry, specifically the extent to which complexity as a perspective was being used. It was found necessary to revisit the conceptualization of complexity with regards to the phenomenon of interest. Complexity terms like dissipating structures, adaptive tension and critical value were included in the scope of the research. Data analysis aspect of the research was also evolved to provide higher weightage to the narratives.

The Phase II of the research consist of Chapter 4 – Research Design and Chapter 5 – Findings. The Chapter 4 delves deeper into the aspects of ontological perspective, and methodology. The section on ontology summarises the arguments related to the philosophical perspective of a complexity based research enquiry and then provides a rational for using Critical Realism as the ontology of choice for this doctoral research. This is followed by a discussion of research strategy and analytical framework. The subsection of analysis recommends the use of retroductive grounded theory and provides details on its operationalization.

Chapter 5 presents a detailed discussion of the findings from Rep Grid Interviews. The interview data from 22 managers from 21 firms and 167 cases of supply chain disruption are ordered to represent agent behaviours, growing adaptive gradient in the organization and instances related to emergence or chaos. A discussion of cases that reflected resilience to disruption are also presented.

The Phase III of the thesis tries to answer the why and how questions regarding the findings and tries to position it in the overall knowledge of this domain. In this phase there are two chapters, Chapter 6 – Discussion and Chapter 7 – Conclusion. The discussion chapter presents a model of micro to macro transformations in supply chain. This model looks at different pathways a system, under adaptive gradient, could traverse. The chapter on conclusion presents a synthesis of the thesis and a discussion of the contributions of this research.

1.7 Summary

This chapter introduces the phenomenon of interest and the motivation to undertake this research. It identifies that that existing supply chain literature is deficient on its accounting of agent contribution to the phenomenon of SCD. It also argues that micro to macro causation has been studied in various natural and organizational studies and the study is important for the progress of supply chain research. The chapter furthers the debate by introducing complex system perspective as the most appropriate scholarly foundation to study the transformation of micro state agent behaviours into emergent system wide outcomes. The chapter goes on to present an introductory discussion of the philosophical stance taken by this thesis and a short summary of the contributions. The chapter ends with a section on the structure of the thesis.

The next two Chapters 2 and 3 present the first phase of this three-phase research enquiry. This first phase investigates the extant literature and conducts a pilot study to test the research framework in a controlled environment. Essentially this phase prepares the ground for conducting the main study.

Phase I:

Setting up the foundation of the study

2 LITERATURE REVIEW

2.1 Introduction

The objective of this chapter is to gain an overarching view of the phenomenon of interest and other relevant literatures informing the research. The findings from this section will shape the structure of the pilot study and provide a relevant research question to for the pilot.

The phenomenon of interest for this research enquiry is to study the influence of individual behaviours and interactions on macro level supply chain phenomenon and to recommend particular agent behaviours and mindsets that contribute to the occurrence of SCD. To set the scope of this research and to gain an overarching view of existing debates in SCD and the maturity of the domain with respect to agent contributions, a comprehensive review of supply chain literature was conducted. A review of the complex system theory was also undertaken to validate its usefulness in providing a theoretical foundation to the research enquiry, particularly with respect to the chosen context of SCD.

The chapter begins with a discussion of a systematic literature review conducted on supply chain disruption. This is followed by a discussion of complex systems theory and its contributions in the study of supply chains.

2.2 Supply chain disruptions

Disasters and catastrophes are beyond human control. Every system, how so ever robust it may be, is destined to fail (Perrow, 1999; Christopher and Lee, 2004; Craighead *et al.*, 2007) and this will include the modern supply chain. Events of supply chain failure are termed as disruptions and it includes occurrences when desired quantity or quality of goods or service fails to reach a designated location.

Supply chain disruptions (SCD) can have disastrous impact upon a firm's performance. Frequent minor disruptions of material flow variations, also referred as disturbances (Greening and Rutherford, 2011) compel supply chain operatives to engage in constant firefighting, while the less frequent but catastrophic large scale disruptions can have

extreme consequences on the brand and shareholder value of a firm (Hendricks and Singhal, 2003, 2005; Wagner and Bode, 2008; Narasimhan and Talluri, 2009).

2.3 Objective of the review

In the last decade supply chain disruption research has had many valuable contributions (Papadakis, 2003; Chopra and Sodhi, 2004; Craighead *et al.*, 2007; Kleindorfer and Saad, 2009; Stecke and Kumar, 2009). Researchers have broadly focused their arguments either into the network /structural drivers of disruption, dealing with the relative positioning of the focal firm on the extended array of network and relationships, or on strategic drivers of disruption originating from organizational strategies and initiatives that are adopted for achieving higher efficiency and control. However, current literature seems to have ignored the micro to macro impact of variables or in particular the literature seems to be deficient in accounting for the agency aspect of SCD. In order to gain a better understanding of the current literature on SCD and to be able to identify research areas with a potential to contribute, a systematic literature review of the domain is conducted.

Since determinants of the phenomenon of SCD are often coinvestigated with related constructs like supply chain risk, vulnerability, resilience and robustness, this thesis proposes to retain a broad scope of the literature search and converge the findings at a later stage of the literature review. The review was conducted using the following research question;

2.3.1 Research question for a systematic literature review

Literature review question: What are the factors that influence the likelihood of a supply chain disruption?

This will be investigated using the following two sub questions

Q1 a: *What are the drivers of supply chain risk, vulnerability and disruption?*

The causes contributing to the likelihood of a disruptive event are embedded in the inherent risk and vulnerabilities of a network and a study of these could help gain useful insights about factors triggering disruptive events.

Q1 b: *What are the supply network strategies that influence the risk and vulnerability profile of a network?*

Organizations are aware of a disruption threat and thus use many safeguard strategies and tactics to reduce the likelihood of a disruptive event. This question will help understand the current approaches adopted by organizations to influence events of disruption.

2.3.2 Rational for a systematic literature review

There are many approaches to undertake a literature review, such as the traditional narrative literature review, but for the purpose of this thesis, a method of systematic literature review is selected to gain an overarching and holistic view of the field. 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, Mulrow and Haynes, 1997; Tranfield, Denyer and Smart, 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, Denyer and Smart, 2003) . It is a good technique to acquire collective knowledge of a given phenomenon or field, its subfields and related constructs (Tranfield, Denyer and Smart, 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 next section presents a description of selected databases, keywords, search strings and details about the number of articles shortlisted for review. Articles were selected based upon their relevance to the research and the quality of contribution.

2.3.3 Keyword

There are three major themes that emerge from the review question; disruption, risk and vulnerability. A contrasting term to disruption and vulnerability is ‘resilience’, which is

also considered as a major theme for the literature search keywords. Along with these major themes, their relevant synonyms and antonyms are also added to the list of literature search keywords. Supply chain and its synonyms are included to provide the context to the search. Table 2 presents a list of the selected keywords.

Table 2: Keywords for the literature search

Theme	Risk, Vulnerability	Disruption	Supply chain
Keywords	**Synonyms:** Vulnerability, Network Failure, Disruption, Targeted attack **Antonyms**: Resilience Robustness, Risk Mitigation, Disaster preparedness, attack tolerance, Network Survivability	Disruption, disrupt, disrupted, disturbance, attack, fragility, breakage	Supply Chain, logistics, supply network, supplier, buyer, procurement, Inter firm, inter organization

The literature search was conducted using three electronic databases; Business Source Complete (EBSCO) and ABI Inform Global PROQUEST. 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. Snow bowling technique was used to include a few more relevant articles. Table 3 gives details of the number of articles for each stage.

Table 3: 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
Selected for inclusion	81
Selected from Cross reference	15
Total article reviewed	96

2.4 Findings

2.4.1 Theoretical foundations and method of analysis

The Table 4 illustrates the theoretical foundations of the reviewed articles. Among the grounding theories the 'graph theory' perspective has been the guiding theory to most of the articles. These include Meepetchdee and Shah (2007); Nair and Vidal (2011);

Wagner and Neshat (2010); Yang et al. (2011) Second most cited theoretical foundation is of 'systems theory'. This has been used by Peck (2005); Pettit et al. (2013); Zsidisin et al. (2005). A view on SCD from 'High reliability theory' or 'Normal accident theory' is presented by Speier et al. (2011); Wagner and Neshat (2012). The theoretical foundation of 'Resource dependency theory' and 'Social network theory' has also found mentions. Figure 1 presents a description of selected papers from the methodlogical aspect.

Table 4: Theoretical Foundations of Articles

Study	Theoretical Foundations
(Göran Svensson, 2002a; Skipper and Hanna, 2009; Simchi-Levi *et al.*, 2015; Park, Min and Min, 2016)	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
(Kumar, Liu and Demirag, 2015; Clemons and Slotnick, 2016)	Enactment theory
(Peck, 2005; Zsidisin, Melnyk and Ragatz, 2005; Pettit, Croxton and Fiksel, 2013)	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
(Ponomarov and Holcomb, 2009)	Supply chain Management and Interdisciplinary
(Xiao and Yu, 2006; Meepetchdee and Shah, 2007; Wagner and Neshat, 2010; Nair and J. M. Vidal, 2011; Kim, Chen and Linderman, 2015) (	Graph Theory
(Yang et al., 2010)	Social network analysis and Graph theory
(Adenso-Diaz et al., 2012)	Supply Chain
(Goetschalckx et al., 2012)	Systems engineering approach
(Wagner and Neshat, 2012; Marley, Ward and Hill, 2014)	Normal Accident Theory and High-Reliability Theory
(Ivanov, Sokolov and Dolgui, 2014)	Control theory
(Cantor, Blackhurst and Cortes, 2014)	Regulatory focus theory
(Xiao and Qi, 2008; Friesz, Lee and Lin, 2011; Xiao, Yu and Gong, 2012; Chen and Xiao, 2015; Sarkar and Kumar, 2015)	Game theory
(Pal, Sana and Chaudhuri, 2012; Baghalian, Rezapour and Farahani, 2013; Chen and Xiao, 2015; Giri and Bardhan, 2015; Sawik, 2015)	Economic theory
(Golgeci and Ponomarov, 2013)	Dynamic capability theory

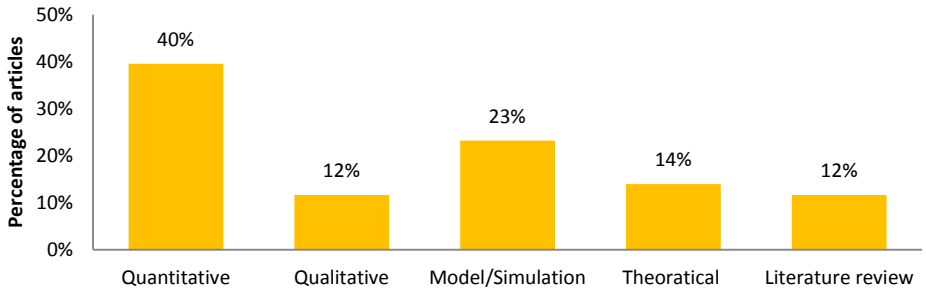


Figure 1: Percentage of articles by method of analysis

2.4.2 Defining supply chain vulnerability, resilience, robustness and reliability

2.4.2.1 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 , (Göran Svensson, 2000, 2002b, 2002d), 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 (2002a) 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, 2002a: p. 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 (2002b, 2002c), in another pioneering cross sector SCV and SCRes research, at the Cranfield University Centre for Logistics, Helen Peck, (Peck, 2005, 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 (2006, 2005), 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) and Juttner et al. (2003). Juttner 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''.

(Juttner et al., 2003: p. 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: p. 6)

Sheffi and Rice (2005) define SCV as the likelihood of disruption and severity of the consequences; while 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.

2.4.2.2 Supply chain resilience (SCRes)

Contemporary supply chain risk and disruption research is moving from the domain of focal firm to the network level (Harland, Brenchley and Walker, 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: p. 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 5 presents some of the widely quoted definitions and authors from the SCRes research.

Table 5: 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, 2006b)	"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, 2006)	"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"

2.4.2.3 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:p. 121)

Thus, it can be concluded that SCRob concerns the network preserving its functionality, irrespective of disruptions. However, resilience and robustness definitions seems to have conceptual closeness and thus these constructs require additional clarification.

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 (Christopher and Peck, 2004; Ponomarov and Holcomb, 2009), thus on getting exposed to a disruption a resilient system will transform or reconfigure into another structure while a robust system will work to preserve its original structure.

2.4.3 Drivers of supply chain disruption, risk and vulnerability

At a time where organizations are faced with a highly complex, interdependent and uncertain business environment, the pursuit of efficiency and efforts of over optimization have resulted in networks that are often extremely fragile and vulnerable to disruptions (Christopher and Peck, 2004; Harland et al., 2003; Hendricks and Singhal, 2005; Tang, 2006a). A supply chain disruption is an event in the supply network in which one or more products fail to reach their planned supply chain nodes or destination in the designated quantity, designated quality or designated time. If the delay in the time is more than the safety stock available at the destination node and if no other corrective or contingency plan is available, then that node fails. This disruption event has a cascading nature as all products dependent upon the disrupted product, will inevitably also become disrupted. Mulani and Hau (2002) argue that 40-60 % of supply chain managers' time is spent on handling disruptions.

The domain of supply chain disruption and vulnerability research is a fast evolving body of literature with many notable contributions. (Stecke and Kumar, 2009; Chopra and Sodhi, 2004; Kleindorfer and Saad, 2005; Craighead et al., 2007; Papadakis, 2003). Table 6 presents a summary of the literature review findings. We classify these studies

Table 6: Structure and strategic features of supply chain disruption

Drivers	Article details
Structural drivers of disruption	Tight coupling in supply chain nodes (Albino, Garavelli and Okogbaa, 1998; Peck, 2005; Wagner and Neshat, 2012)
	Complexity of network, lack of visibility and lack of predictive capacity (Juttner, Peck and Christopher, 2003; Blackhurst *et al.*, 2005; Craighead *et al.*, 2007; Stecke and Kumar, 2009; Wagner and Neshat, 2010, 2012; Adenso-Diaz *et al.*, 2012)
	Connectedness and coherence of connectivity (Huang, Zhang and Zhang, 2010; T. Pettit, Fiksel and Croxton, 2010)
	Supplier concentration or network density (Sheffi, 2005; Craighead *et al.*, 2007; Huang, Zhang and Zhang, 2010; Adenso-Diaz *et al.*, 2012)
	Supplier network structucture (Juttner, Peck and Christopher, 2003; Wagner and Neshat, 2010; Adenso-Diaz *et al.*, 2012)
	Overall environment of supplier cluster (Geographic, economic, political, social etc) (Chopra and Sodhi, 2004; Peck, 2005)
	Power relationships between supply chain actors (Blackhurst *et al.*, 2005; Peck, 2005; Zsidisin and Wagner, 2010)
	Infrastructure node and link depedndecy (Peck, 2005, 2006; Wagner and Neshat, 2012)
Strategic drivers of disruption	Small supplier base (G Svensson, 2002; Chopra and Sodhi, 2004; Sheffi and Rice, 2005; Tang, 2006b; Wagner and Bode, 2006; Tang and Tomlin, 2008; Stecke and Kumar, 2009; Wagner and Neshat, 2010; Adenso-Diaz *et al.*, 2012)
	Global or far sourcing (G Svensson, 2002; Juttner, Peck and Christopher, 2003; Chopra and Sodhi, 2004; Blackhurst *et al.*, 2005; Wagner and Bode, 2006; Manuj and Mentzer, 2008a; Stecke and Kumar, 2009; Wagner and Neshat, 2010)
	Specialized supplier or source criticality (Göran Svensson, 2002c; Peck, 2005; Wagner and Bode, 2006; T. Pettit, Fiksel and Croxton, 2010; Adenso-Diaz *et al.*, 2012)
	Lean and over optimization (Juttner, Peck and Christopher, 2003; Peck, 2005; Meepetchdee and Shah, 2007; Wagner and Neshat, 2010)
	Outsourcing and fragmented ownership (Juttner, Peck and Christopher, 2003; Peck, 2005; Stecke and Kumar, 2009)
	Time and sequencing constraints in the system (G Svensson, 2000; Blackhurst *et al.*, 2005; Tomlin, 2006; T. Pettit, Fiksel and Croxton, 2010)
	Stable world and controlable supply chain assumption (Peck, 2005, 2006)
	Resource limit of supplier base (T. Pettit, Fiksel and Croxton, 2010; Adenso-Diaz *et al.*, 2012)

into structural and strategic drivers of supply chain vulnerability and disruption. Structural drivers of disruption refer to the relative positioning of the focal firm in an extended array of network and relationships, while strategic drivers of disruption include the organizational strategies and initiatives that are adopted for achieving higher efficiency and control of the supply chain.

2.4.3.1 Structural drivers

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 (Adenso- Diaz *et al.*, 2012; 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 (Sheffi, 2001; Sheffi and Rice, 2005; T. Pettit, Fiksel and Croxton, 2010). 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 (Peck, 2005, 2006; Wagner and Neshat, 2012).

Supply Chain Complexity

Supply chain complexity is attributed as one of the prominent structural vulnerability driver (Choi, Dooley and Rungtusanatham, 2001; Surana *et al.*, 2005; Datta, Christopher and Allen, 2007; Pathak *et al.*, 2007; Nair, Narasimhan and Choi, 2009; Pathak, Dilts and Mahadevan, 2009). A much detailed and elaborate discussion of supply chain complexity is provided in the next chapter.

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) 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.

Apart from these drivers, supply chain vulnerability and disruption literature mentions some more drivers of such as; connectivity or the degree of interdependence and reliance upon critical sources or nodes (T. Pettit, Fiksel and Croxton, 2010), power relationship among network actors (Blackhurst *et al.*, 2005; Peck, 2005; Zsidisin and Wagner, 2010). It can be conclude that the structural aspect of the supply chain has a significant bearing on supply chain vulnerability to disruption.

2.4.3.2 Strategic drivers

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, 2006b). 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.

The rationale behind reducing supplier base is often motivated by efficiency initiatives and this leads to more integrated and vulnerable supply chains (Juttner, Peck and Christopher, 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.'

Specialized Suppliers

A very unique product in a supply chain could be a cause of disruption concern (G Svensson, 2000; T. Pettit, Fiksel and Croxton, 2010). 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.

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 (Juttner, Peck and Christopher, 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, Peck and Christopher, 2003). Another downside of global sourcing is that network uncertainties

become more pronounced, escalating the likelihood of disruption (Manuj and Mentzer, 2008a, 2008b). 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.

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; Craighead *et al.*, 2007; Zsidisin and Wagner, 2010).

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 (Juttner, Peck and Christopher, 2003; Peck, 2005; Stecke and Kumar, 2009). 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.

2.4.4 Structural strategies to influence risk, vulnerability, disruption and resilience profile of supply chains

The domain of supply chain topology and network perspective builds on graph theory based resilience and attack tolerance research of real world complex networks (Thadakamaila, 2004; Nair and J. M. Vidal, 2011). 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 disruption and resilience perspective (Wagner and Neshat, 2010; Nair and J. M. Vidal, 2011; Adenso- Diaz *et al.*, 2012). There could be managerial interventions designed to influence aspects of structural resilience. Table 7 presents these strategies.

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. Regarding behaviour of actors, Kleindorfer and Saad (2009) 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, 2009: p. 56)

Table 7: Structural strategies

	Proposed modification	Empirical studies	Theoretical or conceptual studies
Reducing occurrence probability	Manage weak nodes /links	(Kleindorfer and Saad, 2009; Oke and Gopalakrishnan, 2009)	(Chopra and Sodhi, 2004; Tang, 2006b)
	Design low network density	(Craighead *et al.*, 2007; Nair and J. M. Vidal, 2011)	(Greening and Rutherford, 2011)
	Intelligent structural positioning of safety stock		(Chopra and Sodhi, 2004; Tang, 2006b)
	Reduce node criticality, network complexity, cluster complexity	(Craighead *et al.*, 2007; Adenso-Diaz *et al.*, 2012)	
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	(Blackhurst *et al.*, 2005; T. J. Pettit, Fiksel and Croxton, 2010)	
	supply chain reconfiguration	(Blackhurst *et al.*, 2005; T. J. Pettit, Fiksel and Croxton, 2010)	

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.

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:p. 139)

The author argues that firms are more concern about regional clusters getting affected by disruptions rather than a single supplier getting affected.

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 J. M. Vidal, 2011).

Thus we can infer that structural aspects of resilience and robustness are very crucial strategies. Although the agent contribution to structural drivers has been recognized yet not much emphasis on the perspective has been laid.

2.4.5 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 8 presents these.

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

Table 8: Operational strategies

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

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: p. 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, Banwet and Shankar, 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: p. 254)

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

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. It can be argued that visibility and collaboration cannot be achieved without having a supporting human agent, but none of these studies talk about the human contribution to visibility or collaborative working

2.4.6 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 9 presents a list of articles recommending these strategies.

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. Juttner 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 (Juttner, Peck and Christopher, 2003). Sheffi

and Rice (2005) propose flexibility to be practiced in five dimensions: suppliers, conversion process, systems, distribution channel and corporate culture.

Table 9: Strategic approach

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

Using a very simple set of assumptions Tang and Tomlin (2008) identified and empirically tested these five flexibility strategies for mitigating supply chain risk. These were; flexibility in suppliers via multiple suppliers, flexible supply contracts, flexible manufacturing, flexible product strategy via postponement and flexible pricing. 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:p. 20)

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:p. 443)

To improve robustness and resilience, the literature suggests many other strategic modifications such as decentralized decision making approach, risk sharing among network partners and redundant capacity. However, humans remain to be at the core of implementing these strategies and if they are not willing to decentralize decision making or embrace process and design flexibility, then the initiative will fail to realize its intended objectives. Despite this fact, all of these research papers adopt the most contagious assumption, a complying and rational human agent.

The field of complex system research is known for its conceptualization and inclusion of the agent and agency perspectives in macro level phenomenon. The next section presents a discussion of complexity and its tenets.

2.5 Complex systems: A review

Before conducting a study of microstate agent behaviours connected with events of SCD, it is necessary to define the underlying theoretical foundation governing micro to macro transformations. Within the natural science and social sciences literature, Complex system theory is argued to be most effective theoretical foundation to study agent driven micro to macro system transitions. This thesis proposes to use complex system theory to understand the microstate agent interactions related to events of SCD.

Following sections present a discussion of the genesis of complexity, its formative elements and its usage in the current supply chain literature.

2.5.1 The genesis of complex system thinking

Humans have always been surrounded by many natural and artificial systems with extraordinary complexity like eco systems, immune systems, communication networks, infrastructure networks, the internet , stock markets or the global economy (Cohen and Axelrod, 1984; Amaral and Ottino, 2004; Holland, 2006; Newman, 2011). Modelling of these systems or generating predictive capabilities about them has proved to be challenging as these systems are impermeable to conventional reductionist approaches. A growing field of interdisciplinary studies, *'Complex Systems Theory'*, represents a cluster of ideas that provides concepts, principles and tools to interrogate such systems that demonstrate dynamic, disorderly or unexpected behaviours (Newman, 2011).

The genesis of complex system thinking can be attributed to four intellectual movements that collectively laid its foundation. These were Catastrophe theory, Chaos theory, Cybernetics and System's theory (Anderson, 1999). Drawing on the knowledge of feedback control devices from the Second World War era, Cybernetics and System's view argued the relevance of feedback loops for governing systems with inherent complexity, thus rejecting a top down reductionist view of control and coordination (Ashby, 1956; Bertalanffy, 1972). Catastrophe theory contributed to the domain by demonstrating the possibility to use small changes or perturbations in systems to explain large shifts in a system's equilibrium (Zeeman, 1977) . Contribution of chaos theory to the field of complexity is that the theory of Chaos brought into focus the aspect of

deterministic order in dynamical systems that appeared to have random behaviours (Thiétart and Forgues, 1995).

Formative elements of Complex system thinking such as; relevance of feedback control loops, system away from equilibrium at an edge of chaos, and possibility to explain dynamical and random looking system patterns, can all be traced back to the above four.

2.5.2 Characteristics of complex systems

Prominent complexity researchers, Holland and Sigmund (1995); Kauffman, (1993) argue that there are some characteristics common to all complex systems. These characteristics are: high degree of interconnectedness and interdependency among components; existence of feedback loops among subsystems; difficult to study the system in isolation; exhibition of emergent behaviours where the systems outcome manifest out of small scale interactions among its subsystems; nonlinear and dynamical response; sensitivity to initial conditions and a seemingly unpredictable response (Holland and Sigmund, 1995; Kauffman, 1993; Ramalingam et al., 2008; Varga et al., 2009). These systems are often argued to be at the edge of chaos, self-organizing and co-evolutionary (Varga et al., 2009).

Within the many proposed conceptualizations of complexity, there is one particular form of complexity that finds its utility to argue systems dominated by agent or agency related interactions. In these systems, a rich array of interactions among diverse system agents has been found to produce dynamic, co-evolutionary, self-organizing and emergent behaviours. This kind of complex systems are dealt under the umbrella term of *'Complex Adaptive Systems'* (CAS). Since supply chains are systems with diverse array of human agents involved in multitude of dynamical and parallel interactions, a CAS view is particularly relevant to interrogate supply chains. The next section provides a discussion of CAS and its utility to study supply chain phenomenon.

2.5.3 Complex adaptive systems

Many, but not all, complex systems demonstrate the characteristic of agent adaptation and such complex systems are referred as complex adaptive systems (CAS) (Newman, 2011). CAS view of complexity is most suited to investigate and compare the actions

and interactions of agents, individual groups, species, or their strategies against their competitors (Gell-Mann, 2002; Holland, 2006; Newman, 2011). Typical characteristics of a CAS are threefold. First, they have a large number of diverse agents with a high degree of connectedness and evolving pattern of nonlinear interactions (Holland, 2006). The agents of a CAS seek to maximise their fitness through an evolutionary and self-organizing behaviour (Gell-Mann, 1994; Dooley, 1996; Newman, 2011). Second, to be able to respond to their environment, to various stimulus and environmental conditions, these agents develop fluid mental models or schemas (Gell-Mann, 1994, 2002; Dooley, 1996). Third, the agent diversity is a result of continuous adaptation which never lets the system stabilize instead it takes the system towards perpetual novelty or in other words these systems exhibit evolutionary characteristics (Holland, 2006).

Complex adaptive system view can provide explanatory relevance to the self–organized co evolution of many peculiar stochastic micro events concerning agents such as molecules, genes, neurons, particles, organizations or individuals , into emergent structures (McKelvey, 1999b).

The key objective of an agent within a complex system is to maximise its fitness and the fitness function of an agent in a complex aggregate is determined by many global and local factors, including the mental models or schemas maintained by each individual agent. Often synonymously used by complexity researchers, terms schemas, mental models, agent internal mechanisms or mind frames are terms that convey the same meaning in the field of complexity science. These are the lowermost fundamental unit that influences an agent's interactions and in turn provide emergent and self-organizing capabilities to the system at a macro level. The next section presents the view of complexity researchers on agents and their schemas/ mental models/ internal mechanisms.

2.5.4 Mechanism and schemas in a CAS and its status in supply chain research

Holland (1993) argues that a less obvious however a very important aspect of a CAS is the set of internal rules or models that an agent uses to predict the outcomes of their actions. Driven by local and global stimuli the agents develop, update and modify these rules, also referred as agent schemas (Gell-Mann, 1994; Dooley, 1996) and use them to interpret reality or respond to a stimuli (Gell-Mann, 1994; Dooley, 1996). In a supply

chain context (Choi, Dooley and Rungtusanatham, 2001) were the first to point out that an aggregation of several such nonlinear agent schemas and mental models can aggregate into internal mechanisms leading to complex supply chain behaviours. Following up on the argument some other supply chain complexity researchers investigated the role of agents and agency in a supply chain context. A few notable contributions among these are; Nair, Narasimhan and Choi (2009) that dealt with aspects of cooperation and opportunism among network firms; Datta, Christopher and Allen (2007) that looked at internal decision making and supply chain resilience; and Varga et al. (2009) that evaluated the evolutionary aspects of supply chains.

Theoretical relevance of agent schemas in determining the evolutionary behaviour of a complex supply network has been relatively well argued, however SCD research is yet to identify relevant agent schemas and mechanism that exist in an operations setting. This research aims to extend our understanding of supply chain agent schemas and mechanisms associated with the phenomenon of SCD. The next section looks at supply chain complexity literature. Since the context of this study is disruptions, the maturity of supply chain complexity literature will be evaluated from perspective of SCD studies.

2.5.5 Supply chain networks as CAS

One can argue that a supply chain network is a CAS of dynamic elements where in a real time, due to an interaction between agents, the network topology evolves in a nonlinear and heterogeneous fashion (Surana et al., 2005; Varga et al., 2009). These typical characteristics of a CAS, a nonlinear behaviour, parallelism modularity, adaptation and self-organization, can be argued to be reflected in many business networks, typically in organizational supply chains (Choi, Dooley and Rungtusanatham, 2001; Surana *et al.*, 2005; Nilsson and Darley, 2006). Recent advancements in supply chain complexity research confirm this CAS view on supply chains (Choi, Dooley and Rungtusanatham, 2001; Surana *et al.*, 2005; Pathak, Dilts and Biswas, 2007; Varga *et al.*, 2009)

Nilsson and Darley (2006) argue that the complexity in a supply chain network arises out of agent's interaction in the network. The authors view these interactions to be reactive and often leading to deliberately proactive behaviour affecting other entities or subsystems in the network environment, giving rise to complex behaviour of the

network. Surana et al. (2005) attribute the complexity in supply network to vast span of a supply network over several tiers with bi-level hierarchy and heterogeneity in the network. Surana et al. (2005) further suggest that nonlinear network behaviour emerges out of the complex nature of interactions between various supply chain agents such as customers, supply chain executives, truck drivers, etc. Surana et al. (2005) recognise that although these agents are autonomus individuals with their individual targets and goals, yet on aspects of collective performance goals these agents act in a highly interdependent manner resulting in a co-evolutionary behaviour. The authors quote:

"at present, networks are largely controlled by humans, the complexity, diversity and geographic distribution of the networks make it necessary for networks to maintain themselves in a sort of evolutionary sense"

(Surana et al., 2005:p. 4243)

Choi, Dooley and Rungtusanatham (2001) argue that the escalation of micro agent interactions into emergent and self-organizing supply chain outcomes is dependent upon the internal mechanism of agents which include; agent internal models or schemas, dimensionality of agent behaviours, self-organizing and emergent properties of the relationships and the degree of network connectivity. The authors present this in a model to demonstrate underlying dynamics of supply chain as complex adaptive system; figure 2. The authors view agent schemas as norms, beliefs, values etc; while dimensionality is degree of freedom or kinds of behaviours that an agent can demonstrate. The authors argue that these behaviours or agent's dimensionality could be altered by system aspects like managerial interventions, rule regulations or institutional pressure.

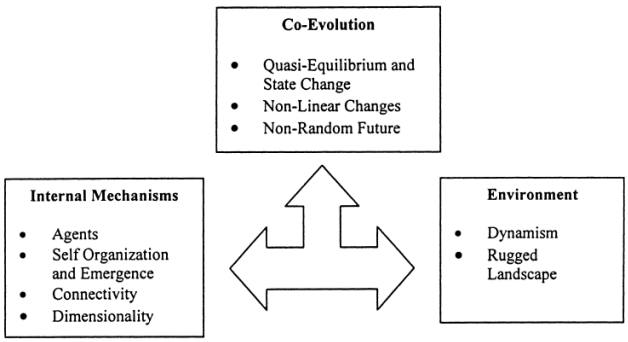


Figure 2: Underlying dynamics of supply chains as CAS

Adopted from: (Choi, Dooley and Rungtusanatham, 2001:pp 353)

2.6 Summary and implications

This chapter presented a discussion of supply chain disruption literature, complexity and the overlap of complexity and supply chain literatures. This section summarises the prominent debates of this chapter and presents its implications for the next phase.

The findings from systematic literature review of SCD literature provided with many useful insights. It is evident that aspects of network structure and supply chain strategy have gathered most contributions from disruption researchers while agent's contribution to events of SCD has not yet been exclusively researched. Although, some author/s have either made a passing reference to the necessity of considering agent interactions or the human aspect, yet none of them have made an independent enquiry of this proposition.

Some debates in the domain of human antecedents to SCD draw attention towards the aspect that organizational risk measures are often biased by managerial perceptions leading to inefficient and inaccurate accounting of risk (Blackhurst et al. 2005). It is also argued that firms with more employees are more susceptible to disruption (Wagner and Neshat, 2012);suggesting that a correlation exists between number or quality of human interactions and susceptibility to disruption. Cantor et al. (2014) argue that an individual's regulatory focus can also have a negative impact on supple chain decisions. This argument brings down the disruption debate to the level of an individual's mindset or mental schema that may define his/her regulatory focus towards tasks. Other aspects that define an individual's demeanour have also been found to be correlated to likelihood of disruption such as; cultural biases, social preferences and leadership styles (Dowty and Wallace 2010), compliance behaviour ((Hung, Ro and Tangpong, 2009). Possibility of intentional human act leading to disruption has also been suggested in the literature such as; theft, terrorism and deliberate contamination (Speier et al. 2011). Whilst these studies highlight the importance of agent behaviour in supply chain disruption, a comprehensive understanding of how micro level agent behaviours translate into macro level system outcome like an event of disruption is elusive.

Thus, it can be concluded that existing research of supply chain management does not sufficiently explain the role of agent behaviour in bringing about supply chain disruptions and there is a need to consider alternative paradigms. Among the available alternatives, complexity theory is advantageously positioned to argue the 'how' and 'why' questions about the amplification of micro level actions into macro level effects.

CAS view of complexity has been used in numerous domains to model and explain emergent and self-organizing macro structures based upon micro agent interactions or simply bottom up causation. The argument of a complexity driven explanation of micro to macro causation and the spontaneous emergence of co-evolutionary self-organizing macro structures has also been embraced by a small body of supply chain complexity research. Accepting supply chains as CAS, this body of growing supply chain research argues that agent schemas, mindsets behaviours and actions are at the core of supply chain phenomenon and that emergent network structures can be explained by the aggregation of these micro interactions. However, the proposition has not yet been empirically verified, particularly for SCD scenario.

This doctoral research abides by the burgeoning debates in the field of supply chain complexity and intends to investigate the micro to macro aspect of the disruption phenomenon. To gain a preliminary insight about the phenomenon and to develop a robust research design, this doctoral research proposes to conduct a pilot study to study the phenomenon in a small scale and controlled environment. Based upon the findings from the literature review, this doctoral research proposes a preliminary research question for the pilot study;

"What are the contributing causal mechanisms to the phenomenon of supply chain disruption?"

The next chapter presents a discussion of the pilot and implications of its findings for the future phases of this doctoral pursuit

3 PILOT STUDY

3.1 Introduction

This chapter presents the outcomes of a pilot study that was conducted to test the effectiveness of the research protocol and to gain preliminary insights about aggregated system patterns emerging from micro agent interactions connected to events of SCD. Despite a limited scope, this pilot study still stands out as an independent empirical work in its own right. The outcomes of the pilot were presented in two prominent international peer reviewed conferences. The valuable feedbacks received from these helped change the future phases of this research.

The preliminary research question developed on the basis of the literature survey was;

"What are the contributing causal mechanisms to the phenomenon of supply chain disruption?"

The research question reflects the broader objective of the enquiry to ascertain agent behaviours that on aggregation could result in macro system outcomes. The next section presents a brief discussion of the methodology followed by a discussion of key findings from this pilot study.

3.2 The pilot

A pilot study provides a researcher with an opportunity to interact with his research in a controlled manner and helps the researcher refine the methodology (Yin, 2009). The decision to conduct a preliminary pilot study was undertaken to test the validity of the data collection instrument and to gain preliminary understanding of the phenomenon. The next section presents details of the research design and key findings for this empirical pilot study.

3.2.1 Research design for the pilot study

3.2.1.1 Sample strategy

Since the pilot was conducted at an early stage of the doctoral process to gain an overarching view of the phenomenon, thus only the people from top managerial position of procurement and supply chain functions were considered for data collection. This idea is consistent with the purposive or judgemental sampling technique (Glaser, Barney, 1967). In order to understand that what profile of organizational respondents will be most likely to lend the

most valuable perspective to the phenomenon under investigation, intentionally a broad spectrum in the profile of respondents was considered; such as industrial sectors, hierarchical level in organization, years of supply chain and procurement experience etc. A formal criterion was drafted for selection of respondents. This was

(i) The firms selected for the pilot should have as diverse characteristics as possible in terms of ownership, size and sector of their operations.

(ii) The respondents should have diverse organizational and supply chain experience.

(iii) Efforts to be made to have respondents form different level of organizational hierarchy and organization function.

Ease of access to the respondents was also a very important consideration. Based upon the laid down criterion, three firms were selected for the pilot study. Table 10. presents details of the sample

Table 10: Description of the sample for the pilot study

Identification code	Description	Industrial sector	Division	Position of Interviewer	Mgt level & Experience (yrs)
Firm1	Global food manufacturing , processing and conglomeration firm.	Chocolates	Procurement and supply chain	Head Procurement and Supply chain	Senior(20)
Firm2	Public sector aerospace manufacturer	Aviation	Vendor development and Procurement	Manager Procurement and vendor development	Middle (11)
Firm3	Countries' leading Food processing and manufacturing	Canned food and beverages	Procurement	Procurement head	Senior (14)

The respondents from these three firms provided details for 31 cases of supply chain disruption and yielded close to 150 mins of recorded interview data.

3.2.1.2 Data collection

The choice of data collection instrument was guided by two key aspects pertinent to this research enquiry. Firstly; complex and highly interdependent nature of supply networks makes it very difficult for the people involved in it to be able to identify or isolate various causal mechanisms responsible for a phenomenon. Secondly; despite having abundance of contextual and tacit knowledge, managers often find it hard to conceptualize, articulate or

express their views on complex and unexplored issues. From these arguments it was evident that a very intuitive data collection tool was required to support the objectives of this pilot study. The data collection instrument recommended for this pilot study was Repertory Grids (Rep Grids). The next section provides a discussion of Rep Grids.

3.2.1.3 Repertory grid technique

Conventional interview methods are not sufficient to investigate organizational mechanisms. Causal mechanisms are underlying constructs that require to associate deeper meaning with the phenomenon and also require linking individual observations to collective process (Anderson, 2006). It is relatively well argued that conventional interview processes are not fit to investigate fields with such attributes (Rogers and Ryals, 2007) like associating implied or deeper understanding of observations. However, there is an alternative structured interview technique, '*Repertory Grids' (Rep Grid)*, that is suited for study of mechanisms. Rep grids are useful in developing theory particularly for fields where there is dearth of extent literature (Hair, Rose and Clark, 2009) or for fields that are undefined, exploratory and difficult to articulate or conceptualize (Rogers and Ryals, 2007; Goffin *et al.*, 2012). The Repertory grid technique stimulates the respondents to compare and contrast elements, such as past events and decisions, to identify underlying constructs.

Rep grids as a tool was devised by an American Mathematician and Psychologist George Kelly to investigate his '*Theory of Personal Construct'* (Kelly, 1955). The theory of personal construct is founded on the assumption that every individual, based upon his past experiences, maintains a personal theoretical framework of cognition or a personal construct system that s/he uses to make sense of world around her/him. An individual uses this personal construct system to control and predict his/her environment (Bradshaw *et al.*, 1993). It helps the individual to formulate intuitive expectations or hypothesis about future events and informs his/her actions and decisions. However, not all intuitions or hypothesis prove to be correct and outcomes of these instances are used by the individuals to create new constructs or amend existing ones. This process of self-discovery continues in cyclic order of formulating, testing and amending one's personal theoretical framework of cognition or personal construct system. In an organizational setting it can be argued that intuitive expectations of managers and decision makers are linked to their past work experiences or their personal constructs. Rep grids as an instrument could effectively explore these mechanisms as constructs.

3.2.1.4 Rep grids: elements of comparison, constructs and linkages

Rep grid is a systematic interviewing tool that prompts the respondents to compare and contrast events and experiences. Rep Grid provides a systematic method to elicit constructs and explore relationship among them. Unlike other interview techniques where a respondent presents a lengthy account of events, the method of comparison and contrasting enables respondents to look beyond the surface level phenomenon into deeper levels of associations and linkage among constructs.

The structure of the grid is divided into two dimensions of rows and columns The columns presents a listing of alternative events, system states, people or other entities, called '*Elements*'. While the rows list bipolar '*Constructs'* that provide the dimension of distinction among elements.

Constructs

Kelly (1955) suggests that individuals create and maintain a system of dichotomous constructs that help them interpret their interactions and experiences of their universe. Constructs have a bipolar dimension of distinction that individuals make about people, events or things. For example in a supply chain context, a distinction among various Tier one suppliers could be made using bipolar constructs like; Reliable-Unreliable, Rigid-Flexible, Supportive–Unsupportive etc.

In the Rep grid interview process, elicitation of the constructs is a significant step and a very important piece of information. Based upon the number of elements offered to the respondent for contrasting and the technique used for questioning, there are three approaches of eliciting constructs; Triads, Dyads and Full context (Jankowicz, 2005). Table 11 presents a sample of construct eliciting questioning technique associated with each of the approaches.

Table 11: Sample questions associated with each type of Construct eliciting technique

Construct Eliciting Approach	Number of Elements offered for contrasting	The questions asked from the respondents
Triad	3	How are two of these elements similar but different from a third?
Dyad	2	How do these two elements differ from each other?
Full context	all	How do any of these elements differ from any of the other?

Adopted from: (Hair et al., 2009:p. 54)

Among these three approaches, Triads approach was selected for this study as it is one of the most commonly used technique (Jankowicz, 2005).

Elements

Kelly (1955) defines Elements as *" Things or events which are abstracted by a construct"* (Kelly, 1955, p137). These represent the objects / things to be investigated or the context to which the constructs are applied (Rogers and Ryals, 2007). In a supply chain context it could be a list of suppliers, customers, products, events, strategies, decisions etc.

For the purpose of this study events of supply chain disruption were chosen as Elements. These are the phenomenon of interest in the research study.

The Grid

The grid is a systematic way of documenting the process of a Rep Grid Interview. A set of selected and agreed upon Elements are listed in the columns and then the interviewee is presented with a set of three elements to compare and contrast for similarities and distinctions. The respondent is stimulated further by using probing questions like *'Why', 'How'* etc to elicit constructs and their bipolar opposites. The discovered constructs and their bipolar opposite are written down in the first and last column of a row. Then using a Likert scale the respondent is asked to rank all elements between the construct and its bipolar opposite.

3.2.2 Analysis

For every instance of supply chain disruption, the Rep Grid data provides an insight about the respondent's cognition of individual agent and system behaviours. The Rep Grids were analysed to discover patterns of similarity. These similar or dominant patterns were then used to conjecture schemas relevant to the phenomenon of disruption. The analysis was carried out in two stages: the first stage used quantitative techniques to group constructs of Rep Grids; the second stage used a qualitative approach to conceive schemas relevant to these grouped constructs.

The quantitative stage of the analysis used the Principal component analysis (PCA), with a varimax rotation, to identify groupings among constructs. The assumption of uncorrelated factors was used to choose varimax rotation. The qualitative data analysis followed the Strauss and Corbin (1998) framework of data coding. The interview data was subjected to

three stages of coding; open, axial and selective coding, following recommendations of Miles and Huberman (1984); Strauss and Corbin (1990); Yin (2009).

3.2.3 Findings of the pilot study

3.2.3.1 Quantitative findings

The Rep Grids (table 12,13 and 14) provide a details of disruption events, as columns in the grid, and subsequent constructs emerging as rows. A liker scale of 1 to 5 is used to demonstrate the weightage of a construct in influencing a given disruption event. Table 15 presents a collated list of all the 30 constructs and their bipolar opposites (separated by '– 'symbol).from the three cases, reflecting the respondents' cognition about supply chain disruption events they had encountered in the past. These constructs are mentioned in the exact way and order in which they were communicated by the experts. Among these constructs one construct, construct of *Incorrect Supplier Assessment*, was mentioned by all the respondents while, '*Complex Product Design'* and issues around internal conflict were common to the two large scale manufacturers. In the table 15, the common constructs are highlighted by bold text.

With the objective of finding statistically significant grouping of constructs a principal component analysis (PCA) and cluster analysis was performed on each Rep Grid. The motivation for a PCA was to discover dominant construct groupings by selecting Eigen value greater than one. Table 16 provides a summary of the PCA results and a description of a aggregated meaning expressed by the latent variable grouping.

In the table 16 it can be seen that for Firm 1 and Firm 2, close to 60% of the variance is being explained by first two components. For these Rep Grids, in which 60 % of the variance was explained by two components, an additional, two component PCA plot was plotted to visually express the groupings. These two component plots are presented in figure 3. In Figure 3, overlaying dotted ovals are used to highlight the closely associated construct groupings.

Among the latent variables creatively conceived to represent the findings of PCA, there are three constructs that require an additional discussion. These are heedless performance, lack of sense making and normalization of deviance.

Table 12: Rep Grid of firm 1 with disruption events in columns and constructs with their 5 point Likert scale ranking in rows

Disruption event	Laminate Rejection on line	Short fall butter scotch	Laminate Start up	Glucose lumping	Cashew shortfall	Jar rejection (E)	Hair contamination	Cartoon short fall	Sugar rejection	Corrugate box	
Construct (Ranking 5)											Construct Opposite (Ranking 1)
Product stock out	1	5	5	1	5	1	1	5	1	4	Unusable stock
coordination communication and collaboration error	3	5	5	1	5	1	1	5	2	2	Not a Coordination error
Transport / handling issue	1	1	1	5	1	1	1	1	5	5	Not a transport / handling issue
Incorrect assessment of supplier's capability	5	1	1	1	1	5	1	1	1	1	Correct assessment of supplier capability
Complex product design	5	1	1	1	1	5	1	1	1	1	Not a design problem
Late involvement of procurement in design or production planning	5	1	1	1	1	3	1	1	1	1	Not related to procurement involvement
Work culture / personality conflict	3	1	4	1	4	4	4	3	2	2	Not a personality or work culture issue
Quick fix	1	1	1	1	1	4	3	1	1	4	Robust fix
New product development /site expansion stage failure	3	4	2	1	4	1	1	1	1	1	Regular product failure
Lack of understanding of extended network lead times	3	4	3	1	1	4	2	4	2	3	Clear understanding of network lead times

Table 13: Rep Grid of firm 2 with disruption events in columns and constructs with their 5 point Likert scale ranking in rows

Disruption event	Skin panel disruption	TRS disruption	Cage free wheel disruption	Bottom stretch	Dyna Tech (E)	Supporter tube	Legend disruption	Frame 9	MGB	
Construct (Ranking 5)										**Construct Opposite (Ranking 1)**
Incorrect Vendor competence assessment	3	2	1	1	1	5	3	1	4	Vendor assessment was correct
Single tier product	5	1	5	2	5	5	1	5	5	Multiple tier product
Lack of internal competency	5	4	5	1	5	3	1	5	5	Internal competency existed but internal conflict
Single part	4	4	5	5	5	5	1	5	5	assembly
Complex procedure job	5	5	5	1	5	5	4	4	5	easy job
Established Outsourcing processes	5	1	5	1	5	5	1	5	5	Unestablished outsourcing processes. Was recently out sourced (Tacit knowledge not shared)
Contract Breach	1	1	1	1	5	1	1	1	1	No Contract Breach
Technical knowledge not shared	1	3	4	5	1	3	4	1	4	Was shared but still component failed
Supplier misunderstood contract and penalty clause	5	1	5	2	1	4	2	3	2	Contract understanding was not a problem

Table 14: Rep Grid of firm 3 with disruption events in columns and constructs with their 5 point Likert scale ranking in rows

Disruption event	Packaging quality disruption	Packaging shortfall in expansion	Utility supply issues	Bureaucratic or political interventions	Port strike	Machine spares	New product launch disruption due to design issues	New flavour quantity issues	Unorganised sector procurements	
Construct (Ranking 5)										Opposite (Ranking 1)
Sole Supplier	5	3	5	5	2	5	5	4	1	Multiple suppliers
Unexpected Supplier Behaviour	5	3	4	3	1	5	5	5	2	Expected
Abuse Of Bargaining Power By Supplier	5	1	4	1	1	5	1	2	5	No abuse
Non Substitutable product	5	2	5	1	5	5	4	5	2	Product Substitutable
Government And Policy Issue	1	1	5	5	4	1	1	2	3	Not Related To Government
Low Cost of Negotiation	3	4	2	2	5	1	1	5	1	High Cost
Low Influence Of Product Price	1	4	5	5	5	1	2	5	1	High Influence Of Price
Relevance Of Supplier Flexibility	4	5	5	5	1	5	5	2	4	Flexibility irrelevant
Incorrect Supplier Capability Assessment	5	5	5	4	1	2	5	4	5	Correct Assessment
Process Or Procedure Fault	1	5	5	5	5	1	1	3	3	Product Fault
Dyadic Relationship	5	5	5	1	1	5	1	1	1	Non Dyadic relationship

Table 15: Constructs from Rep grid interviews

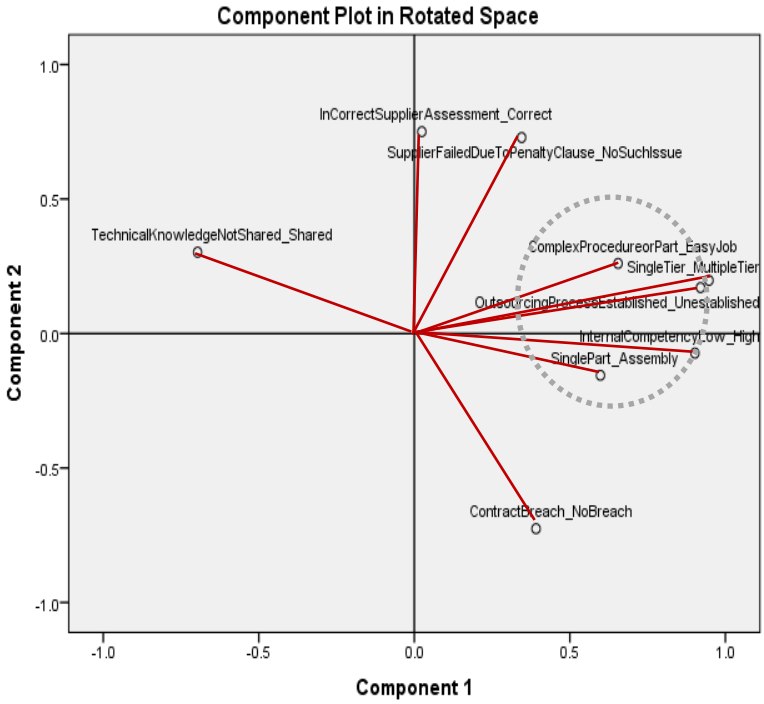
Construct	Firm1	Firm 2	Firm 3
C1	Stock Out – Unusable Stock	**Incorrect Supplier Assessment – Correct**	Sole Supplier – Multiple Suppliers
C2	Collaboration Error – Collaboration Ok	Single Tier – Multiple Tier	Unexpected Supplier Behaviour – Expected
C3	Miss Handling – Ok Handling	Internal Competency L ow – High	Abuse Of Bargaining Power By Supplier – No Abuse
C4	**Incorrect Supplier Assessment – Correct Assessment**	A single part - a part made of assembly of components	Non Substitutable product – Product Substitutable
C5	**Complex Product Design – Not A Design Issue**	**Complex Procedure or Part – Easy Job**	Government And Policy Issue – Not Related To Government
C6	Late Involvement Of Procurement – Not Related	Outsourcing Process Established – Unestablished	Low Cost of Negotiation – High Cost
C7	Work Culture And Personality Conflicts – Not A Conflict Issue	Contract Breach – No Breach	Low Influence Of Product Price – High Influence Of Price
C8	Quick fix Solution – Robust Fix	Technical Knowledge Not Shared – Shared	Relevance Of Supplier Flexibility – Flexibility Irrelevant
C9	Failure Of New Product – Failure Of Regular Products	Supplier Failed Due To Penalty Clause – No Such Issue	**Incorrect Supplier Capability Assessment – Correct Assessment**
C10	Unclear About Extended Network Lead Time – Clear About Lead Time		Process Or Procedure Fault – Product Fault
C11			Dyadic Relationship – Non Dyadic Relationship

Table 16: Percentage variance summary of the results for Principal component analysis of each grid

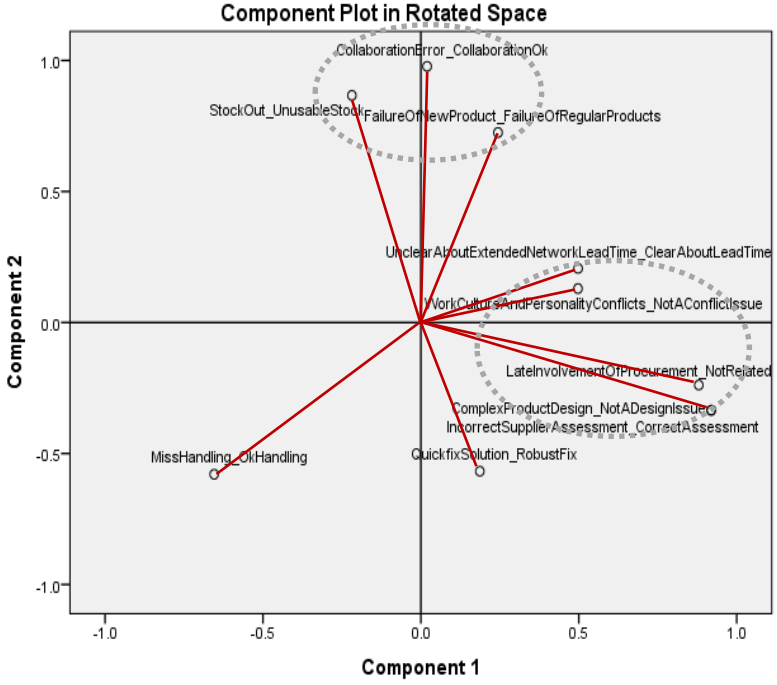
		Principal component number, a latent variable name given to it and results of % variance explained				
		1	**2**	**3**	**4**	**Cumulative % variance**
Firm 1	Construct tags and % Variance explained	(C4, C5, C6) 33.885	(C2, C8, C9) 26.031	(C3, C7) 16.811	(C10) 15.196	90.92
	Aggregated meaning of the latent variable	Heedless performance	Lack of sense making	Normalization of deviance	Procurement Myopia	
Firm 2	Construct tags and % Variance explained	C2, C4, C6) 30.338	(C3, C5, C8) 29.483	(C1, C7, C9) 20.809		80.63
	Aggregated meaning of the latent variable	Low Network dependency products	Heedless performance	Low commitment towards suppliers well being		
Firm 3	Construct tags and % Variance explained	C5, C7, C10 24.609	C4, C6, C8, C9 21.777	C1, C2 20.425	C3, C11 17.156	83.97
	Aggregated meaning of the latent variable	Unfavourable policy issues	Inflexible product or supplier	Single source	Differential in power relationship between the firm and suppliers	

Figure 3: Two component analysis

(a) Firm 1



(b) Firm 2



For Firm 1 the principal component one relates to three constructs; complex product design, late involvement of procurement and wrong supplier assessment. It could be argued that for contexts where product design is simpler, it is highly likely that the fragility of the design to procurement process would not have been exposed, since despite late involvement of procurement, the product would have been successfully delivered. However, for more complex products, it could lead to disruption if procurement is not involved earlier.

A similar pattern is observed in component two of Firm 2 where technical knowledge is not shared with suppliers and in the case of complex products this could lead to disruption. This habitual routine or internal mechanism of 'Heedless Performance' exposed by the act of not sharing technical knowledge is highly detrimental for a firm's performance.

The second PCA component of Firm 1 accounts for constructs C2, C8 and C9 that are collaboration error, quick fix solution and failure of new products respectively. The construct C8, quick fix, was found to be negatively correlated to the other two, suggesting that despite adopting a robust approach the disruptions did happen for new products and also that the instance of collaboration errors were closely correlated to these disruptions. This construct grouping reflects three arguments; Firstly, a false belief of supply chain actors regarding the robustness of their supply chain design, secondly a product supply chain that is neither stabilized nor operationally matured and lastly the inter organizational collaboration is thought to be a contributing factor to such disruptions.

Here collaboration error is used as a blanket term for conceptualising multiple cross functional issues encountered in new product supply chains. This component grouping reflects that supply chain actors failed to conceptualize what could go wrong with their new product launch (as they thought the supply chain to be robust) and on hindsight they argue it to be a lack of collaboration. In other words the stake holders related to a new product launch failed to make sense of the problems or issues that may be associated with a supply chain design that they thought was robust; there was 'Lack of Sense-making'. This failure of making sense of a situation relates closely to the construct of sense making proposed by Weick and Roberts (1993). The aspect of sense

making argues that the reliability of an operation is strengthened by the ability of the people, related to it, to successfully conceptualize what can go wrong and to evaluate viable options (Denyer, Tranfield and van Aken, 2008). It is the ability of people to associate meaning to their experiences and plan for possible contingencies (Weick and Roberts, 1993).

The third PCA component of Firm 1, consisting of constructs C3 and C7, mishandling and work culture respectively. In the context of Firm 1, supply chain agents habitually disregard product handling procedures; it is the prevailing work culture. The act of habitually following a deviant process is similar to the construct of 'Normalization of Deviance' proposed by Vaughan (1996). Normalization of deviance refers to the attitude of people becoming accustomed to behaviours, events, practices and processes that they normally would have considered wrong or deviant from their own perspective (Vaughan, 1996).

The quantitative analysis of the data suggests that there are some dominant patterns connected to the events of supply chain disruption. Naming of the latent variables as per the PCA grouping was carried out intuitively by looking at the components and constructs, however a deeper and more critical analysis of these constructs is undertaken next using qualitative analysis of the data.

3.2.3.2 Qualitative findings

Qualitative data analysis was conducted to attach a context to the constructs and provide meaningful explanation to the statistical analysis results. The depth and richness of data was enhanced by critically examining each participant's experience relevant to individual instances of disruption. The central tenet to this process was to code the respondent's explanations using the Strauss and Corbin (1998) framework of data coding.

The process of coding adopted the following steps; (i) Open coding was used to identify three aspects of disruption: firstly, the agents associated with disruption; secondly the supply chain tasks or processes (related to the phenomenon of SCD) performed by these agents; and thirdly the behaviours and actions of these individual agents contributing towards SCD. (ii) Axial coding is then used to identify causal relationships by

identifying the observed patterns or outcomes relevant to the phenomenon and by establishing the causal conditions and context of the phenomenon such as the agent beliefs, norms, and values governing his/her action or behaviour. These beliefs and norms are governed by the agent's personal construct system. (iii) Selective coding is then used to provide an overarching view of processes by conjecturing the internal mechanism that will hold explanatory relevance to the observed patterns and agent behaviours amplifying into macro outcomes This can be done by either adopting a known mechanism from any other relevant literature domain or creatively conceiving a new one if no known mechanism could explain the phenomenon. Table 17 presents details of open and axial code and the exemplary quotes from the interview that helped formulate these. Table 18 presents the processes and agent actions associated with the phenomenon of SCD.

Among the list of agents found to be contributing to the phenomenon of disruption, the mention of 'Quality function' of the organization and the individual truck drivers or logistics provider came as a surprise. With regards to the involvement of Quality function, firm 1 respondent said that

"*The quality people if do not go an audit the supplier in the right time, then the problems with the supplier, that should have been revealed earlier, would be evident later"*

The respondent shared that on most occasions, strict project timelines and contrary pulls and pressures within the organizational functions, prevents procurement from developing a robust supplier. The delays in undertaking of assessments and instances of incorrect supplier assessments are both significant contributors to disruptions, especially for new product launches. Firm 2 and 3 also had disruptions associated with issues of incorrect supplier assessment and all of these were connected with the organization's quality function. Similarly issues relating to mishandling of goods were found to be connected to transport agents, specifically to the individual truck drivers. In Firm 1, the truck driver agent was found responsible for two significant disruptions, one relating to contamination of sugar and other related to damage of corrugated boxes due to moisture. Firm 3 also had issues with the transport agent, particularly due to transport strikes.

Table 17: Illustrative quotation from the interviews and related open and axial codes formulated using them

Excerpt from Interview	Open Coding	Axial Coding Possible Mechanisms
not knowing the ramp up of the production material anticipation of the future requirement material requirement not in line with production ramp up not working hand in hand close enough look into the future and project those requirements. lack of forward visibility of demand not translating into material ordering functions working in isolation and not realizing the impact of one on the other. planning error departments not working closely enough planning team was not aware plan of the ramp up demand was not visible, manufacturing had planned a ramp up but the planning team was not aware some case it could be a personality conflict So it is never what you envisage it to be or what you conceive it to be, you are not able to execute	Lack of inter functional communication, collaboration, alignment and integration. Inability to interrelate their actions within the system Lack of trust and sharing of information Personality conflicts	Heedful interrelating of actions
from the supplier to our factory, there was a lack of understanding of what all can go wrong The monsoon was just starting and they were not aware that the rainfall will happen he did not put enough rigour, that monsoon will come lack of proper understanding and putting those mechanism in place they have no proactive mechanism making sure that everything is rightly done the lead time in the entire supply chain and constantly thinking about what can go wrong in any project what all went wrong, which can go as a learning in the next project	Lack of operational sensitivity and commitment to process resilience. Lack of engagement with the right ways of doing things Lack of proactive analysis of surroundings to determine what can go wrong	Attention
technology issue	Lack of through thinking regarding the	Mindfulness

was using an old machines machine had to be changed supplier had issues with working capital idea was to develop it and we will be able to manage weightage given to proximity was much higher than understanding the overall supplier's infrastructure went with a more reasonable supplier we thought that capability will not be such a big issue you ask the supplier that I need this material and the supplier says, boss my lead time is 90 days, because I have to put a material in this which I have to import from somewhere else. I cannot deliver you this material in 60 days and suddenly you realize that the lead time required by the supplier, to buy his products, have not been factored anywhere you never told me that you needed the material that soon. ability to understand the lead time in the entire supply chain and constantly thinking about what can go wrong in any project	reliability of the supplier selection False belief of thinking that things will improve over time False belief of supplier's capability to fulfil volume and specification requirements.	
there is actually a document which defines the roll of procurement during specification development It clearly states that if you are in procurement then what you are expected to do during the development phase then you can't blame R&D or supplier It is clearly listed that get involved at these places and this is the value that you need to add to the process No No ..(mild laugh of sarcasm), you create a document with an intent that this is the way to do it but So it is never what you envisage it to be or what you conceive it to be, you are not able to execute The quality people if do not go an audit the supplier in the right time, and then the problems with the supplier, that should have been revealed earlier, would be evident later on. mistakes that you do in one project, you are not able to replicates those learning on other projects. It happens most time that post project failure learnings are not captured appropriately The benefit of hindsight learning gets lost out people don't want to hear bad news, so what all can go wrong discussion is seldom done	Ignoring written procedures Accepting a non-conformity of standard process as an organizational norm Framing their own standards for doing things Disregarding or consciously ignoring the possibility to learn from mistakes.	Normalization of Deviance

Table 18: Processes associated with instances of supply disruption

Open code category	Examples from data collection
Task / processes associated with the phenomenon of SCD	The process of production planning and product ordering Suppler selection Material handling by logistic and transport firms. The process of new product development (Its indicative of coordination between R&D and Procurement functions) The process of capturing usable insights from events of failure Supplier development and management Knowledge sharing Process of contract negotiation The process of buyer and supplier negotiation The process of Government and policy interventions Process of dealing with market mechanism of price changes
Agents behaviour and actions	Agents not sharing or updating production/sales plan Agents not following procedures Agents choosing not to coordinate or work together with other departments or functions Agent behaviour of not putting enough rigour or commitment towards avoiding disruption or agents choosing not to follow set procedures Agents not thinking or preparing for things that can go wrong or about possible scenarios of disruption. Agents failing to capture the learnings and insights from past events of failure. Agents overlooking crucial supplier selection parameter for giving weightage to operational ease Agents unwillingness to discuss about failures or scenarios of disruption. Agents not sharing knowledge or supporting other agents. Agents not challenging outdated and detrimental procedures and routines. Opportunistic behaviour by agents Agents changing design and product specification without discussing with all the internal and external stakeholders such as internal organizational functions and suppliers.

3.2.4 Discussion of pilot study findings

3.2.4.1 Microstate agent behaviours and schemas

The principle argument for this research was that there are some observable system patterns specifically of supply chain disruption that are collectively influenced by agent schemas. The coding of qualitative data was conducted to discover these system patterns linked to the phenomenon of SCD. This was done in parallel with the quantitative coding applying the convergent parallel mixed method process (Creswell, 2013). The Axial coding of qualitative interview data, Table 17 and 18, provides descriptions of system patterns and agent's (beliefs, norms and values) associated with the phenomenon, which help to explain the quantitative components. These agent

beliefs and values connect to observed system patterns can provide valuable insight into the reasons for complex systems behaviours.

Based upon the results of open and axial data coding, the internal mechanism/ schemas of agents were conjectured. To conjecture these internal mechanisms either a known mechanism from any other related literature domain was adopted or a new one was creatively conceived. The agent's internal mechanisms that were found to hold explanatory relevance to the agent actions and the observed system behaviour are; heedless performance, lack of sense making and normalization of deviance. Table 19 presents details of these internal mechanism / schemas. A discussion and rationale for choosing these mechanisms is provided below.

The identified agent mechanisms have their origin in the domain of High Reliability Organizations (HRO) (Denyer, Tranfield and van Aken, 2008). HROs are similar to supply chains, as both are systems of agents and processes that exist to maintain a continuous and reliable flow of material and information in complex environments. HRO is also a system with diverse set of agents working towards continuous operational reliability. In HRO factors like; agent behaviours, actions and agent's understanding of their system, have a significant bearing on the overall system response (Weick and Roberts, 1993). This is similar to supply chain agents, where the actions and subordination activities can influence the overall stability of the network.

Heedless Performance

Weick and Roberts (1993) consider that heedless performance reflects an over-learned or routinized response to situations that require attention or action. The mechanism is enacted in situations where decision makers or agents disregard the contextual conditions or requirement. In instances connected to a lack of heed, agents are often unaware of these contextual and demanding conditions and this is either due to a lack of knowledge or due to insufficient trust of other agents. In several events, at Firm 1, the cause of disruption was suggested to be a lack of information sharing among internal functions. For normal operating situations, the routinized operational processes performed well despite a lack of information sharing, however in demanding situations that required a consideration of evolving contextual conditions, these acts of heedless performance resulted in disruptions.

Table 19: Processes associated with instances of supply disruption

Axial Code Observed System Pattern And Agent's personal construct system	Selective code Mechanisms
Observed System Pattern Material ordering is less than the future material requirement A gross planning and coordination error issues related to the complexity of job not clearly shared with supplier Risk associated with tender not clearly flagged Supplier communication and development is restricted by process Breach of trust by supplier Supplier did not consider the impact of their actions on the operations of Firm 3 Monopolistic and opportunistic behaviour of the suppliers Behaviour prevalent with suppliers of products that may require a long lead time to develop an alternative source Information regarding increase in production volume not shared with suppliers Suppliers do not have the capability or capacity to deliver a product Agent's personal construct system I have full knowledge of the operations and plans No need to update or confirm my information There is no requirement to coordinate with others Lack of trust on others version of knowledge My actions does not impact anyone else Suppliers in 1st, 2nd and 3rd tier have zero lead time Supplier capacity or capability is not required to be factored in. Lack of inter functional communication, collaboration, alignment and integration. Inability to interrelate their actions within the system Lack of trust and sharing of information Personality conflicts Issues related to the complexity of job not clearly shared with supplier Risk associated with tender not clearly flagged Information regarding increase in production volume not shared with suppliers	Heedless performance
Observed System Pattern Lack of proactive analysis of surroundings to determine what can go wrong Agent's personal construct system Lack of through thinking regarding the reliability of the supplier selection False belief of thinking that things will improve over time False belief of supplier's capability to fulfil volume and specification requirements. Failed to conceptualize the impact of design and specification changes on the overall supply chain Failed to understand what can go wrong While drawing a plan for production increase, the production capacity of supplier was not accounted for	Sense making
Observed System Pattern Operational best practice are not followed Directed procedures of coordination, involvement and coordination are not been followed There exits agent version of routines that are deviant from the designed procedures. Agent's personal construct system Habitual of Ignoring procedures. Framing their own standards for doing things Accepting a non-conformity of standard process as an organizational norm Disregarding or consciously ignoring the possibility to learn from mistakes. Lack of operational sensitivity and commitment to process resilience. Lack of engagement with the right ways of doing things Written procedures are not there to be followed as envisaged	Normalization of Deviance

Existence of a heedless performance was also observed in the Firm 2, the aerospace manufacturing sector, where the respondent repeatedly emphasised that a lack of knowledge transfer and information sharing with their suppliers could be judged as a vital aspect of supply disruptions. The respondent acknowledged that Firm 2, being a public sector enterprise with legacy rules and procedures, found it difficult to share technical knowhow and valuable insights with their suppliers. They being in the aerospace sector, with a very low tolerance of error, highly specialized or complex jobs and high penalty clauses, the act of not sharing the information could be deemed as an instance of heedless performance as without a support some suppliers and some complex components or outsourced jobs were bound to fail.

The existence of this mechanism is evident from the respondent's claims that *"communication gap between us and him widened",* the use of pronoun 'him' indicates a Firm 2 supplier. In other Firm 2 respondent's narrative, *"the suppliers were not given adequate knowhow to fulfil their jobs"*, also indicating the existence of the mechanism of Heedful interrelating of actions. In some disruptions related to the Firm 3, supplier demonstrated unexpected and monopolistic behaviour; this too could be argued as an agent schema of heedless performance, since a thoughtless opportunistic behaviour, which is a breach of mutual trust, does not always result in gains. In instance of Firm 3, they changed the supplier.

Lack of Sense making

The respondent from Firm 1 quotes; *"there was a lack of understanding of what all can go wrong".* An HRO mechanism that can be associated with the above remark is the Mechanism of Sense Making (Weick and Roberts, 1993). Denyer, Tranfield and van Aken (2008) suggest that the reliability of an operation is strengthened by the ability of the people, related to it, to successfully conceptualize what can go wrong and to evaluate viable options. The authors argue that this relates to the process of sense making proposed by Weick and Roberts (1993). Here sense making refers to the ability of people to associate meaning to their experiences (Weick and Roberts, 1993). The open coding of the interview transcripts indicates that for events of disruption there are multiple instances where supply chain agent behaviours and actions resonate with the idea of a lack of sense making. These include; people not conceptualizing what can go

wrong with weather variability, with a complex product design, with ramp up production volume being not shared with procurement etc. A lack of sense making is demonstrated in Firm 1 by the fact that the procurement team did not factor in the 2nd tier lead time of materials. Another incident related to a lack of sense making is of a consignment damage from rain due to insufficient weather proofing of the truck, despite the predictability of inclement weather.

Normalization Deviance

Vaughan's (1996) concept of normalization of deviance could also qualify as an internal model or agent schema. Normalization of deviance refers to the attitude of people becoming accustomed to behaviours, events, practices and processes that they normally would consider wrong or deviant from their own perspective. The respondent from Firm 1 talked about the presence of a detailed written guideline documenting when and where should procurement participate in the new product development process, accepting that the recommendations of the document were seldom followed, indicating a decoupling of organizational routines from written procedures. It is a clear case of agents following a schema of deviance normalization. Other examples include not following the product handling guidelines, and not following the production update procedures etc.

3.2.5 Summary of pilot study findings

Before the findings are summarised, it would be worthy to note that the objective of the pilot, its nature and scale of enquiry restricts the pilot study from making any conclusive claim. It just acts as a preliminary tool to understand the nature of results and the effectiveness of the research design.

The results of the pilot study indicate that macro events or phenomenon, like SCD, are influenced by the action, interaction and behaviours of the human agents involved in it. The results highlight the importance of context associated with these events and the underlying agent mindset and schemas governing agent interactions. One of the most important finding of the pilot is that the data demonstrated evidence of some observed system patterns that were found to be connected to behaviour of agents. This finding suggests that there is a possibility to further study system patterns that link micro agent behaviours to macro system outcomes. Or in other words, the amplification of micro

events into macro patters has an intermediate step or a related explanatory mechanism the presence of which is reflected in the observed system patterns connected to the phenomenon.

3.3 Discussion and implication of the pilot for next phase

The pilot study has several implications for the next phase of the research enquiry. This section presents a discussion of these implications from perspective of the phenomenon, research question and methodology.

Implications for the phenomenon

The findings from the pilot reveal that there is a definitive dynamical relationship between the agent's schemas, agent's personal construct system, behaviours and the observed system patterns related to events of SCD. However, the step of theory building, or the step of answering the question that how these constructs are linked to each other, was not so forthcoming. Being aware that complexity has a strong theoretical foundation to argue the 'how' aspect of micro to macro causation, it was perceived that the future phases needed to account more for complexity and its relevant theories and constructs.

A refined conceptualization of Complexity and CAS is presented in the next section. This section adds to the complexity theory, the aspect of dissipating structures and adaptive tension; the two core arguments that have been extensively used to explain micro to macro causation

The adoption of agent behaviour stereotypes from the literature on high reliability organization to argue causal mechanisms was also found to be conceptually an incomplete argument. The reason to it was that although these constructs like; Heedless performance, sense making or normalization of deviance, were a good aggregation of individual/collective behavioural traits or cognitive biases, yet they failed to convey how these behavioural /cognitive biases transform into system wide emergence.

Other reason why these constructs failed to convey a micro to macro transformation mechanism was that the guiding research question of the pilot study was too broad to

argue micro to macro causation. The next section discusses the conceptual gaps in the research question

Implications for the research question

The research question for the pilot study was conceived based on the literature review of SCD. This was;

"What are the contributing causal mechanisms to the phenomenon of supply chain disruption?"

Although the literature review had highlighted the gap to be in behavioural antecedents of SCD, yet the scope of enquiry in pilot was kept broad. This resulted in an in complete account of the transformational aspect of micro agent behaviours. Accepting this as an opportunity to learn and reflect, the research question for the next phase was framed to reflect more on the amplification aspect of microstate agent behaviours. This question is presented at the end of this chapter.

Implications for the methodology

The pilot study adopted Rep Grids as a data collection tool and resorted to a mixed method analysis of the grids. Rep Grid interviews fall under the category of structured interview technique and structured interviews as an organizational research method is often recommended for marketing research or where exact data gathering is a priority (Easterby-Smith, Mark Thorpe and Jackson, 2012). However, due to its link to theory of personal construct and its approach of comparing three randomly selected elements, Rep Grid interviews overcome the hurdles of a structured interview technique. Also, the scope of laddering during the interview process, with questions like; 'why do you think this happened, could you explain further, please elaborate etc., raises the scope of generating insightful qualitative data. The narratives obtained through this approach was found to be conceptually closer to the qualitative data generated in a semi structured interviews.

During the process of analysing the qualitative data from the Rep Grid interviews, the above argument on the quality and thickness of the qualitative data, was further validated. It was found that most of the contextual and behavioural aspects of SCD were

revealed in the narratives, while the conjectured bipolar constructs were not able to sufficiently reflect the aspects of a SCD. The reason to it was that the interviewee was asked to succinctly present a bipolar name tag to indicate the differences and similarity among the three randomly chosen events (Rep Grid elements). The respondents found this step to be a constraint. However, when allowed to freely speak about these differences and similarities among events, the respondents were found to be more relaxed and forthcoming with insightful observations. These narratives provided much deeper and thicker account of the events. The laddering technique used within these narratives also proved to be extremely useful to stimulate a deeper conceptualization of connected constructs. It was also revealed in this process that some people were creatively able to conceive better constructs while others struggled to find appropriate words and thus presented words from their professional jargon which did not add much value to the construct.

The above observation strengthened the idea of giving more weightage to the narratives and qualitative data. It also was useful to find that once the interviewee was presented with three randomly chosen events of SCD, the interview would turn into an open ended, semi unstructured format of interview. Thus, the qualitative data collected from Rep Grid interview should ideally be treated as a semi unstructured interview rather than viewing it a data from a structured interview. These aspects reinforced the utility of a Grounded theory based qualitative data analysis for creating new theoretical knowledge on aspect of agent behaviours and SCD.

The quantitative analysis of the pilot study data also revealed some useful insights about adopting a mixed method approach for this research. Every Rep Grid was different to each other, in terms of the variables (elements and constructs) and thus there was no possibility to jointly analyse these statistically. This aspect of quantitative analysis compelled to reconsider the relevance of conducting statistical analysis in the next phase of the study. The variable reduction technique of PCA would only group constructs within a grid and not among the grids, thus being ineffective for multiple grids when the number of constructs would explode to hundreds in the next phase. If the main research phase looks at more than 20 firms with more than 150 events of SCD, then the statistical

analysis will have no usefulness to present a cross case analysis, however the qualitative narratives could be looked for cross case comparisons.

Reflecting upon the findings of the pilot study, it was decided that the bipolar constructs presented by interviewees would be retained to associate meaning to the narratives but there was no additional advantage gained in testing these bipolar constructs statistically. The next phase of research will be framed purely on the qualitative data and the narratives of Rep Grid interviews.

3.4 Refining the conceptualization of complexity

The outcomes of the pilot study and peer reviewed feedbacks on the findings were indicative that the full potential of complexity as a theoretical foundation was not getting sufficiently exploited. Merely committing to supply chains having emergent and self-organizational capabilities was not enough to support the objectives of this research. It was required to further look into the theory of complex system for answers to 'why' and 'how' questions regarding micro to macro transformation of interactions, which were evident from the pilot study findings. Pilot study had just touched the surface of agent schemas and mental models and was able to highlight some kind of connection between system patterns, agent behaviours and macro supply chain phenomenon like SCD. However, the findings are suggestive that the amplification of micro state agent behaviours into macro system outcomes require further attention. It necessitates investigating why only in some conditions does the system propel a disruption, despite the fact that agents maintain similar mental models and schemas.

Motivated by these questions, before undertaking a full scale study, it was deemed necessary to revisit the tenets of complexity theory, particularly the aspect that reflects upon the amplification of micro interactions into macro outcomes. The next section presents a discussion of further elements of the complexity theory, that are necessary to gain an understanding of mechanisms transforming micro interactions to macro outcomes.

3.4.1 The two views on CAS

Complex adaptive system view can provide explanatory relevance to the self–organized co evolution of many peculiar stochastic micro events concerning agents such as

molecules, genes, neurons, particles, organizations or individuals , into emergent structures (McKelvey, 1999b). The emergence and self-organization of these microstate events can be linked to two popular traditions relating to; dissipative structures (Prigogine and Stengers, 1984) and adaptive landscape (Kauffman, 1993).

In their pioneering work on on dissipative structure theory leading to the research on self-organizing systems, Prigogine and colleagues (Nicolis and Prigogine, 1977, 1989; Prigogine and Stengers, 1984), proposed that adaptive tension in a system, beyond a critical value, can create; (i) Varying complexity fields, (ii) provide alternative explanations to explain the observed complexity, and (iii) produce a complex behaviour at the edge of chaos that may give rise to emergent self-organized structures and adaptive changes in the system.

The fitness landscape view on self-organization by Kauffman (1993), argues that the accumulation of complex interdependencies or adaptive tension will result in alteration of the adaptive landscape and would result in the system self-organizing to something else or in other word the system will exhibit a complexity chaos. This fitness landscape view opposes the Darwinian view on a selectionist evolution of the system. The authors draws a parallel between the rugged peaks of a mountain range and the alternative performance peak/levels available to a system; and argues that depending upon the ongoing energy or fitness level of the system, the system will move from one peak of performance to another without adhering to Darwinian logic of selection.

3.4.2 Dissipating structures and adaptive tension

In his pioneering work leading to a Nobel prise in chemistry, Prigogine explained the way in which physico-chemical open system, also known as dissipating systems, are able to attain a spontaneous order at a finite distance from equilibrium. These systems are characterised by the exchange of energy and matter from the environment and by the spontaneous formation of complex structures that the author named as dissipative structures. Extending the argument to complexity, Prigogine and Stengers (1984) argue that complex system are able to create and maintain structures far above the system entropy, contrary to the laws of thermodynamic, by importing energy into the system, a phenomenon also known as Negentropic effects (Schrödinger, 1944). Prigogine and colleagues further observed that the energy imported in these open systems would

consequently be lost or dissipated and thus these structures are named as dissipative structures.

These self-organizing dissipative structures are both persistent and nonlinear. The persistent nature of these dissipative structures could be demonstrated by the complex processes surrounding the chemical reactions involving autocatalytic hyper cycles (Eigen and Schuster, 1979). In autocatalytic hyper cycles an open system that is exchanging mater and energy from the environment such as a continuous feed chemical reactor far away from equilibrium, there can be produced a class of microstate autocatalytic agent that will create temporal oscillations and dissipative structures and it will help furthers the autocatalytic process. This progress of the autocatalytic reaction is controlled by a positive autocatalytic feedback loop where the activator agent or species enforces its own changes which later are counterbalanced by some kind of parallel inhibitory process resulting in a system maintained at far from equilibrium but still delivering the desired chemical kinetics. During this autocatalytic process dissipative entropic structures are formed within the system over space and time as inhibitory system effects diffuse through a complex oscillatory system. Argued to be sensitive to initial condition and the path of their creation, these autocatalytic disruptive structures are able to generate dynamic system behaviour ranging from stable order to complex organization under chaos or edge of chaos (McKelvey, 1999b). The nonlinearity of dissipative structures is demonstrated by their tendency to either create substantial explosion or a sudden crash of structures. Many such complex, dynamic, self-organizing dissipative structures, similar to the ones generated in autocatalytic process, have been identified in natural phenomenon (Cramer, 1993; Kaye, 1993; Mainzer, 1997), and have been hypothesized to be applicable to the context of firms and organizations (Zimmerman and Hurst, 1993; Levy, 1994; Thiétart and Forgues, 1995; Stacey, 1996).

3.4.3 Adaptive tension

In his dissipative structures theory for open systems maintained far from equilibrium, Prigogine's (1955) conceptualizes the spontaneous creation of adaptive order and complex or chaotic structures to be stimulated by the existence of a tension of energy gradient/ differential between the ongoing system conditions and the environment. This

tension also known as 'Adaptive Tension' is at the core of the complexity argument relating to the process of adaptation and structural emergence (Lichtenstein *et al.*, 2007). In a dynamical open system, far from equilibrium, the adaptive tension argument provides a theoretical explanation for various system behaviours and conditions such as; system in a state of order, in a state of chaos or under influence of structural emergence. Complexity researchers argue that local interactions and energy exchange between the system and environment creates this adaptive tension / gradient that system tends to resolve either by damping it using negative feedback or by using it to support the evolution of dissipating structures through positive feedback dynamics. However, if it crosses a critical value, then the adaptive tension could propel bifurcating or chaotic system conditions.

Critical values of adaptive Tension

Adaptive tension is said to cause rapid transitions in a CAS, from order to chaos. To differentiate among the kinds of system transitions associated with values of adaptive tension, a concept of critical adaptive tension value has been conceptualized (Nicolis and Prigogine, 1989). For each adaptive tension critical value being less than 1 system is expected to be in order, for critical value between 1 and 2 the system is said to be in the emergent zone (Cramer, 1993), or the 'melting zone' (Kauffman, 1993), and for critical values above 2 system is argued to behave in a chaotic manner (McKelvey, 1999b). The value of adaptive tension 1 and 2 are also referred as system's edge of order and chaos respectively.

Nicolis and Prigogine (1989) presented the idea of different levels of critical value for adaptive tension and the formation of dissipating structures using an example of the build-up of a storm. The authors argue that beyond the 1st critical value of adaptive tension, the system of storm particles reaches to the edge of chaos and beyond the 2nd level of critical value the system will move into the realm of deterministic chaos with dissipating structures in form of tornadoes developing and dissipating in multiple occasions. In this zone of emergent complexity, it is often argued that adaptive tension and self-organization of the system may lead to a chaos that could generate more adaptive tension and further emergence through more self-organization. It becomes a recursive relationship where change enforces more change. Holland (1995) calls this as

a ‘scaffolding’ of activities where one activity in a complex chaotic system builds a foundation for the emergence of other system states and activities. This ever growing dynamics of mutual causation driven by the mechanisms of self-organization results in emergence of new structures in time and space (McKelvey, 2004a; Prigogine and Stengers, 1984) and has been argued to be a fundamental cause for the emergence of various structures in organizational settings (Lichtenstein *et al.*, 2007).

McKelvey (1999) successfully apply the idea of critical values for adaptive tension in an organizational context. By comparing Nicolis and Prigogine (1989) storm cell metaphor to interpersonal dynamic communications in an organizational value chain network, McKelvey (1999) is able to present a narrative about the emergence and dissipation of self-organizing dissipating structures due to the build-up of adaptive tension in an organizational setting. The author argue that for adaptive tension critical values less than 1, organizational agents are expected to offer minimum resistance to the ongoing system conditions and produce almost negligible response. For critical values between 1 and 2, organizational members show collective action towards reducing the environmentally generated tension by self-organization and making dissipative structures causing emergence. While an organization faced with adaptive tension critical values more than 2, it will turn into chaotic conditions with lot of local, short lived system patterns emerging and system demonstrating bifurcations.

McKelvey (1999a, 2001) discusses a hypothetical condition of a small firm being taken over by a large company, to argue the aspect of adaptive tension critical values in organizational settings. The author argues that if the bigger firm, the new owner of the small firm, does not force any substantial change in the existing management and process of the newly acquired firm then it could be judged as a condition of critical value less than 1. In such a condition, the methods and processes of the new owner will slowly percolate, from person to person, into the acquired firm and would not result in a rapid phase transformation. In another possibility, if the new owners raise the adaptive gradient by providing targets about market returns, performance efficiency or return on investment, then this will prompt the workers in the acquired firm to self-organize to respond to such pressures. This phase could be argued to have critical values between 1 and 2 and the system will remain in a zone of emergent complexity. However, if the big

firm takes an extreme step of sending in a team of its managers, McKelvey (1999:p.6) calls them "MBA Terrorists", to enforce a radical change in the management system in a very short time, then this will send the system into a chaos. This condition of the system could be argued to have a critical value of adaptive tension more than 2.

The concept of adaptive tension has been utilized by other organizational studies as well. These are presented in the next section.

3.4.4 Adaptive tension in context of organizational studies

Although complexity ideas relating to adaptive tension, emergence and self-organization have emerged from the study of chemical kinetics, autocatalysis and thermodynamics (Nicolis and Prigogine, 1977, 1989; Prigogine and Stengers, 1984), yet the concept has been successfully adopted in organizational settings (Dooley, Johnson and Bush, 1995; McKelvey, 1999b, 2004; Allen and Varga, 2006; Mccarthy *et al.*, 2006; Lichtenstein *et al.*, 2007). Studying nascent entrepreneurs, Lichtenstein and Carter (2007) argue that personal aspirations and perceived opportunities by nascent entrepreneurs leads to the build-up of an adaptive tension in the system that may culminate into the emergence of new ventures or start up enterprises. Mccarthy et al. (2006) observed that in the process of new product development, sequence of decisions, conflicting objectives and agent behaviours outside the formal boundaries of organizational practices can result in bringing about adaptation and self-organization. Allen and Varga (2006) argue that adaptation and structural evolution in complex organizations is brought about by an agent's axiology that is his values system which defines how agents perceive, interprets, define and finally responds to reality and also what motivates or instigates an agent to make different choices.

3.4.5 A note on emergence

Goldstein presented a glossary of terms in (Zimmerman et al., 1998:p. 270); where he conceptualized emergence to be;

"a process ... , whereby new emergent structures, patterns, and properties arise without being externally imposed on the system"

Goldstein, in (Zimmerman et al., 1998:p. 270)

Emergence as a concept has a long history in natural sciences and ecosystems research. However, a system's perspective of emergence could be traced to three fundamental principles; Holism that asserts that evidence of emergence is demonstrated in whole being greater than individual sum of a system's parts, control theory that links the existence of positive and negative system feedbacks to emergent tendencies, and studies that look at energy gradients and system boundary conditions (Goldspink and Kay†, 2003).

In the recent times, the field of complex science has contributed the most to the phenomenon of emergence with many valuable contributions looking at it from various perspectives. Emergence has been studies in natural sciences (Nicolis and Prigogine, 1989; Kauffman, 1993; Bak, 1996) in organizations (Stacey, 1996; McKelvey, 1999a, 2004) and also in the sphere of social enquiries(Eve, Horsfall and Lee, 1997; Buckley, 1998; Goldspink and Kay†, 2003).

Emergence is not a new abstraction to organizational researchers. It has been studied at various levels (Lichtenstein and Plowman, 2009). Plowman et al. (2007) conducted a study on the amplification of small effects into emergent structures at an organizational level. Their studies investigated how small changes led to radical emergent changes for a religious organization. Lichtenstein (2000) use a CAS framework to study and compare self-organized emergence at two firms. Chiles et al. (2004) use the dissipative structures model to argue the emergence of collective organizations. The authors use a longitudinal case study to collectively study the emergent dynamics of a musical theatre and the collective community and other organizations associated with it.

3.5 The next phase

This thesis is poised to study supply chain disruptions from a complex system perspective. One of the founding argument of complexity is that under the influence of an adaptive tension beyond a certain critical value, such that existence of a certain degree of gradient between current and future state of a system, the system will remain either at an edge of chaos and order; and will demonstrate emergence towards new states by the process of self-organization. It can be argued that beyond a critical value, adaptive tension dissipates into structures and activities aimed at reducing the tension. This dissipation of energy results in self-organization and emergence.

3.6 Research question

Based upon the review of relevant literature and through the reflections on the findings of the pilot, following two research questions were formulated for the next phase of the study.

Research question 1:

How do micro level agent behaviours, actions and interactions influence macro level self-organization and emergence in a supply chain disruption scenario?

Research question 2:

What are the factors and micro state agent behaviours that influence events of supply chain disruption?

3.7 Summary

This chapter presented a detailed discussion of a pilot study conducted to test the research design and gain initial insights about the phenomenon of interest. The findings from the pilot and the experience of conducting it helped revisit the methodological and analytical choices of the next phase. It was also observed that there was a need to relook at the conceptualization of the complexity perspective. The chapter went on to present additional discussion on complexity and related constructs like dissipating structures, adaptive tension and emergence. These new constructs and conceptualizations of CAS perspective were positioned to redefine the phenomenon of interest and the research question needed to interrogate it.

This formally concludes the first phase of the enquiry and now the next phase will present details of how the main study was conducted. This includes Chapters on research design and the findings of the main study.

Phase II:

The main study

4 RESEARCH DESIGN

Preceding chapters presented a discussion of the phenomenon of interest in context of the extant literature and offered a theoretical foundation that bounds the scope of enquiry. It also presented a discussion of a pilot study that helped in refining the research question and the research design. Chapter 4 now presents a comprehensive discussion of the research design adopted by this doctoral research. It starts with a discussion of the ontological perspective followed by a detailed discussion of the methodology and analytical framework. To start with, this thesis presents the research question that will guide this phase of enquiry.

4.1 Research question

Based upon previous phase of the research the following two research question were decided for this phase of research enquiry.

Research question 1:

How do micro level agent behaviours, actions and interactions influence macro level self-organization and emergence in a supply chain disruption scenario?

Research question 2:

What are the factors and micro state agent behaviours that influence events of supply chain disruption?

4.2 Ontological stance

The primary objective of this research is to explain the micro to macro causation in events of SCD. In the previous section, it has been successfully argued that complex system theory provides the requisite theoretical foundation to argue the transformational influence of micro to macro causation. It has also been established that complexity science is the most appropriate framework to investigate structure-process transformations of dynamical systems characterised by nonlinear response and dissipative structures (Morçöl and Wachhaus, 2009). So the question of consideration for this research pursuit is;

What is an apt ontology for a research driven by complex system thinking?

The next section presents a discussion of the existing debates on ontology of complex system thinking. The section also recommends an ontological perspective suitable for this research enquiry and presents a detailed discussion of it in context to this thesis.

4.2.1 Ontological stance of complexity

Complexity theorists argue that precise knowledge of individual systems components is not sufficient to predict the future trajectory of a complex system (Morçöl and Wachhaus, 2009) and thus a reductionist or positivist stance does not holds ontological relevance for such an enquiry. Despite criticising Newtonian positivism, complexity fraternity still accepts the existence of a degree of determinism in complex phenomenon. The reason to it is that complexity researchers accept the possibility of causal relationships among elements and events; indicating towards some degree of determinism (Morçöl and Wachhaus, 2009). However, prominent complexity researchers like Prigogine and Stengers (1984) view determinism in complexity with scepticism as they advocate the coexistence of indeterminism along with determinism.

Still, complex systems are considered to be the systems for which the whole exceeds the sum of its individual parts (Anderson, 1999). The view is promoted by the dissipative structure theory of emergence at the edge of chaos (Prigogine and Stengers, 1984), or by similar concept like melting zone/ threshold complexity (Kauffman, 1993). Based on the research on origin of life or origin of structures in chemical phase transformations, these views argue that emergence of structures cannot be explained by reducing it to parts. Thus we can conclude that in general, most researchers will accept complexity to follow a realist tradition with an interpretive or hermeneutics epistemology (Morcol, 2001). The interpretive aspect of complexity arises from the fact that a system's complexity is often jointly determined by the interaction of the system with other systems or human beings/its controllers. Since the knowledge of the system leans on the knowledge and understanding of the agents involved with it, this provides the system with an interpretive epistemology.

Summarising the above arguments on the philosophical perspectives of complexity it can be suggested that an apt ontological stance for a complexity driven enquiry will be a perspective that has a realist feel with an interpretive orientation. Based upon the

objectives defined for this doctoral research, it can also be argued that the chosen philosophical perspective should also be suited for discovering mechanism that may hold explanatory relevance to micro macro transformational effects. The ontological stance that fulfils most of the above desired objectives is 'Critical realism'.

4.2.2 Critical realist ontology

Positioned between positivism and interpretivism, critical realism is a philosophical stance that provides an alternative and unifying ontology to positivist and interpretive research (Archer, 1995; Bhaskar, 1998) by leveraging elements from both of these ontologies (Wynn and Williams, 2012). While retaining the realist perception about the existence of a real world, independent of our knowledge, understanding or perception; critical realism simultaneously acknowledges the interpretive view that our knowledge of this world is subjective, socially constructed, constrained by the context of the social actor and thus fallible (Bygstad and Munkvold, 2011). At a broad level it can be argued that critical realism combines a realist ontology with an interpretive epistemology (Archer, 1995; Bhaskar, 1998).

The key argument of critical realism is that there exists a real world independent of our knowledge and there are rational ways to access knowledge claims (Bhaskar, 1998) or generate theories by scientific research. Despite the existence of real world and theories that could define this world, our understanding and perception of these theories and reality is constrained by the observer's context, viewpoint and understanding of the phenomenon. Thus, our knowledge of these theories and reality is fallible. This notion of observer's inability to clearly understand a phenomenon, takes the critical realism based research enquiry into a different trajectory than a positivist research approach. Using this argument, critical realists reject the positivist viewpoint of a deterministic linear causality relationship between a phenomenon and its empirical data or the predictive capability of the data. Instead they focus on explaining and understanding the underlying mechanisms that are usually not always easily observed.

4.2.2.1 Stratified reality

Critical realism conceives the reality to be stratified into three nested domains; domain of the real, its subset the domain of the actual and domain of the empirical which is a

further subset of 'the actual' (Bhaskar, 1975). The domain of 'the real' consists of entities, structure and objects that exist independent to our perception of them and these structure and objects can either be physical or social. These structures and entities have inherent causal powers and behaviours called 'the mechanisms', which forms the domain of 'the actual'. In the next domain of 'the empirical', these mechanisms, behaviours and causal powers enact to trigger events. These events will be triggered regardless of them being observed or perceived by humans. This concept of nested domains is presented in table 20.

Table 20: Stratified Reality and Nested domains

	Domain of Real	Domain of Actual	Domain of Empirical
Mechanism	✓		
Event	✓	✓	
Experience	✓	✓	✓

Adopted from (Bhaskar, 1975: p. 13)

4.2.2.2 Structures

Critical realists consider structures of real entities to be a set of related objects and practices (Sayer, 1992). Depending upon the unit of analysis, these structures or objects could be considered to be made up of further structures or be a part of a larger structure. However, the behaviour and properties of these structures are not reducible to their individual components (Sayer, 1992); a view that aligns with complexity.

From a supply chain perspective, structures of the reality domain could include physical structures like technological systems, network nodes and connection, organizations in the network their operational rules and practices, etc. and social structures like behaviour of governing bodies, firms, groups, cartels and people.

4.2.2.3 Mechanisms

Conceptually, a mechanism can be explained as a causal power or tendency of a structure to enact something or trigger an event (Bhaskar, 1975, 1998). These behaviours or tendencies are inherent to both the physical and social structures and they

determine the outcome in a specific context by enabling or limiting events (Sayer, 2000; Smith, 2006). Contrary to the positivist assumption, of an objective linear causality, critical realists argue that outcome of a mechanism is subjective, case specific and contextual to other mechanism. This aspect compels the enquiry to focus on subjective and idiosyncratic elements of the cases under investigation.

Thus, from a critical realist perspective the same mechanism may produce different outcome under different context. A critical realist research methodology uses these mechanisms to explain phenomenon or events rather than to predict them. It can be concluded that a critical realism based research enquiry does not sets out to discover universal laws rather it tries to explain the underlying behaviours, tendencies and mechanisms that produce events in a given context.

Table 21: Terms used in critical realism

SNo	Terms used	
1	Object	Structures are made up of objects. Objects could be individual, practices, institutions etc. E.g. supply chain managers, resellers, purchase contracts. Objects can also have some unique properties as age, education, ambitions, duration of contracts etc (Bhaskar, 2010; Rotaru, Churilov and Flitman, 2014) An object can be a part of many structure definitions (Bhaskar, 2010).
2	Phenomenon	Phenomenon are explained by mechanisms. A phenomenon is an emergent systemic ability or capability such as disruption.
3	Causal powers	These are demonstrated by mechanisms (Bhaskar, 2010).
4	Behaviours	Objects have behaviours (Bhaskar, 2010).
5	Events	Event is a thing that happens or takes place. In organizations ,Events contribute to the continuity and change of the object under study (Peterson and Lewin, 1998).
6	Outcomes	Outcomes are effects generated by events or we can say that events lead to outcome (Sminia, 2009).
7	Set of conditions	Conditions that trigger or activate causal powers.
8	Structures	Structures are a set of connected or interrelated group of objects or practices (Sayer, 1992)
9	Mechanism	Mechanisms can be viewed as causal powers or tendencies (Fleetwood, 2005; Smith, 2006)

4.2.3 Critical realism and supply chain

According to the critical realist thinking, all physical and social systems can be argued to have structures and these structures are made up of objects. These objects have behaviours that are triggered by causal mechanisms leading to events or outcomes. In a supply chain context, an event of SCD could be argued to be an outcome that could be

explained using underlying mechanism capable of bringing micro to macro transformations.

The current nature of supply chain enquiry leans heavily on deductive positivist approaches and there are only a numbered research papers that take a pure critical realist stance. On an extensive search of electronic databases, only two journal articles were found that looked at supply chain phenomenon from a perspective of critical realism or causal mechanisms. One of these is a recent paper is by Rotaru et al. (2014) that argue that generative mechanisms like bottleneck management practices, process standardisation, organisational and reporting structure etc.

4.2.4 Critical realist research design

The goal of a critical realist is to explain an event based upon causal powers and mechanisms, rather than predict the event (Wynn and Williams, 2012). The ontology assumes that existence of these mechanisms are often unobservable and non-measurable (Wynn and Williams, 2012). Thus, identification of these mechanisms is most challenging. The process of discovering these mechanisms and building knowledge about them will be driven by a combination of intellectual, perception and technical skills (Bhaskar, 1975, 1989). For a critical realist enquiry to succeed, the chosen research design and data collection tool should be able deliver insights buried under deep ceded tacit and functional knowledge of individuals that people find difficult to articulate or express.

4.2.4.1 Critical realism and emergence

Entities and structures from a critical realist perspective are independent forms that are irreducible to their components (Archer, 1995). The behaviours emerge from the interaction of different structures and their causal powers. This view positions this ontology appropriately to study systemic emergence.

4.2.4.2 Critical realism and open systems

Bhaskar (1998) proposed that critical realist view reality to be an open system that cannot be directly controlled. In contrary to a closed system based enquiry where we can design replicable controlled experiments to isolate specific outcomes, the open system's view considers systems to be in a continuously changing contextual environment with replicable constant condition a rarity thus negating a possibility of a replicable controlled experiment (Wynn and Williams, 2012). The open system assumption of critical realism aligns perfectly with the open system energy exchange phenomenon proposed by Prigogine and Stengers (1984) to argue theory of dissipating structures for system maintained far from equilibrium.

The critical realist assumption of a dynamic , contextual and variable reality of an open system shifts the critical realism based enquiry towards identifying behaviours, mechanisms and tendencies specific to a context, system , environment over a specific period of time (Sayer, 1992). These behaviours may not be generalizable yet provide a powerful narrative of the events and mechanisms.

4.2.4.3 Guidelines for a critical realist enquiry

Wynn Jr. and Williams (2012) suggest guidelines for conducting a critical realism based research enquiry. Although the authors recommendation are typically for a case base method, yet the principles can be generalise to suit the context of this research enquiry. The authors propose five principles for the approach, depicted in table 22.

These five princples ; Explication of events, explication of structure and context, retroduction, empirical cooroboration and tringulation through multimethod, will inform the different phases of my research. Here retroduction is indicative of a techinque that tries to link mechainsms or behaviours to the events under consideration. Retroduction is a kind of an infrence that helps a critical realist identify and verify the mechanisms that are influencing the phenomenon under investigation (Wynn and Williams, 2012).

It can be concluded that the critical realist ontology aligns with theoretical foundation of complexity as both conceptualise system's to be open systems that are influenced by a multitude of causal tendencies and demonstrate emergent behaviours.

4.3 Methodology

This section presents the key research design decisions that informed this doctoral research and the rational of taking those decisions. Although a few modifications in the research design were considered after reviewing the outcomes of the pilot study, yet there were many aspects of the methodology that remain unchanged. It was felt that the research design decisions for this doctoral research were particularly challenging because of the

Table 22: Principles of critical realist research

Critical realism based principle	Ontological and epistemological basis	Evaluation criterion
Explication or account of events Identify and abstract the event to be studied. Use experiences as a guiding principle to understand what really happened.	Stratified ontology Mediated knowledge	A comprehensive description of case story including actions and outcomes. An abstracted chain of events, including experiences of participants and observers.
Explication of Structure and Context Identify components of structure Identify contextual environment Identify the relationships among them. Critically redescribe these from actor's viewpoint into theoretical perspective.	Stratified ontology Open system's perspective Mediated knowledge Unobservability of mechanisms	Description of the structural entities, constituent parts, and contextual conditions existing in the case Identification of the relationships among the entities • Description of the resulting emergent properties
Retroduction Identify and elaborate on powers/ tendencies of structure that may have interacted to generate explicated events.	Emergence Focus on explanation of mechanisms Multiple explanations Unobservability of mechanisms	Identification of a set of plausible candidate causal mechanisms Logical and analytical support for the existence of proposed mechanisms linking the structure to events
Empirical Corroboration Ensure that proposed mechanisms have causal power and that they have better explanatory power than alternatives.	Independent reality Stratified ontology Unobservability of mechanisms Multiple explanations	Analytical validation of proposed mechanism based on case data Assessment of explanatory power of each mechanism relative to alternative explanations Selection of the mechanism(s) that offers the *best explanation*
Triangulation & Multimethods Employ multiple approaches to support causal analysis based on a variety of data types and sources, analytical methods, investigators, and theories.	Independent reality Mediated knowledge Unobservability of Mechanisms Multiple explanations	Multiple theoretical perspectives Multiple analytical and methodological techniques Variety of data sources and types

Adopted from : (Wynn Jr. and Williams, 2012: p. 796)

complexity consideration and the nature of study surrounding micro agent interactions which called for organizational actors to formulate a rich and relevant account of organizational events such as events like SCD. We start the discussion with a comment on the challenges followed by a discussion about the importance of methodological fit and a discussion of comprehensive research design strategy.

4.3.1 The methodological challenge associated with complexity

Research methodology is a philosophical principle that guides the process of conducting research (Dawson, 2002) and for it to be able to deliver quality research outcomes, it should have a methodological fit with the research objectives (Edmondson and McManus, 2007).

However, there exists a methodological challenge associated with the research enquiry of this doctoral research. The challenge is that the choice of research methodology is burdened to deliver the following two research objectives; firstly, to identify micro agent behaviours that could trigger system level self-organization and emergence for events of SCD and secondly, to establish a logical explanation or to identify a relevant mechanism that may explain this transformational influence of micro interactions.

The choice of methodology needs to address the above two challenges. The next section provides a discussion of the methodological positioning of this research and an appropriate research design that suits both a complex system thinking and a critical realist enquiry.

4.3.2 Methodological fit

The notion of methodological fit in organizational studies calls for a research methodology to be aligned to the existing knowledge of the domain (Edmondson and McManus, 2007). Since behavioural aspect of operations research is currently not a mature field of literature (Gino and Pisano, 2008; Tokar, 2010), and aspect of micro macro causation have not yet been emepirically investigated in the supply chain complexity research, thus this doctoral research could not borrow a proven methodology from any of the previous empirical research in the domain of SCD. Instead it was burdened to seek elsewhere for answers.

The conditions surrounding this research enquiry closely resonates with the description of *"Nascent Theory Research"* suggested by Edmondson and McManus (2007: p. 1161). The authors suggest using an inductive theory building technique for domains that have little or no availability of prior theoretical knowledge or are deficient in methodological foundation. Authors further argue that a field enquiry, with real organizational informants, explaining about real events and observations will be most relevant for such a domains to answer the 'how' questions by leaning over paradoxes or unexplained occurrences. To gain a better understanding of patterns associated with enquiries of nascent research domains, Edmondson and McManus (2007) recommended to adopt a grounded theory based qualitative research framework that draws on inductive logic to build theory. Edmondson and McManus (2007) define field research as management enquiries that are based upon qualitative or quantitative data collected from real world organizations.

Accepting the views of Edmondson and McManus (2007), this thesis posits to use a qualitative data driven field enquiry methodology that aims to identify patterns linking micro agent behaviours to macro events of SCD. The theory building is proposed to be driven by inductive logic.

As this doctoral research is already committed to a critical realist ontological stance, it was necessary that the recommendations of Edmondson and McManus (2007) were looked at in juxtaposition with the theoretical foundation and philosophical stance of this thesis. The next section presents a discussion of a particular kind of qualitative research enquiry that will closely aligns with tents of Critical realism and complexity.

4.3.3 Research strategy

The review of methodological fit highlighted the nascent nature of the enquiry and the need for conducting an inductive logic driven, qualitative field enquiry. This section now goes further into the granularity of research design decisions by converging into methods, tools and analytical strategies that align with previous recommendations and help maximise the effectiveness and extant of learning. The changes in the methods originating from reflecting on the pilot study outcomes have been incorporated.

4.3.3.1 Key assumptions

The research strategy of this thesis is driven by the nature of the enquiry and the assumptions that define the research landscape. Since, this research is particularly interested in the micro agent interactions leading to macro supply chain outcomes, it was deemed fit to view human agents as autonomous entities. The views of this thesis about human behaviours, their decisions and actions, are more aligned to the bounded rationality assumption of the broader organizational studies literature that subscribes to the notion of guile, opportunism and non-rational behaviour (Williamson, 1985, 1998; Romar, 2004). Thus, at the outset of conducting this research, I feel obliged to state the assumptions guiding this research enquiry. The research enquiry was driven by three key assumptions that set the future course of the analytical framework. These were;

(i) The human agents neither comply nor behave in a rational manner.

(ii) The organizational members are "Knowledgeable agents" as they are aware of their role within the organization and they can express their thoughts actions and beliefs.

(iii) The investigator or researcher is also equally knowledgeable and witty as S/he can look beyond the narratives into data patterns and concepts that may be difficult for the informants to articulate or conceptualize and the researcher can further these patterns into theoretically relevant terms and constructs (Gioia, Corley and Hamilton, 2013).

The first assumption violates the most subscribed supply chain and operations research assumption of rational and complying human agents by considering the possibility of bounded rationality driven with guile. The second assumption establishes that interaction with organizational members can provide a thick and adequate account of a respondent's experience and thus providing legitimacy to an interview based research enquiry. The approach of giving voice or recognition to the respondent's experience in the initial stages of data gathering and analysis can provide with rich opportunities to conceptualize new concepts and constructs. (Gioia, Corley and Hamilton, 2013). While

the third assumption provides the researcher/ investigator with the liberty to illustrate connections, relationships and patterns among emerging construct.

Driven by the above assumptions and the nascent nature of enquiry it was necessary to adopt a research strategy that aligns with the circumstances surrounding this research enquiry. A broad taxonomy of research strategies available to an organisational or social researcher are; experiments, case studies and surveys (Robson and McCartan, 2016). Among these three, case study method is often accepted to be the most appropriate for theory building in fields that are yet to attain maturity or research enquiries that seek to form deeper conceptualization of a phenomenon (Yin, 1994). For this doctoral research, case study research strategy was considered to be the most appropriate and aligned to the goals.

This research proposes to use an exploratory case study to develop theory about micro to macro transformational influences associated with events of SCD.

4.3.4 Sampling criteria

A purposeful sampling technique was adopted for this study (Tashakkori and Teddlie, 1998; Patton, 2002; Glaser and Strauss, 2009). The conscious choice of a purposeful sampling technique over random or theoretical sampling was guided by a will to capture diversity of experience, industries and disruptions. Purposive sampling uses a controlled degree of variety and similarity among its cases to get a better control of theoretical categorization within its cases (Tashakkori and Teddlie, 1998; Patton, 2002; Glaser and Strauss, 2009) and this informed choice of cases is also beneficial for our study. It was considered that although every disruptive event will be idiosyncratic to a context but from an agent mechanism viewpoint, despite the diversity similar system patterns and agent mechanism will be evident.

With a motivation to look for presence of similar agent mechanism in diverse case settings, a careful choice of firm and participant diversity was desired. A total of 22 middle managers and senior managers were interviewed from 21 different firms. The selected participants represented 15 different industrial sectors, varying degree of responsibility, and 6 to 29 years of work experience in both upstream and downstream networks. In all there were 167 cases of supply chain disruption were investigated. Table 23 represents the details of the sample.

Table 23: Description of the sample

Case Marker	Company	Industrial sector	Division/ function	Position of Interviewer	Mgt level & Experience (yrs)	SCD
Firm 1	Leading Car manufacturer	Automotive	Supply chain risk	GM Supply Chain and operations	Senior (18)	10
Firm 2	Leading Car manufacturer	Automotive	Procurement	Manager Supply chain and procurement	Middle (8)	8
Firm 3	Global polymer manufacturing & retail	Polymers	Sales and distribution	Regional Sales Manager	Senior (18)	8
Firm 4	Asia's leading Semiconductor components distribution firm	Electronics and semiconductors	Sales and distribution	Country Head Sales and marketing	Senior (21)	6
Firm 5	Countries' leading Food processing and manufacturing	Food and beverages	Procurement	Procurement head	Senior (14)	12
Firm 6	Global medical diagnostics manufacturer	Speciality chemicals and medical diagnostics	Logistics	Logistics manager	Middle (7)	7
Firm 7	international Pharmaceutical firm	Pharmaceuticals	Materials management	Sr Manager materials management	Senior (12)	12
Firm 8	global manufacturer packaging material and equipment	Packaging materials	Purchase	Manager Purchase	Middle (6)	6
Firm 9	Petrochemical cracking unit	Polymer division	Marketing and distribution	Sr Manager Marketing	Senior (18)	9
Firm 10	A world leading petrochemical firms	Polymer division	Marketing and distribution	Assistant Vice president	Senior (18)	6
Firm 11	A world leading petrochemical firms	Crude and petroleum	Distribution	GM	Senior (20)	7
Firm 12	Leading Polyester manufacturer of Asia	Polymer	Manufacturing	Vice President manufacturing and operations	Senior (25)	4
Firm 13	Global supply chain consulting firms	Manufacturing and operations consulting	Consulting	Senior Consultant Supply Chain and operations	Senior (18)	10
Firm 14	Engineering project installations	Engineering projects	Projects	Senior Engineering management	Senior (16)	5
Firm 15	Global engineering project installations	Engineering projects	Projects	Senior Project Manager	Senior (20)	6
Firm 16	Operations consulting firm	Consulting	consulting	Senior Consultant	Senior (11)	12
Firm 17	Nuclear power plant	Defence Manufacturing	Procurement and vendor development	Senior Manager Procurement and vendor development and	Senior (18)	5
Firm 18	Leading Shipping Company	Shipping	logistics	Manager Logistics	Middle (9)	8
Firm 19	Global wealth management	Banking and finance	Operations	Senior Vice president operations	Senior (29)	7
Firm 20	Global food conglomeration firm.	Food	Procurement	Head Procurement and Supply chain	Senior(20)	10
Firm 21	Public sector aerospace manufacturer	Aerospace	Procurement	Manager Procurement and vendor development	Middle (11)	9
Firm 22	Medical equipment manufacturing firm	Medical equipment	Supply chain and Procurement	GM Supply chain	Senior (29)	6

4.3.5 Unit of analysis

Events of supply disruptions and variations in material flow were considered as the unit of analysis. It is important to understand that events of SCD are embedded in an extended network of organizations, relationships, people and processes. Thus, organizational actors were asked to discuss these about the people, functions or network organizations contributing towards the occurrence of these events. The unit of data collection was individual managers from firms within the supply chain network.

4.3.6 Data collection

The outcomes of the pilot study had highlighted the effectiveness of the Rep grid based data collection tool. The tool was found to be effective in enticing deeper conceptualization about SCD events and participants found them to be very interesting as it was a first experience with Rep Grids for most of them.

There was no change made to the data collection tool. A thorough discussion of Rep grids has already been presented in the chapter of Pilot study.

4.3.7 Interview protocol

A thorough interview protocol was developed, tested in a pilot and then improved to ensure that it correctly represents our data collection need, it does not stray from the phenomenon of interest, it remains focused on our research enquiry and research question, it is thorough enough to be able to account for related phenomenon and underlying constructs and finally it avoids interviewers bias by not guiding on leading the witness to a desired outcome.

In line with the recommendations of the grounded theory approach by Glaser and Strauss (1967), as the research progressed, some minor and subtle revisions were made to the protocol, although after a very close evaluation and after extraordinary deliberation. Most changes were made to entice the respondent to delve deeper into the causes and concerns connected with cases of SCD, particularly in regards to the people and processes associated with them. These changes were mostly about the way laddering was done during the interview process. Accepting the importance of the

insightful and deeper conceptualizations to be revealed in the narratives, the process of laddering was extensively used.

For the purpose of this research, the participants were asked to comment about instances of supply chain disruptions experienced by them. It being a systematic interview process, the participants were asked to compare three randomly selected events using a common question*; "How two of these events are similar and different from the third?"* Table 24 provides details of the interview protocol.

Table 24: Interview protocol

Step 1	The participant was briefed about the interview process and about key terms such as what could qualify as a disruption. Then a permission for digital audio recording of the interview was taken.
Step 2	The participant was then asked to provide a brief description of 6 to 10 events of delay or disruption faced by him/her in recent times. The events were given a name tag and were written down on different flag cards.
Step 3	The participants were provided a random set of three event flag cards and were asked ; *" How two of these events are similar and different from the third?"*
Step 4	The dimension of similarity and dissimilarity were documented in a grid format as bipolar constructs. To further the understanding about events and the expressed dimensions of similarity and dissimilarity, the participants were asked probing questions like why, how , can you elaborate it further etc.
Step 5	Step 3 and 4 were repeated until a conceptual saturation was reached.

4.3.8 Analytical framework

Having justified the relevance of a qualitative methodology, it was now important to resolve the methodological tension of the theoretical foundation and ontological stance. For empirical investigation of mechanisms, critical realism expounds the virtues of using retroductive mode of inference (Peirce, 1955; Hanson, 1958; Bhaskar, 1975); while the most suited methodology for a qualitative study of nascent organizational fields is proposed to be Grounded theory (GT) (Edmondson and McManus, 2007).

A conjugation of both, retroductive logic and grounded theory, is suggested by (Kempster and Parry, 2011). This approach that follows a qualitative GT analysis following a retroductive logic, often referred as retroductive grounded theory (Kempster and Parry, 2011), has proven its utility in the field of leadership and learning (Kempster and Parry, 2014) and is deemed fit for the purpose of this research.

4.3.8.1 Retroductive grounded theory

Retroductive reasoning, also sometimes synonymously referred to as abductive approach (Shah *et al.*, 2008), is most suited for research enquires that intend to interpret or explain observations or a phenomenon using mechanism from an existing theoretical lens (Peirce, 1955; Bhaskar, 1975; Shah *et al.*, 2008), which in perspective of this research is CAS theory. Contrary to the hypothesis-deductive research approach, retroductive research design engages with an initial theory, in a creative and iterative manner called "Theory matching" (Dubois and Gadde, 2002), to test the efficacy of observations and in turn validates or further specifies theories (Poole *et al.*, 2000; Shah *et al.*, 2008). To simply put, a retroductive argument suggests a theory that if true will render explanatory relevance to any observation or empirical data connected to a phenomenon. For the ontological domains where notion of causal powers and generative mechanism are the fundamental principles of explanatory approach, like critical realism (Sayer, 1992), retroduction research design is unarguably the most appropriate approach for postulating causal mechanism linked to a phenomenon.

Retroductive approach suits the context of this study because the observed complex system behaviour of a supply disruption serves as the perfect instance of an observation that requires interpretation. And in absence of any known mechanism, retroductive research design provides a valid basis to interrogate the phenomenon of SCD using existing theoretical framework of CAS theory.

A retroductive approach, which is a part of the wider realist tradition, encourages an iterative and in depth analysis of causal mechanism using a particular context or theoretical foundation. Such a postulation of mechanism having explanatory or causal influences on observations or events could be argued to complement the principles of grounded theory (GT) research (Kempster, 2006). GT is an apt methodology for investigating beliefs and perceptions that underlie action of social actors by simultaneously accounting for contexts, human interactions and business processes (Glaser and Strauss, 1967) and when used in conjunction with retroductive logic, it can help postulate mechanism using qualitative data (Layder, 1990; Sayer, 2000; Volkoff, Strong and Elmes, 2007). Often recommended for poorly understood and complex social phenomenon, GT succeeds to deliver theoretical explanations about behaviours of

actors by providing a thorough account of actions and interaction of individuals and the logical and emotional underpinnings of decisions shaping these actions (Glaser and Strauss, 1967).

A grounded theory based data analysis posits a systematic categorization of data into bundles conveying similar ideas (open code), then to creatively evolve these into themes relevant to the phenomenon (axial code) and finally provide an overarching theory that hold explanatory relevance to the phenomenon (selective code). Although the grounded theory analysis based upon open code, selective code and axial code, is most common approach in qualitative supply chain research (Manuj and Mentzer, 2008b; Manuj and Pohlen, 2012; Gligor and Holcomb, 2013; Thornton, Esper and Morris, 2013), yet this thesis proposes to adopts a modified version of it, known as the 'Gioia methodology' (Gioia, Corley and Hamilton, 2013), that is now been positioned as more robust and thorough way of conducting grounded theory based qualitative data analysis (Hannah and Robertson, 2015).

Elsewhere in organizational research it has been successfully argued that framework of grounded theory can be used in conjunction with the retroductive argument to explore and reveal causal powers, influences and agent mechanism related to organizational phenomenon (Parry, 1998; Kempster, 2006; Kempster and Parry, 2011).

4.4 Operationalising key constructs

Accounting for Adaptive Tension Emergence and Self-organization

Based upon their beliefs, schemas and mental models, agents are continuously making choices and decisions about complying or rejecting organizational rules, routines, model behaviour etc. The autonomous behaviour of agents adapts and independently evolve into new structures and configurations. To reach to or achieve a critical level of adaptive tension and to be able to self-organize (Anderson, 1999), the system will require sufficient amount of energy to maintain itself at the edge of the chaos. When this energy takes the system to this zone of emergent complexity, the system acquires tendencies to generate emergent dissipating structures that may appear and dissociate in time to consume the excess energy accrued in the system. In an organizational setting it is argued that this internal energy required for the system to self-organize or be maintained

at the edge of the chaos is generated by the existence of a wide variety of autonomous and diverse agents, the imposition of organizational routines and rules governing their actions, the coupling between decision rules and processes, prevailing organizational structures, conflicting priorities, the requirements related to obtaining formal permissions, time pressures and constraints associated with the process, etc (Eisenhardt and Sull, 2001; Chiva-Gomez, 2004). Similar to the factors governing autopoiesis in chemical reactions, these organizational factors serve conditions assisting the system to self-organize or emerge into new structures and forms (Dooley, 1996).

Mccarthy et al. (2006) have demonstrated in a new product development scenario that organizational culture, decision rules and management practices along with pressure from the environment influences the system's ability to self-organize or emerge. The authors propose that organizational practices that allow agents to take exploratory or out of the box actions, experiment with prevailing routines and rules, break rules etc presents with a very high possibility for a system to self-organize or show emergence.

In an organizational setting, when agents are exposed to both organizational expectations and the pressure from the environment, then a CAS framework can help explain how diversity of agents, hierarchy in their decision rules, and the mental models, mind-sets and schemas governing behaviours, actions and interactions of agents, can aggregate to produce adaptation, self-organization and system level emergence. Choi, Dooley and Rungtusanatham (2001) acknowledge the role of local choices over expected norms in generating self-organizing and emergent supply chain behaviours. The authors argue that organizations as agents can be driven by self-interest, can make changes to their organizational goals and can also chose to alter processes and structures; all these could bring about emergence and self-organization in the whole supply network.

For the purpose of this thesis we will consider the following as factors that will generate adaptive tension.

i. Agent experimenting with prevailing routines and rules or breaking rules
ii. Conflict between agent's personal aspiration and goals with organizational values and goals
iii. Agent behaviours driven by system of agent appraisal and reward

iv. High variety of agents associated with tasks
v. Organisational culture and practices about imposing organizational routines and rules
vi. Management practices governing agent actions
vii. Organizational, values, structure priorities conflicting with agent aspirations or personal goals
viii. Degree of rigidity in enforcing the requirements related to obtaining formal permissions
ix. Process or task associated time pressures

Agents characterised by diverse set or organizational and personal targets and ambitions, when act using their own set or simple rules to deliver organizational goals, can produce outcomes that may be radically diverse and distinct from what the organization originally designed, envisaged or planned for. This is a true example of self-organization in organizations and will result in emergent processes, structures and norms. It can be said that evidence of supply chain self-organization and emergence will be evident from these events that may be considered as equivalent of dissipating structures getting generated and dissociated at a high value of adaptive tension.

i. Change in the structure of the network
ii. Change in any established process
iii. Change in agent behaviours
iv. Change in agent internal models , schemas or mind set
v. Change in priorities or goals

Accounting for Resilience and Robustness

The survey of literature (table 5) is suggestive that a system is considered to be resilient if it demonstrates responsiveness, can respond to unexpected events, demonstrates ability to quickly regain a desired operational state on being disturbed or has ability to survive , adapt and grow in face of disruption. The system is resilient if it maintains continuity when faced with disruption and demonstrates control over its structure, function and connectedness during such eventualities. Based upon these formative elements of system resilience, the following list is populated that can help isolate instances where system demonstrates resilience.

i. Preparedness for unexpected
ii. Effectively respond to disruption
iii. Quickly recover from an event of disruption
iv. Quickly return to original system state
v. Move to a more desirable system state
vi. Survive a disruption
vii. Adapt and grow in face of disruption

While in instances where the system demonstrates ability to preserve functionality without reconfiguration, it can be termed as robustness.

4.5 Data analysis

With an intention to develop a new theory and to bind it to ongoing practice, this research adopts a qualitative case study approach (Eisenhardt, 1989; Lee, 1993). The choice of qualitative study was also driven by a desire to capture livid experience of organizational agents relating to their actions, behaviours and mind-sets relevant to SCD and also about the circumstances surrounding these events. This thesis follows a modified grounded theory qualitative enquiry framework proposed by (Gioia, Corley and Hamilton, 2013). This framework adopts the popular inductive qualitative approach of grounded theory (Glaser & Strauss, 1967; Lincoln & Guba, 1985; Strauss & Corbin, 1998) however it goes beyond that to offer a very scientific method of presenting the 1st order or second order findings corresponding to axial code, selective codes of the grounded theory. The systematic interview data from interviews was subjected to retroductive grounded theory based qualitative data analysis.

Based upon the recommendations of Gioia, Corley and Hamilton (2013) and consistent with a critical realist research design, the data analysis was conducted in four phases. All along these phases, retroductive logic was been consistently used, in creative and iterative manner, to align the results with tenets of complexity theory.

Analysis Phase 1: Producing a summary of each interview

The analysis of the data started with a preparation of summaries for each interview. The summary was used as an opportunity to elaborate about the respondents role in their company and to gain an overarching view on their nature of interaction with cases of

SCD. Based upon the recordings, notes taken during the interview and after interview comments and feedbacks generated by the interviewer, these summaries attempted to position the respondent's dispositions in the overall objective of the research and also to present knowledgeable insights about the respondents perspective and experience. These additional summaries to the codded transcripts helped in the qualitative coding stage to ground the words and sentences in the overall perspective of the whole interview.

Analysis Phase 2: First order coding

The first stage of qualitative coding looked for bundles of words, sentences and dispositions conveying similar themes or ideas. Gioia, Corley and Hamilton (2013) call it 1st order analysis and the process is conceptually similar to the open coding framework suggested by Strauss and Corbin (1990).

This stage of coding deliberately refrains from altering the words or terms used by the respondent and it also refrains from converging bundle of ideas into few categories. The stage rather prefers to let the number of categories explode into as many as possible conceptualizations and meanings about the phenomenon of interest. The stage often is accompanied by a feeling of been buried under a heap of data that may initially seem to make no sense and the researcher might get a feeling of being lost (Gioia, Corley and Hamilton, 2013).

The themes originating in the first order coding have been preserved and presented in the findings along with the other codes.

Analysis Phase 3: Second order coding

This stage of codding seeks to develop connections among categories and themes identified in the first order codes. The effort is upon discovering patterns, similarities and differences among categories, an approach that is similar to the axial coding step proposed by Strauss and Corbin (1990). The bundle of ideas are converged to represent a few categories that could be labelled or described by a few sentences, phrases or words. This step of theorising second order themes is the first attempt to structure the findings according to the objectives of the enquiry. The retroductive logic is used to theory match the emergent themes with existing ideas proposed within the theoretical

foundation that is informing the enquiry. This step also calls for accepting the researcher as a knowledgeable agent who has adequate authority and capability to conceptualize the discrete looking first order themes into meaningful categories relevant to the enquiry. Gioia, Corley and Hamilton (2013) call this step as;

"answering the important question ''What's going on here?'' theoretically"

(Gioia, Corley and Hamilton, 2013: pp20)

It can be concluded that while developing the second order themes, we are iteratively interacting with the governing research phenomenon, theoretical background and the ontological perspective. The step is firmly grounded in the theoretical realm of the research enquiry as the researcher tries to make sense of events , observations and dispositions to describe and explain the phenomenon that one tries to observe or explain (Gioia, Corley and Hamilton, 2013).

Analysis Phase 4: Aggregated dimensions and Grounded theory building

The second order themes are further converged to represent aggregated dimensions of the findings. These aggregated dimensions are an overarching view of the cases that promises to deliver answer to the research questions. All these themes are presented visually in form of a data structure.

The step of presenting these first order, second order and aggregated themes in form of a data structure is the most valuable contribution of the Gioia methodology (Gioia, Corley and Hamilton, 2013). This format of presenting the qualitative data steps provides a process accountability demonstrating how meaning was drawn out of narratives. It serves a key criterion of demonstrating rigour in analysis of qualitative data and providing an auditable trail of decisions taken by the researcher. The next stage of this phase is building theory out of the grounded theory approach.

The step of theory building was not restricted to the aggregated themes, rather an inclusive view on the phenomenon was conceived using the connections and meanings of both the second and aggregated themes. With retroductive grounded theory guiding the process, the stage of theory building conceived, evaluated and refined ideas reflecting the amplification of micros state agent behaviours into macro outcomes of

SCD. The iterative implementation of retroductive logic helped conceptualize contribution emerging from simultaneous analysis of data, emergent themes and theories, and the extant literature. At this stage of theory building, the emerging ideas were constantly contrasted with the summaries of the case, second and higher order themes and the overarching theory of Complexity. This helped clarify patterns in abstract interpretations within the data and paved the way for developing a conceptual model that is presented in the chapter of discussion.

4.6 Summary

This chapter on research design presented a discussion of the philosophical, methodological and analytical choices made and the rational for those choices. After a discussion of the ontological stance of complexity an argument was made to adopt a critical realist philosophical stance for this thesis. This was followed by a discussion of adopting a case based research strategy and a qualitative grounded theory based analytical framework. The chapter also presented an argument for adopting a purposive sampling criterion and the SCD as a unit of analysis. A summary of the data was also presented that accounted for 21 firms, 22 executives and 167 events of SCD.

The chapter ended with a discussion of the data analysis steps adopted for this thesis. The next chapter presents a detailed presentation of the findings.

5 FINDINGS

5.1 Introduction

Complex system thinking in organization studies promotes a view that microstate behaviours and interactions of agents can give rise to adaptive tension which when crosses a critical threshold may result into self-organization and system level emergence. The analysis of the data was conducted with two objectives; firstly, to look for evidence of adaptive tension, self-organization and emergence in a SCD context and secondly, to identify agent behaviours that could be argued to have played a mediating role in building adaptive tension or creating circumstances for the supply chain network to self-organize and emerge into a new state.

It is widely accepted that agent diversity provides a richness of interaction as guided by their individual mental models and schemas, diverse agents act and behave differently to similar feedback signals from dynamic and ongoing system conditions. Recognizing the importance of context and diversity, we begin this section of findings with a discussion of the type of agents involved in these events and the ongoing conditions influencing their interactions. This is followed by a discussion of SCD data from an aspect of CAS characteristics like adaptive tension, self-organization and emergence.

5.2 Context and agents involved

Most of the events discussed by respondents were related to procurement side or upstream supply networks and only a few respondents discussed disruptions impacting downstream networks. Supplier relations were the most prominent theme followed by aspects of internal alignment and cross functional interactions.

Respondents provided a rich description of the circumstances that led to these disruptions and when probed with the standard Rep Grid question of comparing the similarities and differences among three random events, the respondents were able to provide deeper insights into human aspects of the issues. In most of the cases, it was found that the order cycle, from point of requirement generation to the final delivery, was in the range of two to three months, which provided a rich data of SCD related interactions transpiring among members of the focal firm and other supply chain

organizations and stakeholders. Table 25. provides a detail of context and figure 4 gives the number of times a particular agent type is mentioned in these interviews.

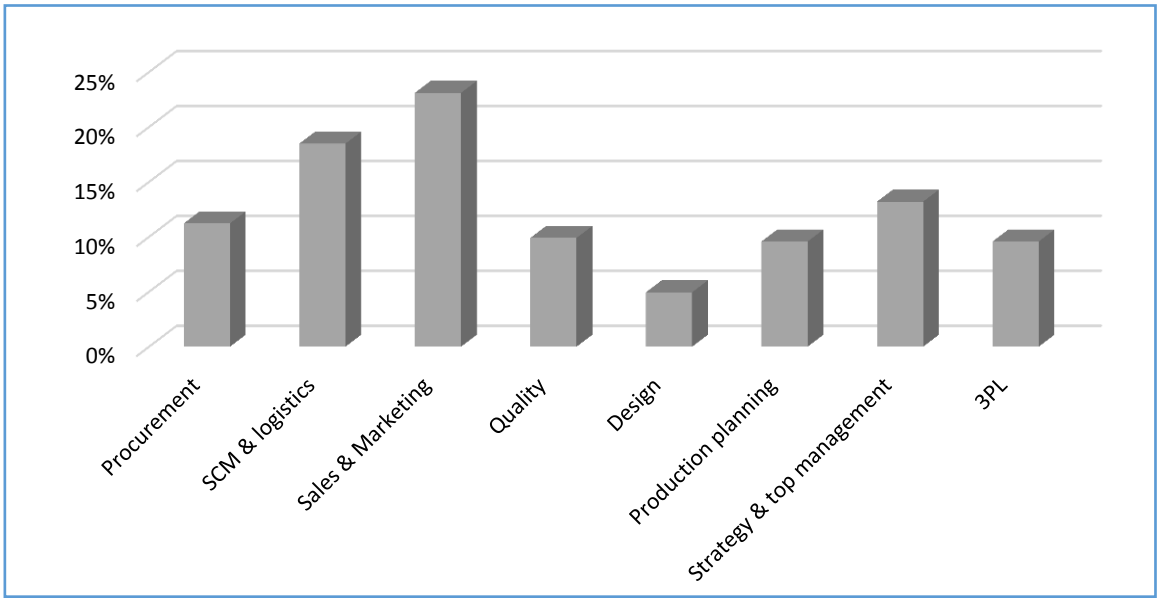
Table 25: Context associated with events of supply disruption

Context	Cases that reflect this aspect
Functions/ Agents involved	
• Procurement	• 1,3,5,7-11, 19-21
• Supply chain and logistics	• 2-5, 7-13, 17, 19-21
• Sales/Marketing	• 2-7, 11-15, 20
• Design	• 5,7,8, 10,14-17,20-21
• Production and Operations planning	• 2-9, 16,17, 20-21
• Strategy and top management	• 1-2, 4, 6-13, 15-17, 19-21
• Third party logistics provider (3PL- Truckers and shippers	• 1, 3, 5-7, 9-13, 16-18, 20
Nature of procurement	
• Internal	• 4,6,7
• External	• 1-21
Power relationship	
• Buyer power high	• 1-21
• Supplier power high	• 2,4,6,9,11,14-16
Relationship between participating firms	
• First time purchase	• 5-7,14,15,17
• Established relationship	• 1-21
Frequency of purchase	
• Regular buying	• 1-21
• One off purchase	• 5-7,14,15,17
Product characteristics	
• New product or service	• 5-7,14,15,17, 20,21
• Existing line	• 1-21
• Complex product or job	• 7,14,15,17,20,21

The data revealed the initial and on-going conditions, listed in the table 25, that were found to be associated with the investigated cases of supply chain disruptions. The data from the 167 instances of SCD revealed 6 important conditions; functions and agent involved, the nature of procurement, power relationships, relationships between participating firms, frequency of purchase, and product characteristics.

The histogram in figure 4 presents the percentage of times a particular organizational agent gets mentioned in the interview narratives. Since most of the respondents were from procurement or supply chain function thus these were mentioned most often. However, a very high mention of sales and marketing agents followed by strategy and top management and third party logistics providers (3PL) was a surprise. This was followed by quality, production planning & control and design functions being mentioned in the order of decreasing priority.

Figure 4: The ratio of agents mentioned by organizational function



A high ratio of cases being linked to marketing function or 3PL firms could be due to the fact that these functions do not share the same priorities and performance measures as a supply chain function and thus lack motivation or commitment towards securing supply chains against disruption. Participants stated that marketing functions, that lacked understanding of the extended network and logistics priorities, put additional burdens on supply chains and enhanced the potential for disruption. Respondents also noted that conflicting priorities and differing KPIs were also to be blamed for these issues. The respondent in firm 9 said;

"So in material planning there are conflicts because everybody has their own KPI. The crude Trader will say I will bring in the cheapest crude because that's my KPI. But that may not be of use to my refinery because the product Trader would have requested for a particular grade of product to get better margin. This is his KPI".

The other context associated with these events was the nature of procurement. With regards to the nature of procurement, most of these products were sourced from external sources except for five events from firm 4, 6 and 7 that had internal or within company procurement. The firm 6 and 7 were both pharmaceutical companies from Asia with their parent company and most of the production facilities located in Europe; while firm 4, an electronic components trading firm from Asia, had their consolidation and procurement activities based at Singapore. Only a few relationships were found to be

disproportionally balanced in power towards the supplier. Apart from one event from firm 2, two from firm 5, one from firm 7 and two each from firm 14, 15 and 20 where supplier firm was found to be leading the relationship, otherwise for all other cases the buying firm commanded a higher power. It is worthwhile to point out that one off purchase of highly specialized or high value customized units that were often made to order had a very high element of power disparity favouring supplier as the supplier were almost certain that there would not be a repeat order or purchase. This element was revealed for firms 7, 14, 15 and 20. For firms 7 and 20, the product ordered were long working life components or machines for their manufacturing unit, while firms 14 and 15 which were global leaders in engineering mega project installations faced similar issues around ordering high capacity customized engineering equipment

Product and design complexity also played a significant role in the contexts leading to disruption. This aspect was found to be active for firms 5 and 21 belonging to the food sector where packaging design and substrate caused disruptions, while complexity of job and design in firms 17 and 21 from nuclear and defence industry also contributed to disruptions.

5.3 Adaptive tension: evidence in the data

Adaptive tension refers to the gradient between actual/operational and planned/expected conditions. In an organizational context, a system operating within the range of acceptable behaviours and efficiency will signify normal or design operating condition. The underlying assumption for achieving such performance is that complying and rational human actors will perform their designated tasks with outmost sincerity and commitment. However, if action or behaviour of actors starts to conflict with optimal system tendencies or centralized decision making, and consequently starts to move away from acceptable operating conditions, then the system could be viewed as a system accumulating adaptive tension. Thus, for the purpose of this thesis, any system condition that provides a proof of a departure from expected or design conditions could be judged as an indicator of the existence of adaptive tension.

The interview data was qualitatively coded for elucidating evidence of tensions and conflicts between designed system conditions and real operating conditions. Figure 5 and table 26 presents the findings arranged in first order and second order codes along

with exemplary quotations demonstrating proof of departure from normal operating conditions. The higher order aggregation of themes originating from the narratives indicated of two system conditions that signified a departure from optimal or design conditions. These were; increased disruption probability, and an impaired crisis management capability.

5.3.1 System with an increased disruption probability

The first of the aggregated higher order themes provides details of a system with an increased disruption probability. It is obvious that disruption is not a desired outcome of an efficient supply chain design. Thus, if the ongoing system conditions affirmatively point towards an increased likelihood of an adverse disruptive incident, it could also be taken as an evidence of accruing adaptive tension. The data revealed several ongoing system conditions that could be argued to increase the disruption probability. These included; (i) system conditions supporting ethically deviant and casual work practices, (ii) system's inability to challenge wrong beliefs and assumptions, (iii) prevailing condition of a loss of attention, sincerity and sensitivity.

(i) Prevailing conditions of ethically deviant and casual work practices

In firms 2,6,7,9,16,18, 20 respondents reported of agents harnessing an apathy and undisturbed attitude towards the possibility of SCDs. The respondent from firm 6 conceded that SCDs were an inevitable reality. In firm 2 the respondent stated that in a case of a new product launch where marketing forecast was wrong by more than 200%, the top management and marketing people were pushing to expedite procurement to make up for the deficit.

This unwarranted pressure from the top management and a rigid insistence to comply could be viewed as an evidence of a growing adaptive tension. This particular incident also indicates an unhealthy organizational practice of not considering events of accepting high forecasting errors as a deviation or error. High forecast errors were also reported by firm 3, 6, 8, 10, 15, 16 and 20. Importantly, respondents reported errors that were typically at a granular level of the forecast, such as at stock keeping unit (SKU) or seasonal level, which were causing disruptions despite the total volume of forecast being tentatively right.

First order concepts Ongoing system conditions	Second order themes
• Disruption and delays are considered as normal operational realities that do not require any action • False commitment being given without considering their repercussion or outcomes • Production over prevention • No learning from near misses or events • Reporting error is neither appreciated nor supported • Liabilities of success are ignored	**Prevailing conditions of ethically deviant and casual work practices**
• Wrong belief that suppliers can and will fulfil their commitments • Rigid mind-sets about one's own processes or decisions resulting in sever operational bottlenecks for others • Maintain a belief that forecast or planned numbers are always wrong whether generated by system or furnished by other functions and people.	**Inability of the system to challenge wrong beliefs and assumptions**
• Make careless mistakes in processing documentations or following routines • Make or change operational plans without informing others • Habit of not following the defined routines • Silo working with severe misalignment among functions • Make frequent request for expediting dispatches, changing volume outlay or making purchases • Lack of understanding of environmental and infrastructure availability • Failure to understand what could go wrong • Fail to understand that how will ones action reflect on others	**Loss of attention, sincerity and sensitivity towards situations**
• An organizational culture that discourages the pursuit of out of the box or innovative solutions to a disruption causing situation or event. • Dated routines and prevailing culture prevent from giving an effective response to crisis as it occurs • Organizational actors fail to negotiate or manage a surprise or a situation not previously encountered or thought off	**Unfavourable organizational culture and routines preventing from responding to an event of disruption**
• Conventional decision structures and escalation of problems through hierarchies • Management disregarding important strategy recommendations proposed by managers closest to the problems	**Fixated to hierarchy over knowledge and expertise**
• Communication gap widening with multiple emails and other forms of communications failing to resolve the issue. • Forced to visit the supplier location to seek a settlement. • Lower and middle management rendered incapable to resolve an issue and higher management or board intervention required. • Escalation of anger, frustration and friction.	**Unwilling to resolve**

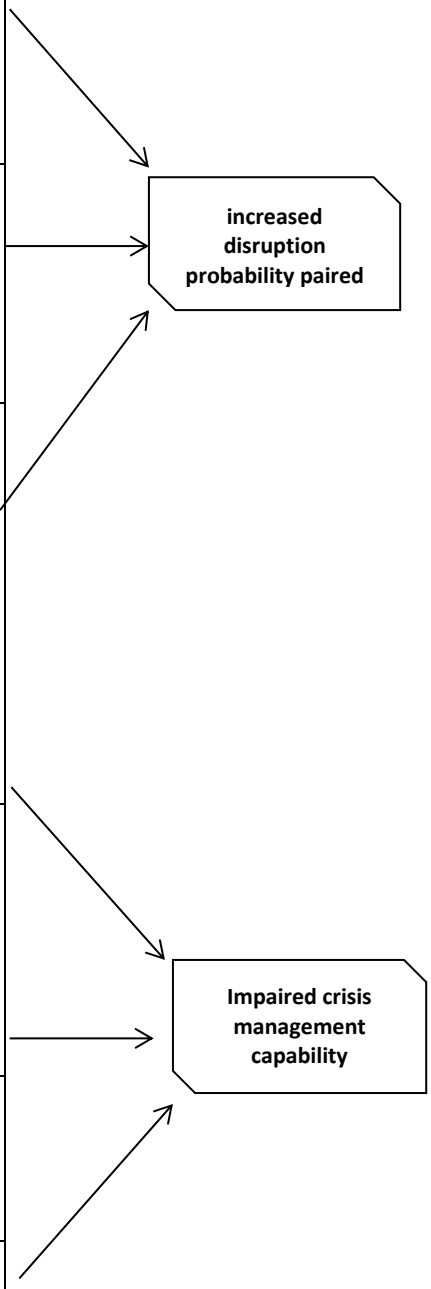


Figure 5: Data structure of the coding for adaptive tension

Table 26: Illustrative quotations of first -order concepts

Second order themes	First order concepts	firms that conveyed this aspect	Exemplary Quotations
	Ongoing system conditions		
Prevailing conditions of ethically deviant and casual work practices **SCD events are generated by a casual or indifference attitude towards failures or potential incidents**	• Disruption and delays are considered as normal operational realities that does not require any action	• 2,3,6,7,9,11,15,16,20	• **firm 6:** "The problem is that here a few days delays is considered as normal and is in routine. We don't consider it as a problem at all…Ha Ha Ha....that's the biggest mind-set issue here." • **firm 20:** they didn't "understand that, what all went wrong, which can go as a learning in the next project, is I think missed out." • **firm 7:** "it had been running for last 20 years so nobody thought of that some kind of mishaps could happen but one fine day it broke down." • **firm 15 (A case about purchase of a highly specialized and costly machine):** "Well yes we do a supplier assessment, but we did not expect such a big multinational company to have a cash crunch. In the agricultural piping system, the vendor had delivered this at several other plants and we could not anticipate that he will have financial crunch." • **firm 2:** "So in the supplies they told us any a times that a certain material was dispatched, its in the pipeline and will reach us. But actually these materials were never ever dispatched"
	• False commitment being given without considering their repercussion or outcomes	• 3,7,15,16,21	
	• Production over prevention	• 2,3,6,7,9,13,16,20,21	
	• No learning from near misses or events	• 2,6,9,11,16,20	
	• Reporting error is neither appreciated nor supported	• 2,6,7,16	
	• Liabilities of success are ignored	• 1,2,6,7,16,18,20	
Inability of the system to challenge wrong beliefs and assumptions **SCD events are generated because agents discount or ignore data or and fail to question assumptions.**	• Wrong belief that suppliers can and will fulfil their commitments	• 2,5,6,7,9,11,15,18,20,21	• **firm 6:** "Now China (The Chinese subsidiary of firm 6) has a problem that they only want to work with their own registered vendors. So if they have an agreement with DHL or Fedex they will not deal with anyone else. If you want them to use your logistics provider, they will not do that. Firstly, there will be a problem to register him in the system and then they will not give him the material. And our freight and logistics provider are 4 to 5 times cheaper than DHL. • **firm 20:** " there is actually a document which defines the roll of procurement during specification development, It clearly states that if you are in procurement then what you are expected to do during the development phase. (mild laugh of sarcasm), you create a document with an intent that this is the way to do it but no one follows" • **firm 7:** "Our quality team strictly said a no that we cannot use this material as the purity of chlorine was some ppm more. Then I looked into what product it goes and what are the customer's requirement. I called the customer technical and R&D and asked them how much chlorine is permissible in their product and they said that 500 ppm was their limit. I laughed; we were originally supplying 75 ppm chlorine and the alternative product was having 100 ppm chlorine but both were way below than the customer's permissible level. I told my testing that next time match the products with customer's requirement as well" • **firm 16:** I am not sure about the legacy but supply chain people knew that these (marketing) guys are over forecasting so they will always undersupply and these marketing guys knew that the supply chain will always undersupply so they will always over forecast. So there were always second guessing going on forecasts and in most cases they would end up trying to improve the product availability at the 11th hour. The firefighting would start and then warehousing, transport and all the other cost will go very high.
	• Rigid mind-sets about one's own processes or decisions resulting in sever operational bottlenecks for others	• 2,6,7,11,13,16	
	• Maintain a belief that forecast or planned numbers are always wrong whether generated by system or furnished by other functions and people.	• 2,6,7,13,16	
Loss of attention, sincerity and sensitivity towards situations such that **happening and what can it lead to**	• Make careless mistakes in processing documentations or following routines	• 3,6-8,15,16	• **firm 14:** So initially we did the design and sent these designs to the vendor for fabrication. It was a vacuum line and the vendor fabricated the line as per our design. But once we installed the exchanger and started routing the piping from the exchanger to the vacuum system we realized that there was one concrete column in the route. This column obstructed the routing and there was a requirement to have a change on the routing. It resulted in revising the routing and it was a tough time for us to determine how to take that kind of modification in the design. …. In this event the step of checking the original site was missed. Routine were not followed. • **firm 2 (Commenting on design function):** "so they do not consider the supply chain impact of the design…….supply chain issues are not clearly put up and also they should have global backups for those designs and products but whenever there is a shortage we're not able to procure those parts because they are
	• Make or change operational plans without informing others	• 2,5,6,8,11,20	
	• Habit of not following the defined routines	• 6,14,16,20	
	• Silo working with severe misalignment among functions	• 2,6,7,11,14,16,20	
	• Make frequent request for expediting dispatches, changing volume outlay or	• 2,3,6,7,16	

	making purchases • Lack of understanding of environmental and infrastructure availability • Failure to understand what could go wrong • Fail to understand that how will ones action reflect on others	• 1,9,18,20 • 1,2,5,6,7,14,16,18,20 • 2,5,6,7,11,16,20	unique to a product." • **firm 18:** In most of the places the process of pest control fumigation in containers is very long. Actually, here they don't do it properly. They just give you the certificate. If done properly fumigation will cost 10 to £15 but you can get a fake certificate for just £1 • **firm 5**: (i) and unfortunatey when we changed the specs of the size of our packing material our packing material supplier did not have raw film in that specification so , he was carrying a different base material **(ii)**"when we were changing the flavour that we used in our products as ingredients we did not realize that our 2nd and the 3rd tier supplier of the supply chain were unable to supply us the required quantities because they didn't foresee these things." • **firm 20:** "unfortunately when we changed the specs of the size of our packing material our packing material supplier did not have raw film in that specification
Unfavourable organizational culture and routines preventing from responding to an event of disruption • **SCD are triggered when agents lack the knowledge, skills, experience or authority or resources to contain disruptive events**	• An organizational culture that discourages the pursuit of out of the box or innovative solutions to a disruption causing situation or event. • Dated routines and prevailing culture prevent from giving an effective response to crisis as it occurs • Organizational actors fail to negotiate or manage a surprise or a situation not previously encountered or thought off	• 2,6,7,9,11,16, 19 • 2,6,7,16 • 1,3,5,7,14,15,16,17,20,21	• **firm 7: (Case about a long standing supplier supplying inferior components with wrong test certificates resulting in frequent disruptions):** "In a work internals senior management meetings, I suggested to send it for third party testing and and people discourage me by saying that we don't have approval for third party testing we don't have a purchase order for third party testing we cannot send it. So what I did, I paid from my own pocket and sent one materials for testing. You will not believe that the component was stainless steel 202 which is one of the cheapest grade and not the 304 which we were being billed for." • firm **16:** Now on the S&OP , the second guessing on the forecast by everyone was leading to severe confusion. So the correct facts were not coming. It was such a political situation that no one was meeting or discussing among them. Everyone was busy guessing so there were always two numbers; one that was being discussed or told to them and one that they actually thought was correct and worked or used for their planning etc • **firm 17 (Discussing of a crucial and costly nuclear grade material being stolen from the vendor's premise):** "In that case of theft, the company could have taken some sort of insurance so that they could have protected themselves from these unforeseen contingencies."
Fixated to hierarchy over knowledge and expertise **SCD are triggered when the agents with greatest expertise who are closest to the problem do not make critical decisions and take action.** •	• Conventional decision structures and escalation of problems through hierarchies • Management disregarding important strategy recommendations proposed by managers closest to the problems.	• 2,4,6,7,11,16, 20, 21 • 2,6,7,16	• **firm 4:** "if it (Purchase orders in Singapore) is high value then it specially goes for approval to a senior level person of management. Over there it could take 1 day or even 3 months, if the person is not there or is on a holiday. In Singapore for higher value PO , our buyers have a process that only the top management can sign it and that is a process delay." • **firm 9:** The economics of the refinery business is very clear it would always be the traders and businessmen who make the call. They will always think about how to make more margins and they will least care about disruptions in the supply chain. • **firm 16:** We also realized that strategy people like the directors had no sense or understanding of the numbers and data and about the complexity of the supply chain.
• Unwilling to resolve	• Communication gap widening with multiple emails and other forms of communications failing to resolve the issue. • Forced to visit the supplier location to seek a settlement. • Lower and middle management rendered incapable to resolve an issue and higher management or board intervention required. • Escalation of anger, frustration and friction		• firm 15: Finally after a lot of discussion we involved our German counterpart • firm 15: Then of course there were a lot of heated discussions

There was another potentially harmful set of conditions that were gaining frequent acceptability among organizational agents. It related to giving false or incorrect information, commitment or excuses. In firm 15 SCD was generated by misleading commitments made by agents. The respondent stated

"the problem was the mentality that the sales team carry. They thought that they could take an order for the sake of securing an order and then change the specifications later on. It was basically a wrong commitment. They probably knew at the time of taking the order that they cannot deliver this product."

Similarly, the informant in firm 6 revealed that operational hurdles were created in procurement and dispatch processes due to unrealistic commitments made by their company's marketing team. Respondents in firms 2, 7 and 9 also shared related issues about representatives of supplier firms indulging in ethically deviant practices.

In several cases it was obvious that misleading commitments and unfair or opportunistic behaviours of suppliers were a source of growing confrontation in buyer supplier relationships. The loss of trust and growing impatience waiting for things to improve, were adding to the tension in the relationship and the system.

There were numerous cases linked to casual and careless work practices. For example, firms 18 and 20 accepted an ongoing practice regarding careless handling of consignments. Where in firm 18, a shipping liner, accepted that many a times the mandatory pest control fumigation of shipping containers was not performed as per the legal requirements, whereas in firm 20, moisture sensitive consignments such as sugar, corrugate boxes etc, were being regularly transported in inappropriate weather proof trucks. The results of these activities would occasionally result in consignments being damaged and triggering disruptions. Sharing his final thoughts about these occurrences, executive from firm 20 stated;

"In case of box, the rainfall happened and the tarpaulin was not properly secured and hence it became wet. In case of sugar similar issue, it was coming in a truck which was not sealed properly so the sacks of sugar got moisture. The rainy season was just starting and they were not aware that the rainfall will happen on that particular day."

Another aspect of deviant and casual work practices is of indulging in production over prevention by accepting success of past being a proof of success in future. Several SCDs were triggered by agents who were focused more on past success rather than the possibility of future failure. In a case related to firm 7, the procurement team had become preoccupied with production rather than prevention as they had been ignoring a looming issue about a severe process bottleneck related to their most important raw material. The incident relates to the procurement of molten sulphur for their fertilizer manufacturing unit. For years, a daily routine of the procurement team at firm 7 was to push hard for the dispatch of their daily requirement of two tankers of molten sulphur, no matter what. This product proved to be a bottleneck because firstly it was being produced as a by-product only by this particular supplier firm and that too in a quantity significantly lower than its local demand, and secondly molten sulphur had additional handling requirement regarding maintaining a high temperature across the supply chain, negating the possibility to either source it from far or keep a high stock in heated tanks. But since it was getting almost managed by a very thorough but difficult follow-up routine, they had been ignoring adverse possibilities. Executive from firm 7 noted;

"literally my schedule every morning was to get up and call the Transporter, very early in the morning, to follow up that are my sulphur trucks available for pick up or is there any problem. Then before leaving for work actually while starting my car, I will call again."

Being so preoccupied with this not so healthy material procurement routines; firm 7 had almost started to trust the inevitability of this flawed approach that required constant persuasion and follow-up. Firm 7 failed to accept every day as a near miss scenario that was waiting for a disruption to unfold. This disruption eventually happened. Some changes in the market disturbed the fine balance of the demand and supply and the supplier firm chose to give priority to some other firm over firm 7. Firm 7 had no bargaining or leverage position on this key raw material and thus flowed practice of follow-up did not help them in any manner. They should have taken some corrective

action before. Firm 7 executive revealed the corrective action[1] that resolved this situation.

Another organizational practice that could be termed as careless or casual work practice relates to organizational members abstaining from sharing insightful information with other stakeholders. In a case reported by the respondent of firm 21, the organizational practice of not sharing crucial technical and design information with suppliers often resulted in suppliers incurring heavy losses and the firm 21 facing disruptions. The respondent narrated that in their aerospace industry there is a very stringent quality requirements and it would require a very high technical competency for the suppliers to profitably deliver their goods. The interviewee noted that due to the prevailing practices in their firm, an inexperienced small supplier is not provided with sufficient technical support to fulfil a highly complex job and when they fail, being small suppliers with relatively low financial stability, the penalty clause of contracts often put them out of business. This is a very disturbing supply chain condition that promotes the likelihood of disruption, as despite being aware of a possible supplier failure, the focal firm is reluctant to support their suppliers.

(ii) Inability of the system to challenge wrong beliefs and assumptions

The likelihood of disruption was also amplified when agents simplified interpretations and made his own misplaced beliefs and assumptions leading to conditions deviating from normal operations. For example, in firm 1, the organization failed to make sense of an impending diplomatic crisis between China and Japan that led to a major disruption. Recollecting the incident, a firm 1 executive stated;

" I mean everybody knew that this is happening but we had not talked about it from a perspective of that it would impact our business" because agents had convinced themselves that *"it would predominantly be diplomatic in nature".*

Another most common wrong belief harnessed by organizational agents was regarding their understanding of the lead times in the extended supply chain network. In some of the SCD events connected to new products being launched by firms 5, 7 and 20, the

[1] The corrective action is discussed in 5.3.4

production, planning and design teams omitted to factor in the material procurement lead times required by their suppliers. The respondent of firm 20 narrated an incident connected to this;

"A new product is getting developed and suddenly you realize that the lead time required by the supplier, to buy his products, have not been factored anywhere. You are almost on 60 days of material ordering and you ask the supplier that I need this material and the supplier says..well my lead time is 90 days, because I have to put a material in this which I have to import from some where else. I can not deliver you this material in 60 days, you never told me that you needed the material that soon."

(iii) Loss of attention, sincerity and sensitivity

The likelihood of a disruptive event is also amplified by system conditions where organizational members lose attention, sincerity or sensitivity towards ongoing operations. For example quite a few cases of SCD in firms 2, 6, 7, 11, 16 and 20 were created by insensitivity to operations. Most of these cases were linked to incorrect processing of import, export or transport documentation. For example, a lack of attention and sensitivity in the part of one of their offshore supplier, firm 6 experienced a significantly costly and long lasting delay in importing a large consignment of drugs. The incident relates to a consignment being sent by one of firm 6's supplier with incorrect labels, resulting in the consignment being detained at the port and eventually being sent back to the origin for re-labelling, incurring increased costs. Further cost was also incurred in expediting a replacement consignment using airfreight.

In another case linked to a supplier sending incorrect label or documentation, firm 15 faced a critical disruption on a heavy machinery equipment that they purchased from a European firm to use in a chemical plant installation in Asia. The firm 15's respondent narrated that despite having drafted a very detailed and clear purchase order document, with multiple mandatory checks and safeguards, it could only have been a severe loss of sensitivity that could have prompted this mistake to be committed by the supplier.

There were a few more incidents around incorrect entries in ERP (firm 4) or excel sheets (firms 13 and 16) that could be argued as cases of a loss in operational sensitivity

and attention. Across all cases there were erosion of multiple barriers to disruption (e.g. procedures, training etc.) that later amplify to generate SCD.

5.3.2 Loss in the system's ability to manage or respond to disruption

Adaptive tension takes the system to a different energy state than its original design or previous operating condition. Thus, if a system is demonstrating inferior or suboptimal traits in comparison to its original design, the system is under an adaptive gradient. Since supply networks are designed for robustness and continued performance, with operational and strategic safeguards ensuring the system to have a certain level of ability to respond or manage disruptions; thus, if the system demonstrates a loss in its ability to manage or respond to adverse events, it is an anomaly. A supply chain system that evidences a loss in its ability to respond to adverse events could be judged as a system under adaptive gradient. The analysis of metadata presented with evidence of multiple instances where the system was found to have developed tendencies that impaired its ability to manage or respond to disruptive events, indicating the presence of adaptive tension. These instances included; (i) evidence of unfavourable organizational culture, (ii) organizational actors being fixated to organizational hierarchy over expertise or knowledge and (iii) unwillingness of organizational actors to resolve contagious issues.

(i) Unfavourable organizational culture and routines

Organizational culture was found to be intervening with the network's ability to handle disruptions and causing the system to go on an adaptive tension gradient. Among the elements of unfavourable culture, member's commitment to resilience was an important one. In firms 19, 20 and 21, some of the SCDs were caused by a lack of commitment to resilience, particularly incorrect supplier/vendor assessments that initiated problems. Firm 19 recounted losing a vendor firm providing critical operational support. Firm 20 and 21 also faced multiple issues with vendors failing to deliver desired quantity or quality as they had erred in the vendor assessment phase. The respondent from firm 20 argued that despite being mandatory in standard operating procedures, the failure to involve procurement in the design phase sometimes led to SCDs. Similarly, in firm 14 groups that were critical to auditing the safety performance of their mega manufacturing

installations were not included early enough leading to problems being identified too late in the process and resulting in severe disruptions. The respondent from firm 21, an aerospace manufacturer, accepted that they often left the suppliers to manage technical difficulties on their own, providing them with just the bare minimum technical drawings, data sheets and specifications. In the absence of technical knowhow, the suppliers are susceptible to fail and incur heavy monetary penalties. All these events are indicative of a prevailing culture with a lack in commitment towards resilience was interfering with the organization's ability to respond or manage disruptions.

Other cases linked to firms 2, 6, 7, 8,18 and 20 demonstrated lack of commitment to resilience, as individual and groups lost the ability to adapt and cope with disruptions. Problems, such as forecasting errors, were handled by putting additional pressure on the logistics and supply chain function rather than resolving the root cause of the problems. Respondents also reported a failure to learn from experience. For example, the interviewee in firm 20 stated;

"Mistakes that you make in one project, you are not able to replicates those learning on other projects. It happens most of the time that post project failure learnings are not captured appropriately"

(ii) Fixated to hierarchy

Ability to manage disruption was also impaired by an approach that gave more emphasis to organizational hierarchy over knowledge or expertise. The data suggests that many events of SCDs were triggered by failure to defer to expertise. Centralized and hierarchal decision making led to events of disruption in firms 3, 4, 7, 9, 10, 11, 12, and 16. Respondents argued that during disruptions those with the most expertise were not empowered to act quickly, instead problems are escalated through formal hierarchies resulting in delays and inaction. For example, an experienced manager from firm 2 shared his dismay that decision makers were reluctant to understand the problems he was facing

"*every product is not fit for lean (Lean supply chain strategy) but the company is not willing to listen* ".

(iii) Unwilling to resolve

Another element of a firm's impaired disruption management capability was the callous apathy of organizational agents towards finding amicable solutions to ongoing problems. This too was adding to the growing adaptive tension.

Driven by ego and personality conflicts, people were sometimes reluctant or unwilling to resolve disputes and address problems. Executives from firms 2, 6, 7 and 15, shared information around multiple cases with these kind of traits being evident between buying and supplying firms. Firm 15 faced multiple SCD where their tier 1 suppliers did not appropriately respond to the queries and concerns raised by firm 15 about their orders which were getting delayed. The executive of firm 15 disclosed that on numerous occasions they were compelled to send a team of negotiators to the supplier's plant, often in different continents, to seek an amicable solution. Sometimes, the suppliers would delay the issues for so long that a higher managerial intervention would be required to resolve. Similar issues were also reported by firm 2 and 7, where lingering issues of disruption were not addresses due to personality or ego related conflicts. Commenting on unwillingness of people to resolve issues, executive of firm 7 said;

"There was a high level of unwillingness to adopt. There were many issues related to ego. In an organizational context ego plays a very major role. Every function every person has a very high ego."

Microstate agent behaviour and adaptive tension

Having established evidence of adaptive tension, the qualitative data was further analysed to identify individual behaviours contributing towards adaptive tension. The analysis was driven by the tenets of the critical realist ontology that organizational members as observers can comment on some but not all aspects of the phenomenon and there are underlying mechanisms governing the causality. Adaptive tension formed by agent behaviours is a precursor of emergence and thus the findings try and conceptualize aggregated themes of agent behaviours and mind-sets that can be linked to the formation of adaptive tension in the organization. Findings from a three stage grounded theory based qualitative analysis, based upon Gioia methodology, are listed in table 23. Mind-sets are depicted with (M). One theme, 'Lose trust in the organization', was judged as a mind-set , while four aggregated themes;(i) over ambitious pursuit, (ii) use power and privilege to force one's own agenda, (iii) conspiring against acceptable

best practices and (iv) heedless performance, pointed towards behavioural aspects of agents

5.3.3 A gradual loss of trust in organization

An analysis of interview narratives for agent actions and behaviours revealed a set of moods and sentiments related to events of SCD. Buried under the description of SCD were a set of feelings, mental models and mindsets of the agent which were found to be exasperating the occurrence and severity of disruptions. The bundle of ideas related to these sentiments and feelings were aggregated into a higher order themes; a gradual loss of trust in the organization or its members.

One of the major themes informing the accumulation of adaptive tension was a growing mistrust in the organizations functioning. The aggregated meaning emerging from some of the dispositions was that agents had accumulated a general sense of resignation and helplessness to the ongoing situations and state of affairs over which they felt they had little control or authority to change. In the findings, a growing feeling of mistrust towards the organization was been driven by three organizational aspects; (i) a displeasure among organizational actors for being unfairly treated by the organization, (ii) a feeling that one's advice or expertise are neither sought nor valued, and (iii) organizational members having a growing mistrust towards other function and people.

(i) Displeased about unfair treatment

Many respondents shared that supply chain and procurement function was pushed to accommodate the mistakes and blunders made by other functions. Repeated and regular errors in forecasting always kept the procurement and supply chain function preoccupied with constant firefighting. The respondents felt that most of the time and energy of supply chain executives was being spent on coordinating and covering-up for errors and gaps in sales and operations planning. Firms 2, 6, 7 8, 11, 13 ,16 reported encountering regular disruptions due to inaccurate and unscientific forecasting by marketing function. Commenting upon poor forecasting, the respondent from firm 13 stated;

"actually when forecasting at SKU level, the sales team just keys in numbers without giving it much scientific thought. They will look at the total volume and would start keying in numbers arbitrarily to forecast the SKUs..put 5 there 10 here an so on."

.

Table 27: Agent behaviour and adaptive tension

First order constructs Agent behaviours and beliefs	Second order themes	Aggregated themes
• (M) Supply chain function is always forced and suppressed • (M) You have to bear the burden of others mistakes	Displeased about unfair treatment	(M) Lose trust in the organization
• (M)Convinced that top management does not appropriately understand your problems or constraints • (M)You know the solution to the problem but no one is listing	Displeased that knowledge and expertise are not valued	
• Reject forecast numbers provided by others and work with own numbers • (M) Believe that your production and sales forecast is better than others. • Believe that others provide false and inflated forecast.	Distrustful towards other functions and people	
• Adopt an exploratory strategy • Present a novel solution • Bend the rules to do the right thing	Out of the box thinking	Over ambitious pursuit
• Take more ownership of a process than you are expected. • Do not hesitate to invest personal money or resource to pursue organizational issues and also to prove ones point.	Go an extra mile	
• • Top management unwilling to consider alternative solutions to problems • Blindly follow incorrect dated procedures and routines (Incorrect ERP forecast religiously • Fixated to a process, solution or a product with no supporting logic. • Inflexible to address concerns of other functions • Rigid processes or relationship preferences	Denial of problem or expertise	Use power and privilege to force one's own agenda
• Force decisions on others with a use of inconsiderate authority and lack of compassion for how will it impact other organizational members and functions • Top management pushing for unrealistic targets • Dictate the procurement function to support an unplanned high volume despite a possibility of it triggering disruptions on other product lines. • Regularly insist on processing off the working hour dispatches (mid nights) to assuage personal relationships with some selected suppliers • Compel to expedite dispatches without considering its impact on others	Distasteful enforcement and disparate treatment	
• Give genuine sounding excuses for production or dispatch delays when the truth is something else. • Agents accept and commit to orders that they know they cannot manufacture either due to a lack of resources (spare capacity, finance or material or technical capability • Lie about material being dispatched when it has not • Commit to unrealistic delivery dates or schedules • Furnish incorrect test certificates for materials or processes • Agents hide crucial information about constraints in their spare capacity or financial capability to handle a given order	Dishonest demeanour	Conspiring against acceptable best practices

• Agents demonstrate favouritisms for some relationships, people or customers		
• Agents demonstrate favouritisms for some relationships, people or customers • Reject or ignore the process and necessity to collaborate or work with other organization agents and functions • Habitual to violate laid down process guidelines and written procedures.	Disregard process	
• Agents consciously force the supply chain into disruption for the purpose of making more profits as the profit they make is linked to their KPIs and appraisals (this is specific to petrochemical industry trading function and is appreciated and rewarded with associated performance bonus) • Agents indulge withy activities that may be improving their individual or their group's KPI despite knowing it would impact organization adversely • Monopolistic opportunism • Cartel formation • Unethical and incorrect practices and attitudes • To maximise their profits and improve their bottom line some suppliers take decisions, with no empathy for their customers, causing disruptions in their customer supply chains	Opportunistic behaviour	
• Give genuine sounding excuses for production or dispatch delays when the truth is something else • Agents accept and commit to orders that they know they cannot manufacture either due to a lack of resources (spare capacity, finance or material or technical capability	Dishonour a commitment	
• Functions and individual agents plan actions or make changes in isolation without discussing or informing other functions or agents. • Take a conflicting path with your peers and contest very hard to secure ones local, functional or team interests. • Avoid discussing common issues with others • Reject possibility to coordinate	Frame narrow boundaries of success and team working	Heedless performance
• Agents demonstrate carelessness or lack of attention in processing dispatch documentations. • Careless mistakes in material handling • Careless mistakes in crucial excel sheets and data	Careless mistake	
• Lack of understanding about lead times in the extended supply chains • Failed to conceptualize the impact of design and specification changes on the overall supply chain • Fail to foresee the possibility of a failure and how would it impact the operations	Lack of vigour to do it right	

In most of these cases of inaccurate forecasting, the respondents also disclosed that supply chain function was always under constant pressure to do what so ever it will take to resolve such situations. Referring to cases of disruptions triggered by inaccurate or particularly under forecast, firm 2 executive stated,

"there is always a pressure from the management side and from the internal that please find alternative solutions."

Recounting the headache and operational problems originating from such matters, firm 6 executive stated,

"The trouble with supply chain problems in India is that although at the end everything gets managed but the kind of pain it takes the energy that is spent, actually it should not be 1 % of it."

Executive of firm 3 also recognized the burden of this last moment firefighting. Commenting on all the disruption events that the respondent discussed, the firm 3 executive stated

"Everything, 99% is coordination. All the cards of events that you have made is 99% about coordination."

Reluctantly, supply chain and procurement function had accepted this fact that irrespective of blunders and errors done by other functions, the aim of supply chain is to go on delivering without asking for rewards or recognition. A fact that they were not happy about. A statement that summarises the deep seeded feelings of the supply chain personals came from firm 6. The respondent stated,

"The major problem is that we (supply chain function) have to keep the customer happy, keep the vendors also happy, internal company issues are also to be sorted out like tax related , forecast, sales forecast are not proper, but material has to be fulfilled."

(ii) Displeased that knowledge and expertise are not valued

The procurement and supply chain function were also displeased about the fact that the top management had an apathetic disdain towards supply chain issues. This was

effecting the moral and mindset of supply chain executives and was resulting in a escalation of adaptive tension. Many respondents recounted that the operational constraints of the function were neither understood nor addressed. Firm 2 recounted an incident related to a supply issue that had been ongoing for years. This related to the aftersales and spares market segment where a range of products was having frequent disruptions. Sharing his displeasure, the respondent conveyed that top management was compelling the supply chain function to adhere to a lean inventory model while this product with a high degree of demand variability and seasonality was not fit for this approach. But the top management was rigidly insistent on pursuing a ubiquitous strategy of lean supply chain management. In words of the firm 2 respondent

"every product is not fit for lean but the company is not willing to listen we had a long discussion where we proposed that let us put up an external warehouse and stock these clutches (A suggestion that was denied)".

Firm 7 executive also disclosed facing hurdles from other functions and management over exercising alternatives solutions that could resolve ongoing issues. Firm 16 executive also reported facing rigidity and stubbornness from top management executives to accept what he perceived to be the most logical solutions.

(iii) Distrustful towards other functions and people

A common pattern observed over multiple cases was that there was a brewing sense of mistrust among organizational functions. The activity of production planning and sales forecast was found to be flawed by elements of mistrust. In many cases it was reported that marketing people had a belief that planning and supply chain function would always supply less than what they would demand and so to upset this possibility they would inflate their numbers by an arbitrary value. However, operations and supply chain people were aware of this manipulation and thus would further manipulate and undersupply. This manipulation of forecast, what the respondent from firm 16 termed as second guessing and respondent from firm 13 called it a smartness of supply chain function, was having a significant impact on the on-shelf availability and was causing frequent disruptions. Summarising the situation firm 16 respondent stated;

"Everyone was busy guessing so there were always two numbers; one that was being discussed or told to them and one that they actually thought was correct and worked or used for their planning etc. They were not trusting each other and this is why lot of second guessing was happening. They did not trust others numbers and they had their own mandates and numbers that they were planning for."

Citing the lack of trust between the procurement or logistics function and the marketing function, the respondent from firm 13 stated;

"So suppose the demand is forecasted by marketing people about various SKU and is given three months in advance but the procurement guy is smart and will say that this quantity will not be sold so will not order all the material. So procurement changes the marketing forecast based upon there understanding and they say that we know you would not be able to sell this much you have inflated the forecast"

This behaviour of not accepting the marketing forecast numbers by procurement or supply chain function and instead working with their own scaled down numbers is a very serious behavioural issue. However, what differentiates firm 16 disposition from firm 13 is that firm 13 executive approved such a behaviour citing that performance of marketing people is at the core of this issue. The respondent said that production numbers and forecast by marketing function have been highly inaccurate that has made them lose their credibility and trust of other functions. The proof of the claim can be found in these words of the respondent from firm 13;

"See I have seen it forecasting accuracy is very poor, in 50% cases it is inaccurate. If you look at the SKU level forecast then there is even greater error in it. In petrochemical industry this is very high."

5.3.4 Over ambitious pursuit

Events of disruption and conditions leading to them also presented with opportunities to tackle or manage them. From the narrative of the respondents it was evident that some organizational members were highly self-motivated and committed to approach such eventualities. This behaviour of considering events of disruptions as a personal challenge and acting beyond the normal organizational response or expected job responsibilities could be termed as an over ambitious pursue of disruption events.

Accompanying themes to this higher order theme of over ambitious pursuit were; (i) out of box thinking, (ii) going an extra mile.

(i) Out of the box thinking

Some situations call for innovative and novel approaches to resolve. In the 167 incidents of supply chain disruption discussed by respondents there were a few events that stood out as classical examples for out of box thinking. Respondent of firm 7 disclose two such events; one related to bargaining a favourable deal with a critical raw material supplier and the other related to breaking a logistics firms cartel that was pushing for inconsiderate price rise. Both these incidents relate to the same product, molten sulphur, which was the main ingredient of firm 7's fertilizer production unit. Since this raw material was produced as a by-product in a petrochemical refinery nearby and its output was considerably less than its local demand, firm 7 always had difficulties procuring its daily requirement of two truck tankers. An additional handling requirement of keeping this raw material in heated vessels and trucks to maintain its molten state, was putting additional constraints in stocking this in a high volume or buying from locations more than 100 km away. The supplier for this material followed a quota system for allocating material among buyers and sometimes, due to favouritism towards certain buying firms, defaulted on its commitment towards firm 7. For firm 7, the product had been a critical bottle neck for several years and no one had been able to come up with any solution. The firm 7's respondent said that he adopted an out of the box strategy that helped him successfully negotiate favourable terms from the supplier. The respondent enquired about portfolio of products his parent company was buying from the supplying firms at other geographical locations. Then using a combined buying portfolio as a tool of negotiation, he was able to strike a favourable volume commitment from the supplier which was negotiated at the company level and was able to upset relational favouritism practiced by the local team of the supplying firm. Narrating the incident firm 7 executive said;

"We were also buying propylene from the same company but at a different refinery. That was bought for our other manufacturing unit. So I met my counterpart from our other manufacturing unit and said to him that I have this issue, since our company is same, so together we should discuss this. This person was in a senior position to me so I

said to him sir please help me in that, so he said no issues let's talk. Then we went back to the refinery PCL and said to them that we will buy this much quantity of propyline, that you are asking us to buy but on one condition, you will have to also give to us 900 tonnes of molten sulphur."

Similarly, another issue at firm 7 also relating to molten sulphur was that due to its high temperature handling requirement there were only a few transport and logistics firm equipped to provide this service. Due to a monopoly, these firms formed a cartel and pushed firm 7 for a substantial price hike. Pushed to a corner, the executive of firm 7 adopted a novel approach of conducting a forward auction and convincing another logistics firm to quote a comparatively lower price for the service. Although this other firm had no such resource to provide this service yet firm 7's executive used it as an instrument to break the cartel. Intimidated by the new entrant, the established logistics firms accepted a logical price offer and the disruption was resolved. Since the firm quoting the lowest price was not offered a tender, as it was only used as a decoy, firm 7's executive disclosed that he had to make a special note and presentation to explain this to the management and audit teams. The respondent quotes;

" In my tender allocation document I had to write a note, because officially and ethically it was wrong not to award the tender to the lowest quotation, so I had to write additional notes and a document followed by a presentation to the managing director that this act was a deliberate act to break the cartel."

firm 2's executive also adopted an out of the box strategy to upset an upcoming strike in one of the tier 2 suppliers. This particular supplier was a sheet metal component manufacturer and the firm 2's executive recommended a relocation of the complete tool set to an alternative location, which was a challenging decision as the tool had a very high tonnage and also there was no possibility to run the mandatory trials at the new location. Still the transition from one location to the other was achieved smoothly and a major disruption was avoided. Narrating the incident, firm 2's executive said;

"After visiting the plant we took an immediate decision of shifting the tools from the affected factory to an alternative location. A lot of quick trials were run, since complete endurance full body trials and testing was not possible we discussed with our parent

company and the resultant was that within one week we had an alternative location. Thus despite the strike we were not affected."

More experiences relating to an out of the box approach were also disclosed by some other respondents. Firm 11 executive discussed about handling a transit time issues in petrochemicals supply chain by adopting a technique what he called was 'Sale on Water'. This was about sailing ships with different raw materials without orders or forecast and using the long transit time as an opportunity to create the required demand. firm 17 used an innovative costing technique to resolve a disruption. For a product to be used in a nuclear plant application there were issues with inability to freeze the design and the fluctuations in the international price of the rare metal alloys used in it. These factors were demotivating any qualified firm from participating in the tendering process and had resulted in an unresolved disruption. The firm 17 executive proposed an unconventional tender costing mechanism of £/ kg for this component as this was able to overcome later stage changes in the design and also to some extent the fluctuation on the raw material.

(ii) Go an extra mile

There were a few cases of disruption where, the meaning emerging from the disposition of the interviewees indicated that their response to a crisis situation exceeded the expected job responsibilities of an individual; for the purpose of this thesis it is named as an approach of going an extra mile. In an incident reflecting this theme, the respondent of firm 2 went beyond the expected job responsibility of a procurement executive to get personally involved in the testing and sample collection process of an alternate material to influence the approval process of an alternate supplier. According to the respondent of firm 2, the prevailing circumstances had compelled him to do so. The procurement team of firm 2 was struggling to get an alternative supplier and material approved for a product that had been a critical supply chain bottleneck. As disclosed by him, the procurement team was unable to comprehend why the trial runs of the most reputed alternative suppliers suggested by the procurement team were failing in the quality. The executive disclosed that he suspected foul play. So, to upset the possibility of any mischief, the firm 2's executive went out of the way to personally visit the supplier's warehouse and collect some samples for testing. He also made sure

that the testing process in the quality function was being overseen by two members of his procurement team. This extra initiative paved the way for the alternative supplier getting approved and for resolving a disruption causing bottleneck. Narrating the incident, the firm 2 executive quotes;

"Frustrated with these testing issues, intentionally, I personally went to the warehouse of these batteries with the litmus paper and opened many boxes and personally tested these batteries for leaks and then with a marker marked a few of them and sent these for our internal testing. I did this because if somebody tried to do a foul play it would be clearly evident so this is how I got these approved."

There were few more incidents connected to firms 6, 7 and 17, that could be regarded as typical cases of personal interventions or actions by procurement team that go beyond or exceeds their expected organizational responsibilities. In an issue where the executive of firm 7 suspected that the supplier was supplying inferior quality goods than what was mentioned in the test certificates, the executive requested the management for a third party testing of these components. However, when he was denied such an option, due to various organizational processes and constraints, he went ahead and paid himself for an independent lab test of these components. Although the lab test validated his suspicion that indeed the components were substandard and not as per requirement, yet this act of unofficially and without approval sending off components for external testing and paying from one's own pocket for the initiative is beyond the expected working of a procurement and supply chain executive. There were many other incidents linked with firm 7 where this executive adopted similar approaches and went an extra mile to pursue a problem.

The procurement teams of firm 6 and 17 also demonstrated these traits of going beyond the expected, however their motivations were significantly different than the firm 2 and firm 7. Cases disclosed by these two firms were directed towards providing additional support to customers or suppliers while firm 2 and 7 cases were more related to upset the corrupt or unethical practices that had been interfering with their efficient working.

The narratives from firm 6 executives were indicative that in conditions of crisis or disruption, the procurement team of firm 6 was willing to put an extra effort, beyond their committed job responsibilities, to resolve it. This included sending members of

procurement team to personally go in taxis to collect critical goods from suppliers, accessing the warehouses in out of the working hours such as in the night time to process critical dispatches etc.

The case of firm 17 related to vendor support. Firm 17 being a nuclear power plant, has a very stringent quality and material requirement for its components and this could only be achieved when the suppliers are able to follow a very dedicated and committed organizational culture of quality. However, in some case, firm 17 realized that although the selected vendor for a particular job did possess technical capability yet lacked either the required production quality culture or motivation to complete the task. In such situations firm 17's executive accepted to send his team of engineers and quality people to work side by side with these vendors and help them achieve their full potential. This meant that a sizable number of his executives were relocated to these vendor plants for a considerable length of time but this extra effort reaped rich dividends. Discussing a particular case where a supplier purposefully quoted a very low price to engage his idle work force and soon lost motivation as they got other more profit making contracts, firm 17's executive disclosed that they did understand the difficulties faced by the supplier and also understood his initial motivation to quote a low loss making price for this multimillion £ contract. firm 17's took an initiative to go beyond the expected to keep their supplier motivated by ensuring that the supplier make at least some profits and successfully delivers the job. In the words of firm 17's executive;

"We understood that it would be a loss making job for them so we posted our quality assurance teams over there and by expediting our quality assurance process and reducing their rejections and processing their payments early we ensured that they could make some profit."

This is a very peculiar case of vendor support as nuclear power plants with outsourced manufacturing contracts in multi millions have different circumstances than other manufacturing firms.

5.3.5 Use power and privilege to force one's own agenda

Agents at a privileged power positions were found to be enforcing their own agendas and priorities and these behaviours were leading to adaptive tension. The accompanying

second order themes to this behaviour are; (i) denial of problem or expertise, (ii) distasteful enforcement and disparate treatment.

(i) Denial of problem or expertise

Some organizational actor's behaviour was reported to be at a constant mode of denial about disruptions and delays being triggered by their actions. These actors and organizational functions were reluctant to introspect their actions or were blatantly inflexible to adjust to changing and evolving process needs, thus often contributing to triggering disruptions. Organizational members, particularly top management and design function were found to disregard the expertise and suggestions of the people closer to the problem contributing to adaptive tension.

Many of the respondents, belonging to the procurement or supply chain function, conveyed their displeasure about the fact that their advice or suggestions were neither valued nor followed by the management and other organizational functions. Firm 2 conveyed the rigidity of top management to consider a change in supply chain strategy from lean to agile for a group of products in the spares category. The respondent from firm 2 regretfully conveyed that the most obvious solution was being constantly rejected and thus the product line was facing frequent disruptions. A similar case was also presented by the respondent from firm 16. In incidents related to frequent disruptions in the downstream availability of a product line of refrigerators, firm 16's respondent conveyed that the sales and operations planning team was blindly following the forecast generated by the ERP system, despite knowing the fact that these forecast were proven to be significantly wrong, both in total volumes and specific product granularity. Firm 16's respondent raised his concern about organizational members following wrong, incorrect and dated routines resulting in situations causing disruptions.

Respondents also noted that quality and design function had a rigid fixation on processes to an extent that the procedures were being followed mindlessly. Design function was reported by many respondents to be inconsiderate about the operational viability of the designs. Product designs that are difficult to consistently produce in a large scale at a consistent quality due to either the complexity of design or due to a lack of locally availability raw material alternatives, are often the products that are more

prone to disruption. Overlooking these key design elements (product complexity or local raw material availability) in the design in itself is a denial of the existence of an operational problem. Referring to a disruption in a new product line, respondent from firm 20 questioned the validity of design. The respondent stated;

"In case of laminate rejection, the laminate construct was pretty complex, from a design point you could have simplified the design from and R&D stand point. We went with the design but the supplier was not able to manage it."

Executive from firm 2 also raised his concern about the behaviour of the design team that tends to overlook the existence of issues burgeoning from their actions.

"but at the design stage despite of the previous guidelines they don't consider local aspects"

Quality function was also found to behave in a similar manner. Firms 2 and 7 reported several cases around rigid processes and guidelines being followed by the quality function. This inflexibility and lack of subjectivity in decision making was causing several operation concerns and frequent disruptions.

(ii) Distasteful enforcement and disparate treatment

Supply chain function also reported of being unfairly treated by other functions and management. Many examples to it were presented in the previous section of the loss in trust in organization, which presented the narrative from the aspect of the impacts these sort of behaviours had on other organizational functions. However, the act of people inflicting and observing such behaviours could be termed as a use of power and privilege to force one's own agenda. This hierarchical hegemony results in escalation of adaptive tension.

The respondent from firm 6 narrated incidents where the behaviour of top management compelled the supply chain and procurement teams to accommodate errors and blunders made by other functions. Similar behaviours by management and other functions were reported by firms 2 and 20 as well. Top management and marketing functions were found to press the procurement and supply chain function to expedite dispatches, to support unscheduled or unplanned dispatches or material requirement requests, to work

beyond operational hours so as to accommodate misleading and over commitments made by customer facing teams and executives and being asked to firefight frequent material shortfall scenarios triggered by incorrect forecasts. All such behaviours that impose constant stress and pressure on supply chain and procurement function can be argued to be supporting the formation of adaptive tension.

5.3.6 Conspiring against acceptable best practices

Another behavioural theme that came out of the narratives concerning events of SCD relates to agent's unethical and opportunistic demeanour. This aggregated theme was named as 'conspiring against acceptable best practices' and it constituted of; (i) dishonest demeanour, (ii) disregard for processes, (iii) opportunistic behaviour. (iv) dishonouring of commitments

(i) Dishonest demeanour

False commitments and misinformation were observed to be the precursors of operational disruptions. Firm 2, 6, 5, 7, 9 and 15 reported operational disruptions caused by miscommunication or false commitment given by marketing and sales functions of either their own firm or of their suppliers. The behaviour was highly prevalent in events connected with buyer supplier relationships having disparate volume dependency or power distribution favouring the supplier.

Dishonest agent behaviours identified in the events included ; giving false commitments about quality and specifications, lying about delivery schedules, not informing about capacity constraints and providing misinformation about the progress of the production and dispatch activities. Discussing a disruption event related to a one off purchase of a very high value and high capacity power system for installing in a manufacturing plant, the firm 15 faced a five month delay just because the sales team of their supplier, a very reputed multinational power systems manufacturing firm of European origin, submitted a phased out model as a bid for the tendering process. Once they secured the tender, which they were not in a position to manufacture, the sales team kept on giving false information on the progress of manufacturing process and the expected date of dispatch. Finally when the truth was revealed, it was very surprising and damaging for the firm

15 as it resulted in the delay of their chemical manufacturing plant commissioning. The procurement head of firm 15 regretfully said;

"Basically the problem was the mentality that the sales team carry. They thought that they can take an order for the sake of securing an order and then change the specifications later on. It was basically or wrong commitment they probably knew at the time of taking the order that they cannot deliver this product."

Firm 15 discussed similar issues in procuring piping structures, tailored equipment and other goods. Firm 2 also discussed disruption events where the sales and marketing teams of their tier 1 suppliers made false commitments about the dispatch of critical materials. For a particular event connected to an alkaline battery supplier of firm 2, the executive of firm 2 stated;

"So in the supplies they (an alkaline battery supplier) told us many a times that a certain material was dispatched, its in the pipeline and will reach us. But actually these materials were never ever dispatched. Due to these false commitments we started to face a lot of problems."

In a similar incident related to a false commitment being furnished by tier 1 suppliers, firm 7 executive shared a shocking incident of being faxed a copy of the invoice and way bill of goods that were never dispatched. These false and misleading commitments, typically by the outward facing function of the supplying firms, were found to be underlying causes of multiple disruptive events and strained buyer supplier relationships.

In the narratives, there were some incidents, connected to firms 7 and 18, where an incorrect or fabricated document was furnished by agents. This was an extreme case of dishonest behaviour. There were two such events relating to submission of fabricated or false test certificates, one concerning firm 7 and the other firm 18. In the incident related to firm 7, a fake test certificate was provided by a steel pipe and fittings supplier. The respondent of firm 7 conveyed that their process required a higher grade steel for handling molten and corrosive materials but the vendor had been supplying a very cheap and lower grade steel pipes and fittings which were constantly getting eroded and required frequent replacement. The executive from firm 7 disclosed that what alarmed

him about this behaviour was the fact that the request of reorder from his production and maintenance unit of his manufacturing plant was so frequent and so high that it was almost consuming all of his time and he lost his patience dealing with the issue. The executive said that

"one particular time I realised that there were a very high number of this components being repeatedly ordered. Means, I was even struggling to cope up with raising the purchase orders for every procurement request"

This prompted him to probe deeper that lead to the discovery of fake test certificate and inferior material quality resulting in black listing of the supplier. In firm 18, a shipping liner, accepted that many players in the market were giving fake fumigation and pest control certificates for their shipping containers.

Dishonest information being furnished by organizational agents is not only a problem for the other firm, but it also puts additional pressure on the operations of the firm whose executives and agents engage in such dishonest practices. This is evident from the disposition of the executive from firm 6 who accepted of facing severe operational issues such as expediting procurement and dispatch process to meet unrealistic commitments made to their esteemed customers by their company's own marketing team. The respondent from firm 6 revealed that most of their time and energy was wasted to meet these unrealistic commitments by sales team and many a times they had to go to their warehouse and process a dispatch in the middle of the night. However, citing a plausible reason for such a practice he said;

"the way our sales teams work, the kind of pressure they have, that for procuring the order they will do whatsoever and commit any unrealistic thing to get an order."

(ii) *Disregard for processes*

Organizations have a defined process for various organizational tasks, however the narratives point towards many SCD events that were triggered when the actors chose to disregard the established processes. Respondent from firm 20 narrated about two SCD events triggered by acts of ignoring procedures. The first of these two events was about a new supplier being developed for a new product line having a very strict project time line. The process of an early technical or manufacturing capability evaluation of a new

supplier, before the commercial negotiations, was disregarded by the quality function. This caused a critical delay in the project as it was discovered very late in the project that the supplier lacked manufacturing capability to deliver the desired quality product. The procurement team was very disappointed with the act of disregarding the process by the quality function as this had upset all their efforts of developing this new supplier and now they had to start the search for an alternative all over again. In another event , also connected to firm 20, the logistics service provider was known to disregard the weatherproofing and material handling requirements of some crucial hydroscopic (moisture sensitive) products like sugar, corrugate box etc. This often resulted in one or two consignments getting damaged by the rain every year.

firm 14, an engineering project design and installation firm, also discussed a critical operational disruption caused by the act of disregarding processes. The respondent narrated about a chemical plant extension project where they had to install a high pressure heat exchanger in an operational line. The process of designing the complex piping and installation details was to be checked with the existing plant layout drawings and this was to be correlated with an onsite survey. However, the survey element of the process was disregarded due to project timeline pressures and when the engineers reached there to install the tailor-made piping and equipment; they were surprised to find a concrete column obstructing the way. This incident had two errors of process disregard; one by firm 14 of not conducting an onsite survey and the other of the organization where this project was being installed; they did not update their plant layouts after erecting an additional concrete column.

There were many other instances where actors disregarded the processes; for instance marketing function failing to update plans, logistics firms and truck drivers tampering with vehicle tracking devices, supply chain and dispatch agents disregarding the necessity to carefully read the purchase order documents resulting in frequent errors in billing and dispatch documentation.

(iii) Opportunistic behaviour

Signs of opportunistic behaviour were evident in many of the cases that were narrated by the respondents. Typically, with an intention to make more money, agents behaved in an opportunistic manner. Firms 7, 13 and 18 reported about opportunistic behaviour demonstrated by logistic providers. While firms 9 and 11 disclosed a peculiar case of

opportunism, similar to behaviours demonstrated by share and financial trading people, being demonstrated by their trading and sales function.

In the case disclosed by firm 18, the actions and behaviours of logistics firms, in order to save damages of holding containers, propelled prolonged disruption in supply chain of many organizations and sectors. The respondent of firm 18 narrated the events linked to floods in a province of India that had disrupted all the ongoing routes to some major cities. All the major transport and logistics provider operating in that area were sure to lose money on holding the containers till the routes were cleared. So in order to avoid these demurrages, most of the logistics providers offloaded their goods in a public sector logistics firm providing containerized train transport. Despite being aware that trains were also affected and putting additional load on the train system will have further delays due to piling backlog, thus the logistics providers acted only in their own interest. The result of this act was that it took months for the train container organization to clear the backlog and many organizations faced critical disruptions. The firm 18 respondent said;

"a costly road transport option was disregarded which put additional pressure and backlog in the container division of the train. It delayed everything else for quite some time. Cost issue somehow dominated the decision-making of people and idea of being thrifty leads to more problems. The willingness to work out cost bottom line was creating or was for the deepening a problem."

There is another element of opportunism that relates to the act of deliberately propelling disruptions for the sake of making more profits. This is demonstrated particularly by sales and marketing agents from the crude oil refinery supply chain. The agents of sales and marketing division of refineries, also addressed as the trading bench, were found to act in a highly opportunistic manner with a blatant disregard to any process or supply disruption happening within their firm or at their customer's end. Firm 9 and 11 , both petrochemical cracking units, discussed events that could be categorized as opportunistic behaviour and were actually seen in a positive light. The trading function of firm 9 was reported to exercises complete power to override any manufacturing, procurement or operations decision creating deliberate and conscious disruptions but with a rationale to make more money for their own firm. If they were expected to get

better volumes they would alter the refinery productions schedule at the last moment, they would delay arriving ship from birthing at the port and willingly pay holding charges in tune of thousands of dollars to make way for higher margin vessels etc. Although these decisions might result in supply disruption for some customers, yet for the sake of making more money, for getting better margins, the trade function would keep altering decisions and keep manifesting events of disruption. The participant from firm 9 mockingly claimed it to be an act of "fishing for opportunities" and "beneficial delays". Firm 11 cited a similar incident where the trading bench would ask to apply a 'forced measure' an act of discontinuing the production of some particular group of SKUs just because the production was not profitable. Under such a condition of applying a 'forced measure', the company is safe breaking any legally binding commitment to supply a particular product to some other firm. This callous act, motivated solely by a locally optimised profitability decision, disregards the impact it would have on the customer's supply chain who might be waiting for the delivery of these discontinued SKUs. Most of these decisions are top management decisions and the outward or customer facing executives of a firm have a hard timing explain this eventuality to the impacted customer.

(iv) Dishonouring of commitments

Among the 167 instances of disruption discussed by the respondents, it was observed that in asymmetric power relationships or in conditions where the purchase was a one-off purchase, the supplier firm often undervalued the relationship and did not honour their commitments and contractual obligations. A large number of disruption events were found to be connected to suppliers furnishing incorrect information, giving over commitments or demonstrating ego driven bad attitudes and behaviours towards the buying firms.

Sales and marketing teams were often linked to over commitment related issues while top management along with operational planning and production function was seen to be linked to bad attitudes and behaviours which were sometimes accompanied by ego or personality conflicts. One common characteristic of all such events was that the buyer firm was often unaware of the ongoing issue related to their order until the date of committed delivery when the order or supply did not arrive as committed. Then there

would start a series of sequential events where for weeks and months, buried under heap of emails, teleconferences and other formal and informal communications, the buying firm would try and understand the true reason for a default and would persistently attempt to reach an amicable solution to resolve the matter. With passage of time and with its own projects or supplies getting hampered, these issues demonstrated a tendency to easily slip into the domain of a conflict that would require a high level intervention, often by senior board level members. However, as the issue progresses, from the first email sent on the day of expected delivery date to the final day of resolution, the disruption becomes a case of wearing patience and escalating adaptive tension. Some firms reported that in instances where emails and teleconferences failed to clearly establish the reasons for the delay, they had ultimately send their management teams to the manufacturing locations of these defaulting supplier, often in different continent or country, to discuss the issues face to face. This is a tipping point in testing a firms patience as such initiatives are often costly and time consuming and are often considered to be the last resorts.

Another common occurrence among multiple events spread across various firms, was of regular suppliers providing misleading or wrong information about dispatches and expected arrival dates of supplies. The procurement executives of buyer firm often felt violated on discovering that their trust has been misused. Firm 2, 7, 9 and 15 reported issues related to this kind of conduct by their regular suppliers. In an extreme case of misleading information, firm 7 executive disclosed that in one instance for a very critical material , his regular supplier confirmed a dispatch and went on with emailing bogus copies of dispatch documentation. firm 7 was only left with a week of this material and considering a 6 day transit time, the respondent who was a procurement executive for firm 7, was confident to avoid a disruption. However when the material did not arrive by the end of 8^{th} day, as it was neve despatched, the production line stopped and he found himself in a difficult position. Firm 7 executive stated

"He (the supplier) sent me a LR, which is a despatch document, confirming that he had dispatched the materials. The paper had receipt, transporter details truck number driver details everything, it seemed authentic."

The crisis was resolved only when his senior manager intervened and chastised the supplier to get an expedited dispatch. The firm 7 executive said

"It was then that my boss took charge. My boss picked up the phone and he fired the vendor literally all the abuse and nonsensical words that you could think of, he used them. And then on the same day the vendor dispatched the materials on a truck with two drivers so that it could travel non-stop and it reached us the 3rd day."

5.3.7 Heedless performance

There was evidence in the data indicating towards a localised and silo working tendencies. It was found that organizational members, driven by their local beliefs mindsets and performance measures, ignored the possibility of a greater good. Driven by a motive to secure their local interests, these organizational members demonstrated a reluctance to coordinate or work together. There were also many instances where organizational members, involved with supply chain activities, lacked the required vigour or will to do the right things or follow the prescribed routines and best practice recommendations. This often led to member committing careless mistakes triggering events of SCD.

This performance can be best described as a heedless working because it is not intuitive or logical to either subscribe to silo decision making or commit careless mistakes due to lack of vigour or the will to do things right. There were three subthemes identified that indicated to wards a heedless performance; (i) Organizational members framing narrow boundaries of success and team working, (ii) organizational members committing careless mistakes, and (iii) organizational members lacking the vigour or will to do the right thing.

(i) Frame narrow boundaries of success and team working

Procurement and supply chain executives had a general consensus that many a times other organizational functions chose to work with narrow organizational boundaries and silo tendencies that often led to operational difficulties. Firm 20 executive recounted an incident where the procurement team was not informed about a ramp up in production taken up by the manufacturing function and it led to a critical disruption as there was

not sufficient raw material to support increased volumes. The respondent from firm 20 stated that;

"The plan of the ramp up demand was not visible, so manufacturing had planned a ramp up but the planning team was not aware of the ramp up and hence the consumption will go up on the line on a per day basis, that they were not aware of. Hence they had not ordered it."

The respondent further suggested a plausible reason for the lack of alignment among functions. The respondent said;

"You can either owe it to a planning error or owe it to two departments not working closely enough."

Firm 6 also faced similar issues with misalignment leading to disruption. In one such incident a very large and prestigious promotion and marketing activity was planned by the sales function but the stock of material requirement for the activity were not checked with the supply chain function. This lead to a severe disruption and its resolution costed a very high value as most of the material was required to be procured from offshore sources and expediting that resulted in costly air freight. Firm 5 also suffered from such a behaviour of the production planning team leading to a disruption. In two events, one connected with an additive food flavour and one related to substrate of the packaging film, the ramp up of production planned by the manufacturing function was not shared with procurement function and suppliers. This led to a major disruption as the suppliers of these products had either a very long lead times or had capacity constraints that were not factored in by the planning and procurement teams.

Narrow frame of mind was also evident in behaviours where organizational members, functions or firms, in the extended network, rejected a possibility of symbiotic working over their narrow interests. Firm 10 executive discussed an issue where two zonal teams of the same marketing function, were not willing to accommodate requests of each other. Recounting about an incident related to a major multinational customer of firm 10, the respondent disclosed that they often faced internal coordination issues while servicing two, geographically separated, manufacturing locations of this multinational customer. The issue was that these two manufacturing locations of the customer were

allocated to two different zonal marketing teams of firm 10 and each marketing team was fiercely competing with each other towards securing their personal interests and maximising their local profitability and sales targets. This often resulted in losses and disruption for firm 10. The respondent disclosed that often, in cases where there was ether a lack of sufficient material or was a case of an urgent dispatch processing, the two zones would conflict on the dispatch volume and priority of dispatch and his marketing zone was always made to suffer as higher management judged his zone to be of less priority than the other zone. Being denied a volume or dispatch priority by his planning and supply chain team, many a times he was forced to get the material by air resulting in additional cost to the company. The firm 10 respondent stated;

"Since we were located furthest from our production plant so we had a priority on despatches as we had the longest lead time. Yet still there were internal departmental conflicts and in some cases it lead to material rationing and quota system for dispatch priority. Since our competitor was located closer to the southern plant and for the northern plant (where respondent was based) we were having similar lead time to our competitor. So southern sales team was always fighting that they should have a priority of despatch over us as north region can manage. Because of the competitor , they were always pressurising more to get the material first. It used to happen that due to this infighting we sometimes at the north were forced to airlift the material and bear the cost."

This incident highlights the existence of bitter conflict among different teams of the same organizational function, within the same company, demonstrating a behaviour of narrow mind frames. The respondent accepted that this infighting was putting extra burden on the supply chain. Firm 2, 7, 9, 11 also disclosed having operational issues with individualistic behaviours of quality, design and sales functions of their firms.

(ii) *Careless mistakes*

Respondents narrated about multiple events concerning careless mistakes triggering disruptions. Mistakes were committed in processing documentations, managing data, material handling etc. firms 4 and 16 reported about disruptions caused due to errors in entering or maintaining data in ERP and excel files. Respondent from firm 4 accepted

that sometimes double entries or missing entries in the ERP result in planning errors while respondent of firm 16 disclosed that in his various supply chain consulting projects he often discovered managers working and taking decisions based on excel worksheets with wrong data, formulas and many logical errors.

Incidents related to careless mistakes in dispatch documentation were reported by firms 6, 8 and 15. In the firms 6 and 15 the materials were imported materials from far off geographies and the errors in documentations resulted in heavy losses and extended delays. While firm 8 reported of processing a dispatch before the delivery schedule date of the purchase order. In this incident, the material reached to the buyer before the expected date and since the ERP system of buyer did not allow intake of any such material before the scheduled delivery date, the whole consignment was returned.

(iii) Lack of vigour to do it right

In the narratives, there were many disruptive events triggered by a lack of vigour in performing the task in hand. Due to a lack of vigour to do the right things, agents often missed out on crucial elements such as lead times of extended supply chains, impact of design change on the overall supply chain or even failed to see how their actions would reflect on others.

The most common case of lack of vigour was found to be in sales and operations planning, particularly related to the quality of forecast. Commenting on inaccurate forecast errors respondent from firm 13 said;

"See I have seen it forecasting accuracy is very poor, in 50% cases it is inaccurate. If you look at the SKU level forecast then there is even greater error in it . In petrochemical industry this is very high."

The respondent disclosed that the issue was bigger than just the forecast being wrong as the marketing people were not putting enough rigour to improve the accuracy. They neither demonstrated will nor any scientific knowledge to improve these numbers and were , on a regular basis, every year doing the same mistake over and over again.

"Actually when forecasting at SKU level, the sales team just keys in numbers without giving it much scientific thought. They will look at the total volume and would start keying in numbers arbitrarily to forecast the SKYs…..put 5 there 10 here and so on."

This disposition challenges the core behaviour of the marketing teams and raises a question not just on their ability but also in their intent. Questioning the reliability of such forecasts, the firm 13 respondent cited that no consideration of seasonality or trends was making things worse.

"They have no clue of seasonality. What they will do is forecast for the whole year and then break it in equal parts for all the months. Now you tell me ..will the sale be uniform across the months..no it won't be..it's a straight forward fact , but these guys do not care or put effort to forecast at SKU level. They do it on very elementary excel sheets and thus cannot see any trends."

Forced to deal with high forecast errors has been raised as an issue by many respondents and the behaviour highlighted in the above disposition could be considered as one of its reason.

In other instances, connected to a lack of heed, agents are often unaware of contextual and demanding conditions and this is either due to a lack of knowledge or due to insufficient trust on other agents. In several events, at firm 20, the cause of disruption was suggested to be a lack of information sharing among internal functions. For normal operating situations, the routinized operational processes were performed well despite a lack of information sharing, however in demanding situations that required a consideration of evolving contextual conditions, these acts of heedless performance resulted in disruptions.

Existence of a heedless performance was also observed in the firm 21, the aerospace manufacturing sector, where the respondent repeatedly emphasised that a lack of knowledge transfers and information sharing with their suppliers was causing supply disruptions. The respondent acknowledged that firm 21, being a public sector enterprise with legacy rules and procedures, found it difficult to share technical knowhow and valuable insights with their suppliers. Since firm 21 was operating in the aerospace manufacturing sector with a very low tolerance of error, highly specialized or complex

jobs and high penalty clauses, this act of not sharing knowledge was further deepening the problems. The respondent quotes;

"communication gap between us and him (one particular supplier) widened"

In other narrative connected to firm 21, the respondent quotes;

"the suppliers were not given adequate knowhow to fulfil their jobs",

This is a clear case of heedless performance. In some disruptions related to the firm 5, supplier demonstrated unexpected and monopolistic behaviour; this too could be argued as an agent schema of heedless performance, since a thoughtless opportunistic behaviour, which is a breach of mutual trust, does not always result in gains. In instance of firm 5, they changed the supplier.

5.4 Self-organization and emergence

5.4.1 System's tipping point

Not all behaviours leading to adaptive tension will force the system to self-organize or emerge to a new state. Its only when the system crosses a critical tipping point, it demonstrates emergence and self-organization. Among the events chosen by the respondents to discuss, firms 1, 2, 7 and 15 had the most events demonstrating self-organization and emergence, thus were the firms that had the most signs of adaptive tension crossing the tipping limits; while firms 5, 8 and 20 had a few events that resulted in self-organization and emergence and thus consequently lessor evidence of adaptive tension crossing the critical limit. Table 24 presents these system conditions leading to self-organization or emergence.

Act against the people or organization responsible

Some system patterns indicated that there were situations when an organization was compelled to act against the people or organizations causing them troubles. This is a tipping point that culminates in emergent structures or processes. The two system patterns associated with it were; loss of trust and patience, and conflict escalation.

(i) Loss of trust and patience

The loss of trust and patience was the most common tipping point for cases where behaviours like misleading and false commitment by supplier firms were underlying cause for a disruption. In the cases, this tipping point leading the system to self-organize or emerge was found to be a result of several events and interactions spread over as considerable length of time ranging from 1 month to an year. It was observed in the

cases that in a relationship between a supplier and a buyer, to begin with, these misleading or false commitments were considered as truth in a good faith. However, after default on committed supply schedules followed by a chain of communication exchanges over emails, telephone calls or meetings, it would be eventually discovered as an apologetic surprise for the suffering firm that the commitments made at the beginning of the relationship were either false or were not honoured. This process of a slow realization of being cheated or mislead reaches to a tipping point where the suffering firm completely losses its patience and trust in the relationship. Such events were observed in firm 7, firm 15 and firm 20.

Table 28: Patterns demonstrating system tipping point

First order findings	Second order findings	Aggregated dimension
Multiple communication ranging from emails to teleconferences being pursued at various levels in the organizational hierarchy over a significant duration of time. After being furnished inaccurate and misleading information for an extended period of time, the buying firm is forced to visit the supplier firm to find out what exactly was wrong Non relenting and inconsiderate behaviour of monopoly suppliers to accept a fair price for their products and services	Loss of trust and patience	Act against the people or organization responsible for it
Once lower management failed to negotiate an amicable solution higher management had to come in Required arbitration or proof for resolving the conflict Escalating frustration or anger	Conflict escalation	
A growing discontent and grievance among union and workers	Acceptance or realization of a previously ignored issues	Introspect and take a corrective action

(ii) Conflict escalation

Escalation of conflict among partnering firms, beyond a certain limit, was also indicative of a change in structure of the network as the relationship were eventually broken. In multiple events connected to firm 7, 15 and 19 there were instances where the procurement function was unable to resolve an ongoing conflict and the higher managerial or board level interventions were sought. Some events also required legal or neutral arbitration to apportion any sort of financial burden or losses accruing due to a strained relationship. In one such event connected with firm 15, a European supplier shipped very heavy and costly machine equipment to Asia with an incorrect port and

billing documentation. This led to a heavy penalty and significant long delay for firm 15. Firm 15 had to seek a legal intervention and furnish proofs that they had very clearly documented the dispatch and billing details in their purchase order, which the European manufacturer carelessly overlooked. There were also a few cases where attitude and conflicting behaviour of representatives of the supplier firm was causing frustration and anger among the members of the buying firm dealing with scenarios of delays. Firms 2, 7 and 15 reported most of these. This anger and frustration also acted as a tipping point for the relationship to slip into quandary.

Introspect and take a corrective action

Findings were suggestive that in some instances organizations and its members tend to realize that there are some issues and decisions that need attention. It is this realization that leads to self-organized emergence.

(i) Acceptance or realization of a previously ignored issue

In events connected to firms 1, 5, 7, 8 and 20, there were instances where the organizational members realized that an ongoing practice or a previously ignored issue had become a serious concern and needs to be addressed. This realization was a tipping point before the system self-organized or emerged by adopting changed mind-sets and change in established processes or procedures. The executive from firm 1 accepted that after a major labour union strike the top management embarked in the process of introspection and there was a general realization that there were important worker issues that were ignored and it was high time to take a corrective action. The respondent from firm 1 stated;

"A lot of activities undertaken to ensure that the grievance of the union or the grievance of the workforce can be understood better. We upgraded a lot of facilities because it is not that only they created problem it was our infrastructure also which was creating problem for them. So because any industrial relations issue is both ways. The recognition of it is only the best way. And there we invested a lot of money"

Design, quality and marketing and functions of firm 5, 7 and 8 respectively realized that their rigid mind-sets were responsible for propelling a few disruptions and they needed

to coordinate and work along with other functions and teams. Executive of firm 20 conveyed that after multiple disruption issues and coordination errors among functions, there was a realization for the need of working together. The respondent stated;

"In my company, I saw that journey, when I started off in packaging it was very similar story that R&D will finalise a supplier, will complete a product trial and then ask the procurement to negotiate the price. And from there we moved to a position where there would be a common briefing between marketing, R&D and Procurement and then you would involve the supplier together."

5.4.2 Evidence of self-organization and emergence

In an organizational context it was identified that self-organization and emergence would bring about a recognizable structural, process or behavioural change in the system. Table 29 and table 30 provide details of findings from the meta-analysis of the data and illustrative quotations validating it. The data was analysed to isolate evidence demonstrating self-organization or emergence.

Table 29: Evidence of emergence and self-organization

First order concepts	Second order themes	Aggregate dimensions
New supplier developed Established supplier discontinued Relocating manufacturing tools to a new location	Change in network structure	Emergence
Testing procedure changed Product quality requirement changed Tendering process changed Change in approach to sales and operations planning A significant monetary penalty for the behaviour	Change in established processes or procedures	
Agents realized that they need to break a cartel that they themselves had formed	Change in agent behaviour	Self-organization
Started looking at socio political and geographic risk Started an inward introspection process of accepting HR and labour issues Updated the definition of redundancy	Change in the priorities or goals	

Table 30: Illustrative quotations validating first order concepts related to emergence and self-organization

Second Order Theme	First order concept	Illustrative quotations
Change in network structure	New supplier developed Established supplier discontinued Relocating manufacturing tools to a new location	firm 2: After visiting the plant we took an immediate decision of shifting the tools from the affected factory to an alternative location. firm 2: So we got this alternator supplier and within weeks approved another supplier, Panasonic, who was operating from Thailand firm 20: Three to four rejections spread over two to three months. You give a supplier a two to three months window, but if it does not change then you conclude that it's a process or capability issue and you need to change the supplier. Which we did.
Change in established processes or procedures	Testing procedure changed Product quality requirement changed Tendering process changed (Rama) Change in approach to sales and operations planning (the sale on water case)	firm 2: A lot of quick trials were run, since complete endurance full body trials and testing was not possible we discussed with our parent company and the resultant was that within one week we had an alternative location. thus despite the strike we were not affected. firm 7: "I called the customer technical and R&D and asked them how much chlorine is permissible in their product and they said that 500 ppm was their limit. I laughed, we were originally supplying 75 ppm chlorine and the alternative product was having 100 ppm chlorine but both were way below than the customer's permissible level. I told my testing that next time match the products with customer's requirement as well." firm 2: I had to go to an extent that I asked this battery manufacturer to use world's best designed lid from a German company; we paid for the air freight the German lid was such a robust design that even if you turn head 180 degree it would not leak but in our testing that also leaked. To avoid the embarrassment we intentionally put two of our procurement employees to monitor the testing and to everyones surprise even the normal design which was not the German lid, of the alternative supplier passed firm 2: Another issue that happened was that he wanted to sell more diesel cars because there was high demand from the market and we had no spare capacity as we had not forecasted it to that level. So we sat and discussed the ramp up (with an alternative supplier) and we accepted some design changes and supported the company. firm 1: there were around 60% part numbers for which we had to resort to other sources so we ended up doing quick evaluations and getting into. firm 1: So the whole exercise takes 18 to 22 months but these kind of disruptive scenarios we basically look at what is critical on the basis of production location. The concept is already proven and we have a fair idea of what the tooling should look like in this case so it's just, most of these cases it is just the evaluation of the production location with little bit of tinkering on the tool. That's why we are able to shorten the time frame to about a month or two months time. firm 17: After the tender was processed suddenly nickel prices so an

		exponential increase. Now the material procurement was close to 25 tons and the difference was coming out to be 50 million dollars. So the company that had secured the tender denied citing this reason and everybody knew that nickel prices Rising so we had to scrap the tender because our system does not allow any variation after the tendering process. We never did any hedging or price link tendering so we learn from that incident. So the third time we recognised the fact that this particular tender required some flexibility. So then we incorporated those flexibilities into the tender and that was done in a very unique way so normally in our industry the tendering is done on for part basis but we did this in cost per kg basis.
Change in agent behaviour	Agents realized that they need to break a cartel that they had formed	firm 7: The discussion was stuck for more than 3 months and when they finally realised that someone would supply at the lower price they agreed to supply at old prices which was 5.5£ per ton. Although these prices were higher, but I let them supplies they were afraid of two things one that I can disturb the market price and then probably other customers would also use the same alternative transporter. So they agreed to support as they did not want any new entrant into the market it took 3 months but I had awarded a contract which was £1 (per ton) less than the previous.
Change in the priorities or goals	Started looking at socio political and geographic risk Started an inward introspection process of accepting HR and labour issues Updated the definition of redundancy	firm 1: this socio political agitation has thrown up on a lot of issues at our end. In terms of how to make ourselves little more proactive. I mean we are basically going in a different Direction now, we are now looking locational and geographical risk very closely and taking action accordingly. firm 1: At the same time we spent a lot of money insuring that this kind of incident does not happen again. A lot of activities undertaken to ensure that the grievance of the union or the grievance of the workforce can be understood better. We upgraded a lot of facilities because it is not that only they created problem it was our infrastructure also which was creating problem for them. so because any industrial relations issue is both ways. The recognition of it is only the best way. And there we invested a lot of money. firm 1: as a policy, after going through so many incidence in past I mean what I told you is just last two years or three years what has happened. We have developed a policy that if we are buying beyond a certain level, either the supplier has to have multi-location or we will have alternate sources developed

(i) Change in Network Structure

Instigated by behaviours, actions and interactions of supply chain agents, there were a few cases that reflected a recognizable change in network structure and these instances could be viewed as evidence of emergence. Agents self-organized to the events of

disruptions and brought about a change in system structure. The findings revealed that most of these changes were brought during the course of disruption.

A structural change in the system was in the form of either a development of new supplying nodes or discontinuation of some suppliers or manufacturing locations. Firms 1, 2, 5, 7 and 20 accepted of being forced by the demeanour, behaviour and actions of their suppliers to develop alternative sources. Annoyed by continuing false commitments and inconsiderate and non-cooperating behaviour of their alkaline battery supplier, firm 2 executive accepted of going beyond his defined procurement job responsibilities to develop not just one but two alternative sources. Here the decision to develop two additional suppliers conflicted with the company's lean policy and was sure to have financial implications as each supplier and related transactions have a cost of management, but the firm 2 executive was insistent that the behaviour of the previous supplier had left him with no choice but to opt for this not so efficient decision. Similarly, firm 5 and 7 also accepted being forced into developing alternative sources because they had lost trust and patience in the business and moral abilities of existing suppliers.

In two events, one connected with firm 7 and the other with firm 21, the organizations were forced to discontinue a supplier at a very short notice and in absence of an approved replacement it resulted in an immediate disruption. Both these cases were linked to unethical and fraudulent behaviour of the supplier. For firm 7 the supplier was furnishing inferior goods on fabricated test certificates while firm 21 conveyed a case of billing fraud been done by one of its supplier. In comparison to firm 7, firm 21 being an aerospace manufacturer suffered more from such a decision as, in words of the firm 21's respondent, developing a good supplier in aerospace sector is challenging process as often the outsourced tasks are complex and there are not many suppliers having the desired level of technical capability and commitment to quality. It takes time, money and management to develop a supplier in aerospace industry.

A quick restructuring of the network to avoid a certain disruption was also observed in a few cases. In a case related to firms 1 and 2, the respondents narrated incidents where the complete manufacturing machinery and tool set, weighing in tonnes, was relocated to an alternative location. Firms 1 was trying to avoid a socio political unrest happening

near one of its tier one supplier units while firm 2 resorted to the initiative to avoid a call for strike in one of its tier 2 suppliers manufacturing unit. Both these being automobile manufactures, presents a case of high degree of adaptability and self-organization capabilities demonstrated by the automotive sector.

Similar to relocating the manufacturing process, firm 7 demonstrated adaptation of working with alternative sources of raw material, molten sulphur and solid sulphur that could be melted to be made to a molten form, to avoid disruption. This event of switching between raw material sources was driven by non-cooperative behaviour of the supplier firm, market forces and price fluctuations.

(ii) Change in established processes

A change in an ongoing, practice, routine or process can also be considered as an evidence of emergence. In a case connected to inferior piping and fittings been sold to firm 7 by one of its highly trusted and long standing supplier, firm 7's executive was able to justify his management team about a merits of independent testing of components rather than relying on manufacturers provided test certificate. Following this, in firm 7, the established process of accepting the manufacturers test certificate was replaced by a process of randomly sending a few components for independent third party testing. This change demonstrates an emergence of a new organizational reality.
In two other cases connected to firm 7, the quality function was forced to relax their quality parameters and permissible ranges for two products. In one incident connected with sulphuric acid being sold by firm 7 to a large number of small and medium scale metal work firms, the sales team of firm 7 was struggling to adequately price their product in comparison to a cheaper version of their competitors. The effort of firm 7's procurement team to bring down the price of their product was met with a strong resistance from the quality team which insisted on a high purity grade of sulphuric acid that was obviously costlier than the competitors. The procurement team was able to persuade the quality team to lower their quality parameters for this particular product grade as it was being used for meatal etching and the process did not require a grade of high purity. Similarly, in another incident, the procurement team of firm 7 had to compel the quality team to reduce their permissible limits of chlorine in a product that was difficult to source due to a stringent quality parameter set by the quality function. In

this product, which was originally procured internally from another manufacturing location in Germany but now was discontinued, the quality function had set a chlorine content limit of the product as 70 ppm (parts per million) while none of the available alternative suppliers were able to manage a purity beyond 100 ppm chlorine. On enquiring the process requirement of the buyer who was procuring this material, firm 7 executive found out that the buyer's permissible chlorine limit was 500 ppm , which was suitable to achieve even with the 100 ppm chlorine raw material. This led to quality function accepting and updating the permissible limit of chlorine in this product.

Firms 1 and 2 narrated incidents where faced with an eminent disruption they change their testing procedures to reduce the setting up time for a new production location. This relates to the case of shifting the machines and tool sets from one location to an alternative facility. The respondents accepted that normally the outlined procedure requires components from every new manufacturing facility to go through a full body endurance testing which takes close to 18 months. However, faced with events originating in the extended supply chain, the new locations were setup in matter of weeks. With regards to this, the firm 1 executive stated;

"So the whole exercise takes 18 to 22 months but in these kind of disruptive scenarios we basically look at what is critical on the basis of production location. The concept is already proven and we have a fair idea of what the tooling should look like in this case so it's just, most of these cases it is just the evaluation of the production location with little bit of tinkering on the tool. That's why we are able to shorten the time frame to about a month or two months' time."

The firm 2 executive also narrated a similar incident. In his words;

"A lot of quick trials were run, since complete endurance full body trials and testing was not possible we discussed with our parent company and the resultant was that within one week we had an alternative location."

(iii) Change in Agent Behaviour

There were instances where feedback from system level outcomes, triggered by micro state agent behaviours, resulted in a change in the behaviour of individual agents. In a case related to firm 7, the logistics service providers of firm 7 were compelled to abandon their opportunistic behaviour and accept ethical working terms with firm 7.

These logistics service providers had formed a cartel and were using it as a leverage to negotiate favourable working terms and prices. However, the events that followed the evasive actions taken up by the procurement team of firm 7, led to a change in the behaviour of these logistics agents as they willingly dismantled the unethical cartel.

Change in agent behaviour was also reported in firm 18, where the actions and behaviours of the supplier relation team of firm 18 was able to motivate its suppliers in developing quality culture and meeting delivery and production schedules. A supplier of firm 18 who was severely demotivated to complete an order as it had secured other jobs that were higher paying and more profitable. However, a strong supplier support and close working provided by firm 18 led to the supplier successfully delivering the job. The respondent said;

"So we really had to motivate the vendor again. I mostly used to go there 3 times every week. We showed them opportunities of future and motivated them."

(iv) Change in priorities and goals

Many firms accepted that events of disruptions forced them to look inwards into their supply chain strategies, priorities and goals. This introspection led to the firms self-organizing to adapt better with the changed circumstances and accrued learnings. Adoption of these new set of priorities and goals can be argued to be system level self-organization. Firm 1 disclosed many insights about the way post disruption scenarios compelled them to relook at their strategies and priorities. In the disruption concerned with a very long union strike that also saw some industrial violence, the firm 1 executive accepted that although a lot of strict penalties and disciplinary actions were imposed on the agitating workers but once the strike was resolved the incident was thoroughly analysed to establish the underlying causes of such an occurrence. The firm 1 executive accepted that the first step towards it was accepting that the problem was both ways and the organization too was falling short of meeting the worker's expectations. This change reflected emergence of a new realization and the harsh realities of the strike compelled the agents to self-organize and the top management to look into matters that were being ignored for a very long time.

Firm 1 also disclosed that repeated disruptions originating in specific geographies like Japan, Thailand, Philippines and Taiwan compelled them to start grading the risk by political and geographical priorities. This reflected a major shift in their policy. firm 20 also disclosed a similar change in policy. Faced by persistent disruptions due to uncoordinated and silo working culture of various function, the executive of firm 20 conveyed that there was a slow and steady realization of the merits in working together. In his tenure, he saw this transformation as sales, quality, design, production and procurement functions started to work much closely.

5.5 Microstate agent behaviours contributing to system's resilience and robustness to disruption

Among the firms studied, the firm's 1, 2 and 7 discussed the most cases that demonstrated resilience and robustness in terms of handling and managing events of disruption. In all these four firms the procurement and supply chain executives shared behavioural trait of going an extra mile such that beyond their expected and defined scope of their job, to effectively negotiate and respond to crisis situations. For example, the participant of firm 1, a senior management personal, spearheaded an initiative to expedite the testing and approval of alternate sources to SKUs impacted in Japan Tsunami. He shared that a process that normally took 18 months was completed in 30 days, saving them from impact of the catastrophe. Similarly, firm 2 respondent disclosed that to avoid the impact of a labour union strike at their Tier 1 OEM supplier, they helped the supplier move over a weekend the entire manufacturing tool set of several tons to an alternate location. The commitment to resilience demonstrated by the executive of firm 7 was also quite evident in all the events. In a particular incident firm 7 was facing a disruption on one of its products that they sourced from their parent manufacturing firm in Germany and sold to customers after repacking. Due to some restructuring, the German manufacturing unit had stopped the production of this product and firm 7 had to look for local alternatives. The firm 7's executive disclosed that his procurement team was able to identify a few alternative sources but the these alternative failed in their internal quality check as one of the quality parameter, product's chlorine content in parts per million (ppm), of the sample was 100 ppm while their internal quality permissible limit was 75 ppm. Failing to find any supplier capable of providing

75 ppm chlorine content, firm 7 was sure to lose all its customers. However, showing commitment to resilience, the firm 7 executive went beyond his procurement responsibilities and contacted the buyers to enquire about the permissible limits of chlorine. To his surprise, the buyer's processes were having a quality requirement of 500 ppm chlorine, which was well within the range of alternatives sources his procurement team had identified. The firm 7 executive said;

"I called the customer technical and R&D team and asked them how much chlorine is permissible in their product and they said that 500 ppm was their limit. I laughed, we were originally supplying 75 ppm chlorine and the alternative product was having 100 ppm chlorine but both were way below than the customer's permissible level. I told my testing function that next time match the products with customer's requirement as well."

However, such out of the box approaches and contingency actions to upset the impacts of disruptions have a cost. Respondents conceded that there was a high price of resilience. In all these cases the focal firm was able to avoid production losses yet many a times at a very high cost. Firm 1 executive accepted that direct costs of handling some of his disruptions was in millions of pounds and they had not accounted for the overall impact. Commenting on disruption associated cost for one particular event, firm 1 executive said

"Quantitatively it is very difficult to put a number to it but my guess is it was in millions. I mean it is not something we accounted, but it was a huge amount."

5.6 Summary

This chapter of findings presented the interview data structured in a manner to assist the understanding of SCD from a micro agent perspective. The cases of SCD were firstly analysed for their context and environmental aspects. Findings revealed that contexts relating to the diversity of people involved, product characteristics and the nature of relationships played a crucial role in how people behaved.

Further the qualitative data was analysed to discover patterns demonstrating the system to have departed from acceptable operating conditions. These patterns were argued to be an indicator of accruing adaptive tension in the system. It was observed in multiple narratives that patterns associated with events of SCD demonstrated the system to have

lost its ability to manage or contain disruptions. The systems had also developed adverse tendencies leading to an increased probability of disruptive events. This was judged as a departure from expected operating conditions and a proof of system progressing on an adaptive gradient. The findings then investigated micro agent behaviours, mindsets and actions contributing to the above system patterns. Evidence of behaviours like loss of trust, over ambitious pursuit, use of power and privilege, conspiring against best practices and heedless performance were found to be associated with multiple cases. It was also found that not all the behaviours or adaptive tension patterns forced the system to self-organize or emerge. However, the aggregation of some of the microstate agent behaviours did cause the system to self-organize and emerge into either a new structure or a new process or goal. Some behavioural traits were also found to be associated with system demonstrating robustness or resilience to disruption.

This concludes the second phase of this research where the main study was designed, conducted and results analysed in juxtaposition with the phenomenon of interest. The next phase of the study presents a discussion of the findings with respect to the existing body of knowledge and carves the contribution of this research. It essentially answers the question that what do the findings tell us and how do they extend the existing body of knowledge.

Phase III:

What the research tells

6 DISCUSSION

This thesis began by highlighting the importance of accounting for micro agent behaviours in deciphering supply chain phenomenon. Having chosen SCD as the phenomenon of interest, this research is interested to answer the question; How do micro agent behaviours, actions and interactions influence events of supply chain disruption? If they do influence it, then how these individual actions bring about self-organization and emergence at a network level? The analysis of complexity literature revealed that adaptive tension, a measure of energy gradient between designed and real system conditions, can be used as an explanatory mechanism to comment on the contribution of micro level interactions towards system level phenomenon. Guided by a critical realist research philosophy of linking the observed to the real by explanatory mechanisms, this thesis approached the analysis of data to reveal the evidence highlighting the presence of adaptive tension, self-organization and emergence in the events of SCD. Accepting the critical realist view that an objective reality cannot be completely expressed or conceptualized by the observer, this thesis resorted to an abductive logic of moving between established theory and research data to argue the influence of agent behaviours and actions on instances of supply chain emergence and self-organization, with the mechanism of adaptive tension being the crucial link.

In the following discussion, this thesis elaborates the insights depicted in figure 6 and explains how these insights contribute to the literatures of supply chain complexity and SCD. Briefly, the findings of this research emphasize on three understudied aspects of supply chain as CAS: (i) How individual behaviours, actions and interactions produce emergence and self-organization in a supply chain setting (ii) The kind of agent actions and behaviours responsible for emergence and self-organization in a SCD scenario and (iii) why some actions could result in resilience and robustness while others contribute to the fragility of the network.

6.1 Micro agent behaviours to macro outcome: pathways to self-organization and emergence

Established complexity research, whether it subscribes to the theory of chaos and dissipative structures or to the concepts of self-organization and emergent adaptive landscape; both the streams argue that system level explanations have micro level underpinnings (Poulis and Poulis, 2016). This calls for a greater need in organizational studies to account for an agent and agency perspective of organizational complexity. Building on this premise, the current literature on complex adaptive supply chain networks posits that an agent's internal mechanism, schemas, behaviours and actions lead to emergence and adaptation (Choi, Dooley and Rungtusanatham, 2001; Surana *et al.*, 2005; Nair, Narasimhan and Choi, 2009). However, the literature does not clearly explain how individual agent contributions contribute to macro system outcomes. The findings from this thesis, represented in a theoretical model of micro to macro causation figure 6, aspires to answer this 'how' question by dissecting the black box which holds the explanation for the transition from micro agent behaviour to system level self-organization and emergence, as suggested by supply chain complexity literature. The model also describes alternate pathways that a system can take on being pushed to an adaptive gradient arising out of dynamic agent interactions.

6.1.1 Model of micro to macro causation in supply chains: pathways to self-organization and emergence

The findings from the exploratory phases of this doctoral research have been condensed into a theoretical model of micro to macro pathways, figure 6. The model describes how the micro agent interactions result in a rise of adaptive tension and how the accumulated adaptive tension is dissipated by the system in three alternative pathways. Although the supply chains investigated were established networks that did not require any initialization by introduction of agents, yet for illustrating the micro to macro causation cycle and to understand how environment, agent behaviours and macro outcomes are related in a loop, this thesis proposes to considered the environmental and contextual conditions as its starting point.

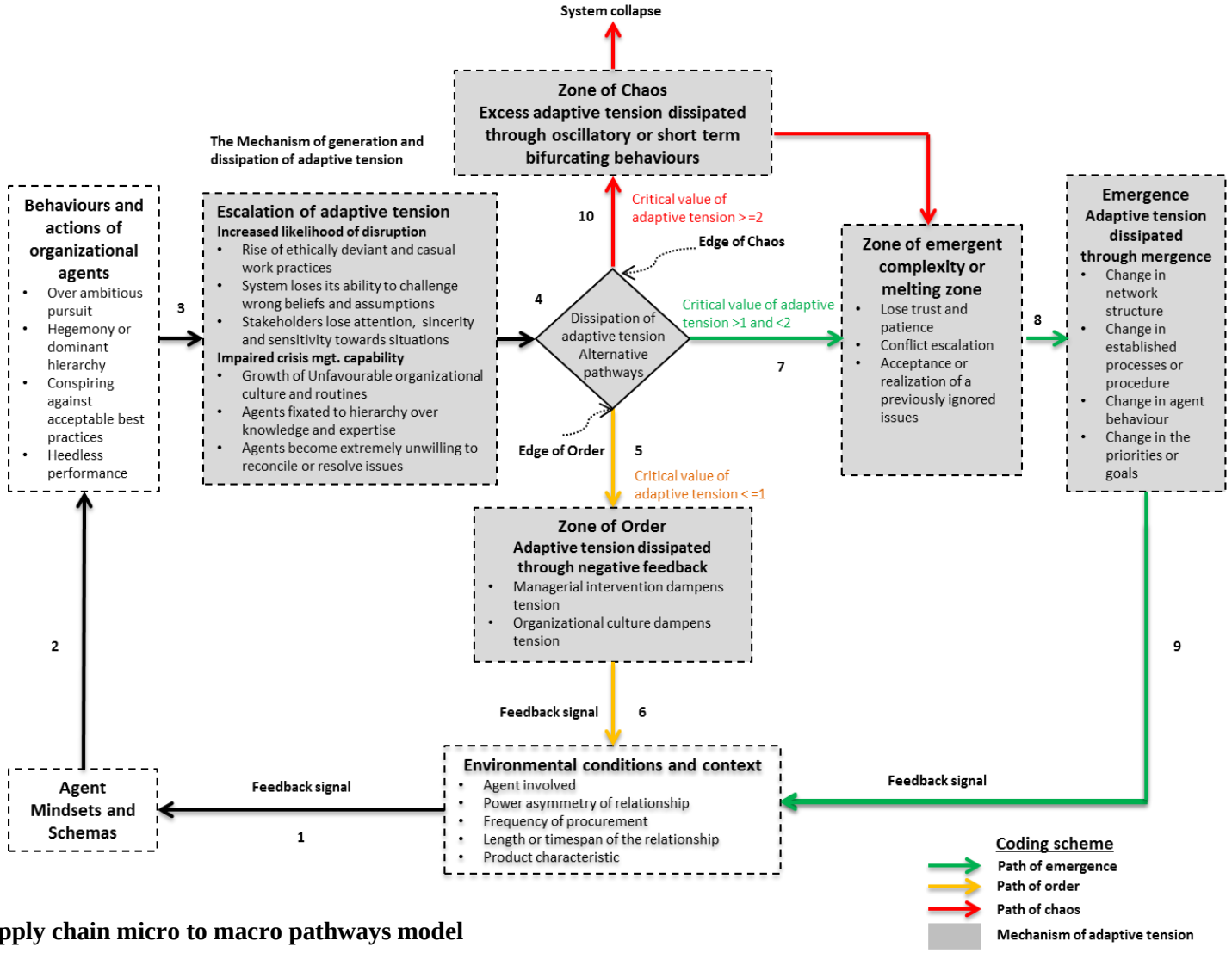


Figure 6: Supply chain micro to macro pathways model

The model proposes that individual system agents use their internal models, schemas and mind-sets to interpret the feedback signal received from prevailing environmental and contextual system variables (depicted by transition 1 in the model). These individual interpretations, depending on agent characteristics and preference, may lead to behaviours, actions and interactions (depicted by transition 2 in the model). Many such actions and interactions of diverse system agents become embroiled or entangles leading to aggregation or dissipation of adaptive tension; ie. dissipation could occur before supply chain dynamics is interrupted. The system responds to this accumulation of excess energy/adaptive tension in three distinct ways resulting in three alternative system pathways: pathway of order, pathway of emergence and pathway of chaos. Since this thesis adopts a critical realist philosophy, it posits that this process of aggregation and dissipation of adaptive tension can be seen as bundle of steps (depicted by grey boxes in figure 6) that may be brought under a definition of one explanatory mechanism; *'the mechanism of generation and dissipation of adaptive tension'*.

In the next section, this thesis presents a discussion of the mechanism of generation and dissipation of adaptive tension. This mechanism is presented as an explanation to answer the question of how individual agent behaviours and actions result in system wide emergence and chaos. This will be followed by a discussion of the kind of micro agent behaviours and interactions produce adaptive tension and how these findings are positioned with respect to broader organizational science research.

6.2 Mechanism of generation and dissipation of adaptive tension

Supply chains are an arena in which a system of actors act, interact, adapt and establish relationships on the basis of their local knowledge, rules (McAdam and Scott, 2005) and system feedbacks resulting in emergent self-organisation (Plowman *et al.*, 2007). Considering supply chains as complex system, it can be argued that the diversity and complexity of such a complex system makes it impossible to predict the outcomes of agents' actions and activities (Holland, 1995) as small changes can be amplified to create dynamic and nondeterministic macro level effects (Plowman *et al.*, 2007). That is, certain catalysing activities bring together the enabling conditions (mechanisms and contexts) necessary for collective action to emerge and have aggregated effects.

This thesis posits that the mechanism that brings about a micro to macro effects in complex supply chains is that of *'generation and dissipation of adaptive tension'*. The mechanism explains how individual agent behaviours contribute towards scenarios where the 'normal' dynamic supply chain is stressed to traverse into a trajectory of emergence or chaos and it also sheds light on the aggregated outcomes of individual agent actions and behaviours.

The mechanism of adaptive tension is theorized to have two constituents; first escalation of adaptive gradient, and second the macro dissipation of it through three alternative system pathways.

6.2.1 Escalation of adaptive gradient

The analysis of the data revealed that two system patterns were at the core of producing destabilizing effects and contributing to adaptive tension. These were; (i) an increased disruption probability and (ii) system's impaired crisis management capability. Each system pattern had several collective agency behaviours contributing towards it. These collective agency behaviours were a direct outcome of the aggregation of contributing micro agent behaviours and interactions.

Inability of the organizational agent's collective cognition to timely detect, interpret or anticipate adverse events was at the core of patterns linked to an increased disruption probability. While a loss in the system's ability to manage, crisis was linked to collective behaviours that allowed a disruption to be handled inadequately because problems were either not contained or were allowed to amplify and cascade.

Failure of collective cognition

Increased disruption probability was directly linked to micro agent behaviours that demonstrated ethically deviant and casual work practices amongst actors. This meant that agents were not constantly concerned about supply chain disruptions so signals of impending problems were overlooked. Other related micro behaviour was concerned with the loss in agent's abilities to challenge or question wrong beliefs and assumptions about possible interpretations of looming SCD events. This was accompanied by agents' demonstration of diminishing sincerity and sensitivity towards worsening

situations. The data revealed that a loss in shared understanding of ongoing operational and environmental conditions of the supply chains resulted in serious consequences.

Problems being allowed to cascade or amplify

Unfavourable organizational culture and deviant work practices were at the core of the loss in the system's ability to manage crisis. An absence of a culture towards resilience contributed to the erosion of barriers to disruption (e.g. procedures, training, corrective action), which meant that problems that were generated were neither trapped nor mitigated. The organization had lost its potential to generate or capture knowledge and learnings from past events. Another element of unfavourable organizational culture was that problems were not being deferred to those with the requisite expertise to resolve the problems quickly and effectively and it led to delays and inaction. The escalation of crisis was also found to be linked to the stubborn and ego driven attitude of agents that inhabits them from finding logical solutions to impending problems.

It was an ongoing and dynamic interaction between these two system patterns; Failure of collective cognition and the problems being allowed to cascade or amplify within contextual factors that led to an escalation of adaptive gradient. That is, these system patterns not only seemed to alter the context of the supply chain, but also that the altered context seemed to affect these system patterns, forming a recursive relation and influencing SCD.

The escalation of adaptive gradient and the recursive relationship of system patterns and context can be argued using structuration theory (Giddens, 1984). It can be argued that human agency and social structure are in a relationship with each other and it is the repetition of the acts of individual agents, which reproduces the structure (Giddens, 1984). When people act they bring events, structures, constraints, and opportunities that were not there before they took action into existence and set them in motion (Weick, 1987). People's actions reinforce and reproduce a set of expectations and it is this set of expectations that shapes future performances of the action. That is, these system patterns together contributed to the escalation of adaptive tension and had a negative effect on the supply chain, which had a detrimental effect on the action of other agents and so on.

The amplification of these micro agent interactions into defining system patterns was quite evident in the data. A possible explanation of it is that when a system is moving toward increased nonlinearity, small changes are more likely to be amplified by other actions and result in unintended radical change (Thiétart and Forgues, 1995). Plowman et al. (2007) note,

"when social systems experience stress, people or groups that were independent become highly interdependent, often as the result of a crisis or turbulence of some sort. In highly interconnected systems, positive feedback reinforces an initial signal and can amplify small changes." (Plowman et al., 2007: p. 520)

That is, when supply chains start to drift toward disruption, the micro level actions of agents are likely to be amplified by other actions and increase the likelihood of a SCD.

6.2.2 System pathways: Dissipation of adaptive tension

A complex system displaced from dynamic equilibrium, due to exchange of energy in with the environment, tends to dissipate any excess energy and tries to attain a new equilibrium state. The process of adjusting and dissipating excess energy will compel the system to follow different trajectories that are often correlated to the excess energy in the system and the amount of energy it dissipates. These pathways linked to different levels of adaptive tension are systems response to lower its energy gradient. Talking about the dynamic pathways associated with adaptive tension and autocatalytic dissipative structures, Depew and Weber (1995) argue ;

"are capable of generating dynamics that produce order, chaos, or complex organization at the edge of chaos" (Depew and Weber, 1995: p. 462)

Similar to the above propositions, the theoretical model suggested in this thesis, figure 6 provides three alternative pathways for a supply chain system under an adaptive gradient. Triggered by micro agent interactions, these possible pathways are determined by the gradient of the prevailing adaptive tension. Based upon Prigogine and Stengers' (1984) conceptualization of critical adaptive tension values and its application for organization studies as argued by McKelvey (2001, 1999), this thesis suggests that the gradient of adaptive tension in supply chains will force the system to descend into either of these three distinct pathways: (i) Loop of order with increased energy

dissipating through local interactions, (ii) Loop of emergent complexity with the increased energy dissipating through emergence of new structures and (iii) Loop of deterministic chaos where the excess energy creates multiple basins of attractors that tend to induce an oscillatory behaviour to the system and its agents, creating multiple short lived processes to deal with increased energy.

6.2.2.1 Loop of order with adaptive tension critical value less than 1

Out of the 167 cases of supply disruption only 23 cases resulted in any form of emergence[2]. In rest of the cases all the organizational actor efforts and behaviours focused on preserving the continuity of the network without altering any of the system elements. The additional adaptive tension accruing due to agent behaviour or interactions was managed and reduced by managerial interventions and agent coordination. In these cases, agents ignored the behaviours causing SCD and accepted these SCD occurrences as unavoidable features of the system that did not require any system or behavioural adjustment. Inevitability assumptions restricted these agents to analyse or reflects on these events and thus there was minimal possibility of the system to emerge or self-organize into a new structure.

For SCD events that did not result in any structural or procedural change, it can be argued that the adaptive tension is below the level that agents perceive would require attention or action. For example, respondent of firm 20 did not see the need to change anything regarding transit damage of their moisture sensitive goods due to a careless handling of consignments by the logistics provider. Top management of firm 2 did not see any merit in altering their lean policy for their automobile spare parts which had a high level of seasonality and demand fluctuation. The executive of firm 6 was comfortable with disruption causing behaviours of their sales and marketing team. In these cases supply chain executives settled for inaction, sometimes due to the assumption that disruptions are bound to happen or sometimes due to a feeling of resignation that their recommendations will not be approved by the higher management. This resulted in the system to continue with its practices, operations, processes and agent behaviours. The occasional SCD events were managed with variations in the sales

[2] Refer to appendix for details

and operations process or manufacturing schedules or, in most cases, production/ sales loss was just accepted as an unavoidable eventuality.

The above discussion of loop of order, signifying the path 1-2-3-4-5-6-1 in the model suggests that despite adaptive tension being induced by the environment and interactions of agents, the negative feedback from managerial intervention or prevailing organizational culture of accepting SCD as an inevitable operational reality, is able to dampen or mitigate this tension.

These findings resonate closely with the tenets of institutional science literature on agent schemas which argues that changes in organizational structure and its operations could be explained more by the actions of its powerful and influential members rather than factors like an organization's size, its business environment or aspects of technology (Bartunek, 1983). Collective outcome of agent's cognitive interpretations and schemas have a tendency to converge around the cognitive interpretation of a powerful leader or an influential manager (Daft and Weick, 1984) and thus at low levels of adaptive tension, less than 1st critical value, powerful organizational actors may suppress the individual agents from self-organizing or influencing system wide emergence. Bode et al. (2011) also argue in their model of SCD that the motivation to act on a SCD is determined by the perception about the encountered variation in performance associated with that event; if the difference in performance exceeds an acceptable or defined level then the supply chain will evoke a corrective or non-routine response. In these cases of findings, where the system avoided self-organization or emergence, the perception about the departure from equilibrium conditions and the accumulated adaptive tension could be argued to be within an acceptable level and thus did not evoke any significant response.

The raised adaptive tension due to agent interactions and behaviours were subdued by managerial decree and higher managerial decisions and interventions. This corresponds to the concept of a negative feedback in the system that tries to avoid structural changes by dampening the system disturbances and diffusing the excess energy through other means such as management. These negative feedbacks are mechanisms to manage, coordinate or control the behaviours generating adaptive tension and relates to effective operational organization (Choi, Dooley and Rungtusanatham, 2001).

6.2.2.2 Loop of emergent complexity with adaptive tension between 1st and 2nd critical value

This loop of emergence and self-organization is depicted in the model by the pathway 1-2-3-4-7-8-9-1. In events connected to SCD, where some actors were found to be conspiring against organizational best practices, other actors were trying hard to negotiate and manage the chaotic situation, leading to oscillation between order and disorder. The findings correlate with leadership behaviour studied by (Lichtenstein and Plowman, 2009) that talks about some behaviours pushing the system to disequilibrium while other agent behaviours trying to stabilize the feedback signals by taking charge of local governance and enactment.

However not all efforts to stabilize the uncertainty and chaos generated by conflicting agent behaviours are successful. The findings suggest that going past the 1st critical value of adaptive tension; the system would eventually self-organize and emerge into a new state. In this zone the system has sufficient energy that creates adequate adaptive tension to support the operations between the edge of order and edge of chaos. The zone corresponds to a zone of emergent complexity (Cramer, 1993), or the 'melting zone' (Kauffman, 1993) where this accumulated system energy is dissipated by the formation of emergent structures; or division of existing ones *'emergent simplicity'* (Cohen and Stewart, 1994) works to resolve the adaptive tension.

In a supply chain context, Wilding (1998) has argued that parallel interactions can lead to demand fluctuations, uncertainty and chaos. It can be argued that supply chain system conditions during such occurrences of parallel, overlapping and conflicting interactions are comparable to the system conditions termed as being at the edge of chaos: systems demonstrating such a behaviour are at the zone of emergent complexity (Cramer, 1993), or in the 'melting zone' (Kauffman, 1993). According to complexity paradigm, it is here that the system will eventually self-organize and emerge to a new form or new operational conditions. The same was observed in the findings from this research.

This melting zone or the zone of emergent complexity is said to occur between the 1st and 2nd level of adaptive tension critical values (Cramer, 1993; Gell-Mann, 1994; McKelvey, 2001). If the adaptive tension is below the critical value, the system is at an increased energy but still in order, however being at an elevated energy level, the

system has the tendency to slip into the zone of emergent complexity with the slightest of perturbations or nudge. While above the 2nd level of critical adaptive tension value, the system will slip into deterministic chaos where multiple forces and attractors will define short lived system behaviours.

The findings suggest that at multiple instances before, during, and after a SCD, the behaviour of agents forced the system to move into a new structure or condition. These findings are consistent with the organizational complexity work presented by McKelvey(2004, 2002, 2001, 1999) that accredits the escalation of adaptive tension and system wide emergence to coevolving agent interactions and dynamic mechanisms. As a direct result of agent behaviours and actions, an escalation of adaptive tension linked to cases of supply chain disruption, was found to be pushing the system to a chaotic and high amplitude oscillatory behaviour. This finding indicates that supply chains follow a similar path of moving from stable operating environment to the edge of chaos, as proposed by Benbya and McKelvey (2006) in the context of emergent information systems. The human actions and behaviours in supply chain settings were also pushing the system to a region of bounded instability (Stacey, 1996), causing the system to flips between order and disorder. System conditions that were found to be tipping the system into emergence were: a complete loss of trust or patience in a relationship, escalation of conflict, and acceptance or realization of previously ignored issues.

Instances of self-organization and emergence were either reflected in a noticeable change of system structure or in a change related to the behaviour, mental models, practices, norms or goals of participating agents.

The aggregation of schematized exploration of rules, options and decisions made by each individual agent results in the creation of a system wide agency and a collective behaviour that confers nonlinear, self-organized and emergent tendencies to the systems (Mccarthy *et al.*, 2006). In the findings, it was observed that agent behaviours contributing towards adaptive tension, linked to cases of SCD, reached a critical aggregation level or an event space/ zone that could be viewed as tipping point for the system. System conditions and agent schemas associated with this event space/zone included: agents reaching to a point of a complete loss of trust on others ability to resolve the situations, disagreements turning into fully blown conflict that may require

legal arbitration or higher management intervention, acceptance of committed errors, mistakes or previously ignored issues and a clear realization for the need to take corrective actions. This zone or event space is represented in the model, figure 6, as 'zone of emergent complexity'. The system conditions in this zone of emergent complexity, represent aggregated schematized mental state of the decision makers and the following actions, decisions bring about self-organization and system wide emergence.

In the findings from the cases of SCD, it was witnessed that on 23 instances[3] the aggregation of adaptive tension causing behaviours results in agents seeking localised changes in the system structures, procedures, goals and agent mind-sets. This local order is neither governed nor instigated by any centralized order or top down decision. Instead it emerges out of the self-organizing behaviour of agents. For instance, in a case connected to firm 2, pushed to a corner by high degree of opportunism and nonchalant attitude of one of its suppliers, an executive of firm 2 acknowledged interfering with the process of quality approvals to expedite the approval of an alternative supplier. This event not only changed an existing organizational routine but also resulted in the alteration of the network structure by the addition of two more suppliers for a product that initially had only one supplier.

It is noted that this change conflicts with the prevailing lean manufacturing culture of this Japanese automobile firm, yet localised actions of the procurement team could induce a not so lean structural change. The transaction cost economic view would argue that this initiative will increase the cost of administration and relationship management and thus diminish the overall efficiency (Handfield and Nichols, 1999). This drop in efficiency validates another complexity axiom that localised adaptation might not improve efficiency, rather it may, considering the mountain metaphor of the rugged landscape conceptualization (Kauffman, 1993), move the system from one peak of performance to another. This localised initiative, without a central directive or motivation was not just restricted to firm 2 but firms 1,7,9,11,15,17,20 and 21 also demonstrated similar traits.

[3] Refer to appendix for events demonstrating emergence

Discussing complexity and emergence in supply chain , Choi, Dooley and Rungtusanatham (2001) quote;

"Emergence can be operationalized as some observable patterns that appear in the SN in an unanticipated way, and case studies can help identify what these observable patterns are in the supply network."(Choi, Dooley and Rungtusanatham, 2001:pp 364)

In the cases of SCD, the observed patterns indicating emergence were found to be; a change in network structure, a change in established process or procedure, a change in agent behaviour or a change in agents' priorities or goals. These system changes were a result of aggregated agent behaviours, their collective schema shaping a collective agency and the accompanying adaptive gradient. Elsewhere in organizational complexity literature it has been successfully argued that a wide variety of autonomous and diverse agent behaviours, the manner of imposing organizational routines and rules to direct or govern agent actions, the nature of coupling between decision rules and processes, prevailing organizational structures, conflicting agent priorities, the requirements related to obtaining formal permissions, time pressures and constraints associated with the process etc, are some of the organizational factors that assist self-organization and emergence (Eisenhardt and Sull, 2001; Chiva-Gomez, 2004; Mccarthy *et al.*, 2006). In supply chain settings, the findings of this research validate these findings from broader organizational literature.

These changes in the organization and alterations in agent's behaviours, goals and mind-sets, act as a positive feedback that feeds into context and organizational environment creating a pretext for inspiring changes in individual agent schemas and mind-sets. The process continues with a new set of updated agent actions and interactions which take the system forward.

6.2.2.3 Adaptive tension greater than 2 and the path of chaos

In organizational settings, McKelvey (1999) argues that organization conditions comparable to adaptive tension value above 2nd critical limit will result in the system to move into a reign of chaos. McKelvey (1999) suggests that under such conditions, a system is influenced by multiple attractors or with possibilities of bifurcated attractor basins, under the influence of which organizational actors and agents are drawn to

oscillatory and short term behaviours to respond or to negotiate the rise in adaptive tension. In this region of bifurcated chaos (Benbya and McKelvey, 2006), a system is bound to demonstrate highly unstable behaviour. The excess energy is dissociated by the chaotic behaviour and the system may either collapse or will return to the emergent complexity zone. In the theoretical model of figure 6 this process is represented by the pathway 1-2-3-4-10.

In the findings of this thesis, there were two events that could be argued to be representative of chaotic behaviour prescribed by organization complexity researchers. Chaos was demonstrated in an event connected to an industrial relation problem; in firm 1, where the worker's union went off into a strike with a complete breakdown of negotiations and efforts to reinstate work. This period of labour unrest was marred by various short term behaviours both by the union and the management to gain control of the situation. The respondent of firm 1 disclosed that many workers were fired and many temporary work force arrangements were used to restore production and all these initiatives were met with a strong resistance from the union. This was a typical case of the system entering a zone of chaos and uncertainty and it was accompanied with a total breakdown of the supply network. However, the company survived the crises and it was followed with multiple initiatives and instruction of safeguards to avoid such eventualities in future. This is representative of the system returning back to the zone of emergent complexity.

Another event of supply chain chaos and a total breakdown of the system operations were disclosed by the respondent from firm 18. This event relates to a severe flood situation in a particular geographical location which resulted in the cutting off of all road and railways links to that area, resulting in transport links being broken for more than 4 weeks. But it was not the environment that triggered the chaos but the behaviour of the shipping and logistics provider operating for this geographical area. Being aware of a possibility of a month long transport link disruptions, to avoid the holding or warehousing cost, some of the logistics firm decided to off load their cargos in a public sector container and inland cargo service firm. As other logistics providers and shipping companies learnt about such behaviours, they too dumped their cargo in the government sector warehouse, resulting in a huge pileup of goods and a backlog that took months to

recover from. Many firms suffered due to this act as their precious cargos were stuck in the public sector warehouse and the logistic firms washed their hands off from taking any responsibility by saying that they had passed on the cargo to another firm. In the case above, it was evident that it was the agent behaviours and their choice of decisions that caused the system to collapse and many supply chains to go into a zone of uncertainty and chaos. Although the environment and floods did play a role but the action of agents extended the disruption much longer than the 4 weeks' period for which the transport links were unavailable. These findings corroborate with Wilding's (1998) concept *of 'supply chain complexity triangle'* which argues that the uncertainties and fluctuations in supply chain are not always a result of external perturbation but are sometimes a result of the operations and system design.

Chaos theory and the concept of attractor space and basins are not as easily adoptable to organizations as these terms are to a natural science (Thiétart and Forgues, 1995). However, axioms like sensitivity to initial conditions, bifurcated attractor basins, strange attractors etc, can lend a complexity perspective to the chaos experienced in organizational settings (Thiétart and Forgues, 1995). The findings of this thesis reveal that situations that turned into chaos had many elements of similarity with the propositions on organization and chaos by Thiétart and Forgues (1995). These include; sensitivity to initial condition, such as growing unrest of workers being ignored by management or a natural disaster like flood; existence of counteracting forces and motivations, unpredictability of outcomes and changes etc.

It is noted here that the chaos discussed in the above examples identifies itself with the deterministic chaos caused by different basin of attractors and driven by simple rules (Cramer, 1993), rather than the a chaos associated with probabilistic distribution of random occurrences (Gell-Mann, 1994).

6.2.3 Summary of the mechanism

Bhaskar (1978), suggests that the understanding of a phenomenon is construed by an individual's ability, viewpoint and understanding of a phenomenon, thus it is unwise to suggest a deterministic causality between an action and the observed outcome. Subscribing to this critical realist ontology, this thesis posits that although in supply networks a deterministic causality can be observed between micro agent behaviours

actions and interaction and the observed macro system behaviours like self-organization or emergence of a supply chain network, yet there is a need to understand this phenomenon from a viewpoint of underlying causal mechanisms. The discussion of the mechanism of generation and dissipation of adaptive tension lends explanatory relevance to the observation of micro agent behaviours translating into macro system outcomes.

The next section of discussion looks into the individual micro agent behaviours that have potential to create aggregated system patterns leading to adaptive tension.

6.3 Adaptive tension causing micro agent behaviours

The findings of this research revealed many micro agent behaviours connected with events of SCD. These included; disruption of existing practices, violation of stakeholders' ethical expectations, breaking of organizational norms and creation of an atmosphere of conflict and tension among participating agents. These behaviours were found to be triggering and propagating operational disequilibrium, uncertainty and disorder in the supply chain network. The observation aligns with the propositions of broader organizational research on human behaviours, dissipative structures theory and CAS (Benbya and McKelvey, 2006). As observed and suggested by Benbya and McKelvey (2006) and Allen and Varga (2006) in information system's research, Lichtenstein and Plowman (2009) in leadership research, Lichtenstein and Carter (2007) and McKelvey (2004) in entrepreneurship research and Mccarthy et al. (2006) in new product development, this thesis also found evidence supporting that system wide disequilibrium was being triggered by micro agent interactions. The analysis of SCD cases revealed that aggregated micro-state agent interactions and behaviours were pushing the supply chain systems away from its equilibrium operating conditions into a region of instability and chaos. It was also observed that parallel, overlapping and conflicting interactions of organizational groups and individuals connected to cases of SCD were a precursor of emergence and self-organization.

However, the first place to look for the roots of agent behaviours is in the prevailing environmental conditions and contextual influences. Context and environment acts as a feedback signal that influences an individual agent's mind-set and subsequently shapes their behaviours and interactions. This is discussed next.

6.3.1 Environmental conditions, context and agent schemas

To help explain findings, that the situated actions of agents and the resulting adaptive tension were shaped by context and environmental factors, we refer to the literature on complexity and mechanisms. Since this thesis subscribes to a critical realist ontology and accepts the view that there are underlying mechanisms capable of explaining observed system patterns and behaviours, an understanding of the interplay of mechanisms and context is very relevant for the findings.

The relationship between mechanisms and their effects is not fixed but is contingent upon context (Sayer, 1992). Mechanisms will only be activated in the right conditions (Pawson and Tilley, 1997). These contexts enable as well as constrain the actions of agents (Giddens, 1984). It is the combination of conditions and the fact that happen together, their conjuncture (Ragin, 1987) which triggers the mechanisms that generate SCDs. Existing theory fails to explain how these outcomes happen. The context shapes boundaries, regulations and motives that guides and bounds an agent's action. Complexity theory, with its emphasis on initial conditions and adaptive tensions (Anderson, 1999; McKelvey, 1999b), enabled the identification of five contextual conditions (type of agent involved, power asymmetry of relationship, frequency of procurement, timespan of the relationship and product characteristics) that help explain how the actions of agents can emerge and lead to supply chain disruption.

Agent and context have a recursive relationship as context defines an agent's schematization of experience while at the same time agents trigger and carry forward idiosyncratic and non-isomorphic changes in organizational environments and contexts, thus providing a clear reason to embrace complexity.

6.3.2 Amplification of micro interactions

The organizational studies and commitment literature view agent and agency as an entity that is influenced by the past, committed to the future and has its decisions and actions informed by the present (Emirbayer and Mische, 1998). This conceptualization of agency does not compel it to be rational by definition or to be explicitly aligned to organizational expectation, instead it just seeks to define it using experiences, expectations and goals of agents that are consistent with past present or future.

Commenting on the rationality argument of agent and agency from a complexity perspective, Poulis and Poulis (2016) observed that the behaviour of agency can yield both aligned or misaligned outcomes because not all decisions of agency can be judged as rational or purposeful and calculative decisions aimed at future optimization. The authors view agents to be immersed in varying forms of organizational complexities and the decisions of agents to be driven by their cognitive and emotional interpretation of past, present and future. Under such premise, it is improbable for actors to be able to always subscribe to normative decisions, to make rational choices to complex scenarios or to be able to always end up with optimal solutions. The factors that suppress the possibility of optimality are structural constraints (such as insufficiency of information, power asymmetries with others) and constraints related to the emotional or cognitive capabilities of actors (Poulis and Poulis, 2016). In the investigated cases of SCD, the agent behaviours that were found to be constraining the possibility to achieve optimal performance were; agent's perceived loss of trust in organization, ambitious pursuit of issues by agents, the use of power and privilege to force their own agenda, agents conspiring against best practice and heedless performance by agents. These agent behaviours and actions were found to be diminishing the possibility of achieving optimal outcomes related to smooth functioning of the supply chain.

In the extant literature there are findings that could be linked to the destabilising agent behaviours observed in the 167 cases of SCD. For example, over ambitious, and unsanctioned pursuit of organizational issues and problems by agents resonates closely with the idea of creative deviance proposed by Mainemelis (2010). The author suggests that when an employee's new ideas or an out of box suggestion is rejected by the managers or management, branding them as unrealistic, or inappropriate; then if the organization culture permits deviance (Mainemelis, 2010) and if the concerned organizational actors are capable, bold and imaginative to misalign with the organizational expectations (Poulis and Poulis, 2016), the employee may choose to violate the organizational recommendation and still pursue the idea. This violation or deviance is referred to as creative deviance (Mainemelis, 2010) and this has a potential to generate undesirable manifestations (Poulis and Poulis, 2016). The behaviour of overambitious pursuit observed in the data was also found to have generated undesirable consequences and to have amplified some responses that inflicted

disruptions either for the agent's own organization or for a supplier firm. It is often argued that organizations avoid or disapprove innovative and entrepreneurial interventions that may be accompanied by deviance from established organizational norms (McClelland, Xin Liang and Barker, 2010). If an actor still pursues an unsanctioned, self-motivated entrepreneurial initiative, this is bound to have repercussions and would result in the escalation of adaptive tension within the organization.

Although, it is accepted that deviant behaviour has personal and relational antecedents, yet the prevailing social context and structure could be argued to be the defining element of such a behaviour (Beyer and Trice, 1984; Staw and Boettger, 1990). In the results, such behaviours were found to be concentrated in a few firms and within these firms there were multiple instances of such behaviours. This is indicative that these firms could have had organizational culture and management related issues otherwise the phenomenon should have been witnessed across cases.

Use of power and privilege to force one's own agenda or dominant hierarchical attitudes also has tendency to amplify the responses in an organizational setting. In an example pertaining to a scenario where a big firm takes over a smaller entity, McKelvey (1999) argue that if the big firm sends a team of managers from the headquarters to impose dominant and hierarchical rules and routines on the employees of the smaller firm then to cope with this tension, the people will act and behave to produce oscillatory response. In other words, the system will have oscillatory tendencies where individual actions have potential to amplify. It is also argued that rigid organizational norms and forceful exercise of privilege and power can demotivate and stagnate organizational actors (Mainemelis, 2010). Aggregation of such behaviours associated with reduced motivation can seriously undermine optimal performance and diminish the potential to manage crisis situations.

In the findings, there were evidence suggesting that a top down enforcement of operational strategies and decisions was creating disequilibrium and tension. In new product development literature , linked to complexity thinking, it has been established that top down hierarchy and coupling between decision levels has a potential to amplify or supress complex system characteristics (Mccarthy *et al.*, 2006). Although Mccarthy

et al. (2006) discuss the effect of hierarchal intervention in a positive light, yet in supply chain settings, as per our findings, this has negative connotations especially for the stability of the system.

It can be argued that in an organization patterns linked to increased disruption probability and impaired crisis management capabilities can both be influenced by behaviours that motivates an individual or a group to conspire against acceptable best practices and to act against the right way of doing things. Behaviours like dishonest attitude, opportunistic behaviour, dishonouring commitments were found to be widespread across cases. Most of these behaviours were found to be connected with the marketing or customer service teams of the suppliers and the motivation behind such behaviours was often to gain short-term benefits and to secure business deals. Such behaviours have been long observed and debated in studies that subscribe to a transaction cost economic view; *"self- interest seeking with guile"* (Williamson, 1985: pp 30, 47). Williamson (1985) argues that a definition of an act of guile should not be restricted to the act of stealing, cheating or lying, instead there is a need to generalise them by including acts like providing incomplete or distorted information, efforts to mislead others, intention to obfuscate or confuse the thinking and perception of others etc.

Commenting on opportunistic behaviour, Romar (2004) observes that in any relationship where the accepted terms of agreement are not fulfilled in spirit is also a form of opportunism. The authors list a few kinds of opportunistic behaviour that resonates very closely to the findings of this thesis. These include; (i) delivering a lower than expected level of performance, (ii) intentionally defaulting on agreed upon deadline, (iii) Promising or committing to deliver higher quality or specification than what is actually delivered, (iv) misrepresenting capabilities. In the findings there were multiple events across cases where such behaviours were prevalent. The transaction cost view is suitable to argue such behaviours in a dyadic relationship however this thesis takes it further and looks at the macro impact of such behaviours.

The discussion above corroborates the findings with similar observations in the extant literature. The findings of this research suggest that behaviours of organizational agents were escalating adaptive tension and consequently destabilising the system. Local

interactions were instrumental in creating conditions and contexts that were considerably undermining a supply chain's ability to ward off or cope with disruptions. Elsewhere in operations management it has been experimentally illustrated that for systems with complex characteristics and feedbacks, with agent demonstrating bounded rationality and possibility of misinterpreting the system variables; there is a possibility for small changes in demand to amplify into large oscillation in the inventory (Sterman, 1989).

Using a distribution game driven inventory management experiment, Sterman (1989) demonstrated that a variance in demand, production order and inventory levels has a tendency to amplify as one moves from customer to its suppliers. Sterman (1989) attributed this variance to be a result of a sequence of behaviours and decisions taken by the participants which author termed as " misperceptions of feedbacks". Drawing a parallel of the experiment with the errors committed on replenishment decisions connected with dynamically complex system/ environments, the author further argues that these amplified variances are a result of decision maker's misperception about the feedbacks and of the individual's insensitivity to the feedbacks that are generated by their own flawed decisions. The underlying cause of these errors and amplification of effects could be traced to the cognitive limitations and flawed mental models of the decision makers (Sterman, 1989). It was also observed by the author that while placing future orders for systems with lead times or significant feedback delays, decision makers often struggle to give adequate weightage to the inventory in their supply lines and thus end up generating large fluctuations in their order rates in response to only a step increase in the customer demand. It is also commonly observed that most participants of this experiment would blame others (other players or the game coordinator) or would suggest external causes for their poor performance.

Sterman (1989) players demonstrated a lack of rationality and were found to be prone to misinterpretation; resulting in destabilising the system. Although, this doctoral research does not investigate any oscillations in inventory, yet it was found that far from rational behaviours, misinterpretations of system conditions/context and local agent mind sets and mental models were prone to amplify system errors and lead to disruption and

destabilisation of the system. The findings correlate with the propositions made by Sterman (1989) in the beer game experiment.

However, apart from the studies related to inventory and order fluctuations in the beer game experiment, the existing supply chain research tends to ignore behavioural aspects of supply chain phenomenon thus undermining the possibility to have higher relevance and preferring the appeal for its existing explanations and models related to observed supply chain phenomenon. This brings us back to the argument that there is a need to account for agent and agency perspective in design and modelling of supply chains (Gino and Pisano, 2008; Tokar, 2010) and a CAS perspective is argued as the theoretical foundation to study the amplification of such behaviours at the system level.

6.4 Agent contributions to resilience and robustness of supply chains

Most of the existing supply chain resilience and robustness studies approach the construct using structural, strategic and operational drivers, typically the ones that influence the strategy and structure at the network level (for details, refer to a discussion of SCD in the literature review section of this thesis). Since this research investigates supply chain resilience and robustness performance from an agent perspective, a perspective that has not been sufficiently researched in the existing body of supply chain literature, it becomes imperative to look for explanations originating elsewhere in the domain of broader organizational science literature.

The dominant behavioural pattern emerging in cases demonstrating resilience was that of agents having strong commitments towards securing resilience and for that they were eager to go beyond their expected organizational commitments. The findings have a similarity to the aspect of resilience and robustness demonstrated by high reliability organizations (HRO). In the HRO literature it is shown that human resource practices targeted at prevention through anticipation or containment of an event are very effective approaches to ensure reliability and robustness performance of complex, dynamic and demanding systems (Vogus and Welbourne, 2003; Sutcliffe, 2011). In doing so, actors in HRO settings develop capabilities and skills to respond to unusual or unexpected occurrences. Some of these capabilities, as proposed by HRO literature, are; (i) agents succeeding in better improvisation of their existing skills,(ii) agent developing multitasking capabilities, (iii) agent learning to adapt and respond to situations, (iv)

agents adopting a flexible hierarchy of decisions and structure of response (Sutcliffe, 2011).

In the instances where agents demonstrated resilience in the cases of SCD that were investigated, some behavioural traits of HRO human resource practices were evident. For instance, the executive of firm 7 demonstrated a proficient improvisation of negotiation skills to avert two events of disruptions relating to supply of molten sulphur. In the first event the disruption that was expected due to the formation of a cartel among logistics providers was broken by using a threat of new entrant. In the second event, cumulative buying portfolio was used to negotiate a favourable deal (full details of the events are in chapter 5, section 5.3.4). Similar skill full improvisation was also observed in firm 2's decisions to relocate a high tonnage sheet metal manufacturing tool set from a supplier facing labour strike to an alternate location. This firm 2 intervention could also be seen as an act of flexible adaptation and quick response. In instances where procurement and supply chain executives personally took ownership of testing and quality accreditation process of new suppliers or batches of supplies, then it could be argued that the agents demonstrated multitasking capabilities and the organizational culture gave them the freedom to flexibly alter the decision hierarchy. Other events discussed in the finding section of agent resilience[4] also resonate closely to the human resource characteristics of HRO.

So why do only few firms demonstrated resilience traits while others did not? The answer to it is that some executives and managers were able to negotiate and react to SCD better than others and this had a mediating role of the prevailing organizational culture as well as the individual traits of the manager. For instance, the executive of firm 7 shared multiple cases demonstrating resilience and these cases were spread across his current firm, a pharmaceutical production unit of a large multinational group, as well as the firm he worked for before, a fertilizer manufacturing unit. Probability of having a very flexible culture of resilience in both the firms is highly unlikely, thus indicating that this particular executive enjoyed taking bold decisions and this could be embedded in his personality. While the firm 2 executive shared experiences where in

[4] Chapter 5: section 5.3.4

some events he was able to take bold, resilience strengthening decisions, while in other events, due to the rigid attitude of the higher management, he was forced to abandon his out of the box ideas. Considering that firm 2's executive was a middle manager while firm 7 executive was at senior position, this also explains why the firm 2 executive failed to implement all his ideas as he lacked the desired level of autonomy or power privilege. Commenting on the ability of executives to bring about a desired change in the policy or operations of an organization, (McClelland, Xin Liang and Barker, 2010) argues that capability to change the organizational practices is contingent upon personal attributes of top managers such as their experience, age, tenure and firm characteristics such as; size of the organization, past performance, the degree of managerial discretion and freedom provided by the organizational culture and the norms of the industry in which the firm is located. All these factors suggested by McClelland et al. (2010) have an influence on the resilience investigation of this thesis. Most of the resilience cases discussed by firm 7 executive were from his previous organization which was a relatively small manufacturing unit. While firms 1 and 2 were both automobile manufacturing units that are characterised by their high volume production and strong time pressure commitments suggesting an industry or sector specific trait of resilience culture.

6.5 Summary

This chapter presents a discussion of findings and positions these findings in the existing literature. Based upon empirical findings, this thesis develops a theoretical model of micro to macro causation, which provides an explanation for system level self-organization and emergence originating from micro agent behaviour. The model also describes alternate pathways that a system can take on being pushed to an adaptive gradient arising out of dynamic agent interactions. Using the model, this thesis further explains the mechanism of generation and dissipation of adaptive tension. The mechanism explanation begins with a discussion of the ways in which a supply network moves away from operating conditions and gathers adaptive tension. The behaviours that were found to be associated with destabilizing system patterns were argued to be linked to the inability of the organizational agent's collective cognition to timely detect, interpret or anticipate adverse events. It was also inferred that a loss in the system's

ability to manage, crisis was linked to collective behaviours that allowed a disruption to be handled inadequately because problems were either not contained or were allowed to amplify and cascade.

The stage of dissipating adaptive tension brought the focus of the study to critical values of adaptive tension and the possible dissipation pathways that could be associated with each level of adaptive tension. The model proposes three pathways; order, emergence or chaos, and elaborates how for different critical values of adaptive tension, a supply chain traverse one of these. For additive tension values critical value less than one, the influence of adaptive tension is dampened by negative feedbacks like managerial interventions or suppressive and hierarchical organizational culture. Under the influence of these negative feedbacks, agents neither act nor respond to factors causing adaptive tension and the system remains in its original state. When faced with critical values in the zone of emergent complexity, the agents act without any centralized order or control and this act brings about a self-organized, spontaneous and radical emergent change in the system. However when forced into a zone with critical adaptive tension value greater than two, a system turns to chaos. Under these situations a system oscillates at a very high amplitude and shows short term bifurcating tendencies. In empirical data, supply chain disruptions associated with industrial relationship issues and strikes were found to demonstrate such tendencies. In such situations either the system collapses or reduces adaptive tension to move to the zone of emergent complexity. settings

The chapter further presented an association of the observed supply chain destabilizing behaviours and similar behaviours argued in the wider organizational behaviour literature. The chapter ended with a discussion of agent's contribution to resilience. The thesis argued that there are also some positive agent behaviours associated with raising the adaptive tension and these behaviours could support beneficial self-organizational and performance enhancing system emergence.

The next chapter of conclusion uses the arguments of this chapter to highlight the contributions made by this study.

7 CONCLUSION

This chapter presents the contribution of this doctoral study to the existing body of literature and to the wider practitioner community. The chapter starts with a re-introduction of the phenomenon of interest and the research question that was framed to support the enquiry. It is followed by a section on how the findings and discussion of this doctoral research answer the research questions conceptualized at the outset. Contributions made to the domains that directly influenced the design of the research question are mentioned under primary contributions. While additional insights gained in related bodies of literature are presented as secondary contributions.

7.1 Research phenomenon and question

The wider complexity fraternity and the organizational complexity research community have credibly established that systems/organizations operating far from equilibrium can demonstrate self-organizing emergence at the edge of chaos, leading to radical changes in system structures or associated processes. Proponents of emergence at the edge of chaos seek to theoretically explain the phenomenon based on adaptive gradient, a measure of energy tension between a system's conditions and the environment, and the microstate element/agent interactions that contribute towards building this tension. These micro agent interactions are said to be driven by agent schemas and can bring about emergence or spontaneous system change without any centralized order or control.

The progressive domain of supply chain complexity research also acknowledges the contribution of agent interactions and mechanisms in bringing about system level emergence and self-organization. However, supply chain complexity research is yet to formalise a theoretical explanation for the amplification of microstate interactions into self-organized emergent outcomes. This doctoral research set out to address this gap and takes a bottom up complexity perspective to study the influence of micro agent interactions on macro supply chain outcomes. To support this enquiry, cases of SCD were selected as the macro outcomes for which contributing microstate agent behaviours were investigated. This was done using the following two research questions.

Research question 1:

How do micro level agent behaviours and interactions influence macro level self-organization and emergence in a supply chain disruption scenario?

Research question 2:

What are the factors and micro state agent behaviours that influence events of supply chain disruption?

The next section summarises the discussion of findings to answer the above research questions and in doing so, the section presents the way this research has contributed to the academic and practitioner community.

7.2 Primary contribution

The primary objective of this research was to elucidate the link between micro agent behaviours and macro level supply chain phenomenon. With SCD as a context and complex system thinking as its theoretical framework, the research also planned to identify a set of micro agent behaviours that could be linked to the cases of SCD.

The starting phase of the research enquiry revealed that the extant literature on SCD was deficient on the microstate agent perspective or behavioural aspect of operations and supply chain management. The majority of existing studies subscribed to the rational and complying human agent assumption and preferred to focus on structural and strategic drivers of SCD. In addition, the results from a systematic review of the literature revealed that the methodological perspective was dominated by simulation or survey based statistical techniques working with a restricted set of assumptions. While only a small number of studies looked at the phenomenon form interpretive or qualitative aspect. The contribution of human actions towards events of SCD was largely neglected in the literature.

As the research progressed, the motivation to establish a firm scholarly foundation to argue micro to macro causation led to the investigation of complex system's literature and its CAS perspective. Within the CAS literature there is a small body of research on supply chain as a CAS. Supply chain complexity literature was found to be aligned in their claim that micro agent behaviours and interactions can produce self-organization

and emergence in supply networks, leading to changes in the structure and operations of the network (Choi, Dooley and Rungtusanatham, 2001; Surana *et al.*, 2005; Pathak *et al.*, 2007; Nair, Narasimhan and Choi, 2009; Pathak, Dilts and Mahadevan, 2009; Bode and Wagner, 2015). However, despite a conceptual agreement on microstate agents' capacity to impose macro outcomes at network level, none of the existing studies list any kind of agent behaviours that could reflect upon the system or provide any empirical evidence to validate this claim. These studies treat micro to macro causation with a black box approach since they fail to provide intermediate steps that would indicate how aggregated agent behaviours result in systemic outcomes.

This doctoral research examines the intermediate steps associated with the mechanism translating micro agent behaviours to macro outcomes. By positioning the enquiry in systems' pattern associated with events of SCD and juxtaposing it with empirically derived agent behaviour and interaction profiles linked to the patterns; this study proposes that agent behaviours impose a tension on the system. In the dissipating structures theory of CAS, a tension imposed by microstate behaviours is called adaptive tension and systems with adaptive tension above a critical value show emergent properties. Supply chains under tension due to agent interactions and behaviours are also likely to demonstrate self-organization and emergence.

Elsewhere in organizational studies, it has been established that micro agent behaviour can lead to adaptive tension and if the adaptive tension goes beyond a critical value then the organization will demonstrate self-organization and emergence. These organizational studies have successfully operationalized terms like adaptive tension, critical value, dissipating structure, self-organization and emergence in leadership studies, new product development, and entrepreneurial studies. However, the conceptualization has not yet been adopted or formally used to argue CAS perspectives of supply chains. This thesis argues that CAS based supply chains studies need to define and operationalise these concepts in a supply chain setting. This is important to understand the influence of micro events on macro system phenomenon.

This doctoral research contributes in this domain of supply chain complexity research by formally introducing the concept related to adaptive tension, critical values, and zone of emergent complexity. It further operationalizes these concepts using an empirical

investigation. This study presents a conceptualization of supply chain emergence and self-organization from dissipative structures and adaptive tension based view of complexity. This is the ***first primary contribution*** of this research and is made to the domain of supply chain complexity research.

In their seminal work on supply chains as CAS, Choi, Dooley and Rungtusanatham (2001) calls for operationalising key constructs like emergence and self-organization in a supply chain perspective by observing system or organizational patterns linked to it. Discussing about the future research directions for supply chain complexity research, Choi, Dooley and Rungtusanatham (2001) argue;

"Supply networks can undergo significant structural changes when crisis is upon them. As the crisis looms and agents in the system become aware of the crisis state, how do they react to such crisis? What relations exist between the way agents reacted and SN performance?"

(Choi, Dooley and Rungtusanatham, 2001: pp365)

The above statement prompts researchers to study agent reactions to supply chain crisis and to formalise the relationship between agent actions and supply network performance during disruption or crisis.

Since no existing supply chain study documents the actions and behaviours of supply chain agents connected to events of crisis or disruption, there is an opportunity to contribute. This study answers the above call and extends the literature on supply chain disruption by going beyond the structural, strategic and operational drivers of SCD proposed in popular supply chain risk, vulnerability and disruption research (Stecke and Kumar, 2009; Chopra and Sodhi, 2004; Kleindorfer and Saad, 2005; Craighead et al., 2007; Papadakis, 2003), into the domain of behavioural operations management. This thesis contributes to the disruption research by identifying a set of agent behaviours and mindsets connected to events of supply disruption (Chapter 5 – table 23). These are; (i) lose trust in the organization (ii) over ambitious pursuit, (iii) use power and privilege to force one's own agenda, (iv) conspiring against acceptable best practices and (v) heedless performance. The findings formally introduce and establish the role of behavioural and cognitive element of human actions in a supply chain scenario. The

formalization of agent's perspective in SCD events and empirical validation of it is the ***second primary contribution*** of this research.

This research further contributes by answering the second question raised in the above statement by Choi, Dooley and Rungtusanatham (2001) about the kind of relationship between agent reactions and crisis performance of supply network. The question raised by Choi, Dooley and Rungtusanatham (2001) resonates closely to the first research question of this doctoral research that aims to explore the link between agent interactions and emergent system behaviours in events connected to SCD. The micro to macro causation model (Chapter 6 – Figure 7) particularly explicates alternative supply chain system pathways that a network under crisis can traverse. These pathways, bifurcating into order, emergence or chaos, are linked to both individual agent behaviours and aggregated system patterns, represented in the model as evidence of adaptive tension. A model that can be used to explain the possible future pathways of a supply chain under crisis is the ***third primary contribution*** of this research.

The micro to macro causation pathway model presented in the discussion chapter, figure 6 , also ***extends*** the existing work of Choi, Dooley and Rungtusanatham (2001), by explicating an intermediary mechanism linking events of emergence in a supply chain to agent behaviours at micro level. In doing so, the model also empirically ***validates*** the conceptual suggestions of Choi, Dooley and Rungtusanatham (2001) , Surana et al. (2005) and Nair, Narasimhan and Choi (2009) that micro state behaviours and schemas play a significant role in emergence and self-organization of supply chain networks and that supply chains are truly complex adaptive systems. This doctoral research affirms the complex adaptive system based conceptualization of supply chain networks by validating the claim that agent schemas and internal mechanism have an explanatory relevance for systemic phenomenon. This is the ***fourth primary contribution*** of this research

7.3 Secondary contribution

During the process of conducting this research, there were some insights gained on related literature domains.

The first secondary contribution relates to the assumption of the complying and rational human agent that is at the core of studies concerned with designing and optimising supply chain networks. It was observed in the literature review that supply chain disruption drivers were (Chapter 2 – Table 6) primarily conceptualized based upon structural and strategic antecedents of disruption. An underlying assumption of these studies had been that agent behaviours and cognition has no impact on the networks. Supply chain models and phenomenon explanations that disregard human aspect of behaviour have been thoroughly criticized in a small body of literature that is referred to as the behavioural operations management domain (Bendoly, Donohue and Schultz, 2006; Gino and Pisano, 2008; Bendoly *et al.*, 2009; Tokar, 2010). Bendoly et al. (2009) calls this lack of consideration of behavioural aspect as a major limitation of supply chain research which restricts the scope, depth and practical relevance of these studies. In theoretical research, Bendoly et al. (2009) present a compelling argument to support the behavioural aspects of supply chain management by positioning supply chain related constructs in four behavioural and cognitive literature domains; cognitive psychology, social psychology, group dynamics and system dynamics. Bendoly et al. (2009) call for future operations research to judge the impact of human behaviours and to present accountability of systemic phenomenon from a behavioural aspect. This call reiterates the suggestions made by Gino and Pisano (2008) to raise the awareness and legitimacy of the behavioural aspects of operations management. The findings from this doctoral research answer the above call. They formally introduce and establish the role of behavioural and cognitive element of human actions in a supply chain scenario. This is the ***first secondary contribution*** and is made to the domain of behavioural operations management.

Furthermore, this study contributes to the domain of supply chain resilience and robustness literature by identifying a link between system resilience and the behavioural and cognitive traits of people managing supply chains. This extends the current resilience debate that until now has not considered the managerial perspective or behavioural antecedents of a system's resilience. It is worthwhile to note that the human perspective of systems' reliability and resilience is an established body of literature in the high reliability organization theory (Vogus and Welbourne, 2003; Sutcliffe, 2011) and organizational safety domain (Reason, 1990, 1998); however, it is yet to be

accounted for in the supply chain robustness and resilience literature. This doctoral research presents a conceptualization and explanation of agent behaviours leading to supply chain resilience and robustness and validates it by using qualitative case data. This extends the current conversation in the supply chain resilience literature and is the ***second secondary contribution*** of this research.

The research also contributes to the ontological perspective of supply chain research which until now remains to be rigidly rooted in a positivist ontology and assumptions of deterministic causality (Aastrup and Halldórsson, 2008). Research approaches leaning on positivism fail to provide a context relevant explanation of 'how' or 'why' a particular supply chain phenomenon comes into existence (Sachan and Datta, 2005). This thesis proposes to use a critical realism driven mechanisms based enquiry to answer the 'how' and 'why' questions. Critical realism as a philosophical stance has found recognition in the wider organizational literature for its ability to provide context relevant explanations of causality (Mingers, 2000, 2006; Easton, 2010; Adamides, 2012; Wynn and Williams, 2012; Henfridsson and Bygstad, 2013; Peters *et al.*, 2013). However in supply chain research, to date, only two critical realist enquiries have been published in quality journals and these are: Adamides (2012) who uses a critical realism to study the inventories in a perishable goods supply chain, and Rotaru et al. (2014) who used Fredendall et al.'s (2009) research about operational failures in post-operative services of the health care industry to illustrate a critical realist methodology. This doctoral research furthers the domain of critical realism based research enquiry in supply chains and provides a field study to operationalise it in a SCD context. To summarise the ontological contribution, this study presents the utility of having a critical realist research design for investigating complex system phenomenon, particularly the ones that require accounting for an agent's perspective. It also demonstrates the utility of abductive reasoning in supply chain theory building. This is the ***third secondary contribution*** of this research.

On the methodological front, the use of Rep Grid triads to compare cases of SCD is unique to disruption research. The approach served its purpose of stimulating the respondent to present deeper levels of association among cases. It helped respondents to access and express insights buried under their abundant tacit and experiential

knowledge of supply chains and the cases they were discussing. The use of the 'Gioia methodology' to gain rigour in the use of grounded theory and present the qualitative findings in a very scientific manner is also a contribution as it has never been utilized for interrogating supply chain data. Together these two aspects of methodology form the ***fourth secondary contribution*** of this research.

7.4 Implications for practice

The aspects of SCD addressed in this research have significant implications for practice. Insights gained from the research can guide managers on aspects of human behaviour and its contributions to the management and design of supply chain networks.

Mulani and Hau (2002) argue that 40-60 % of supply chain managers' time is spent on handling disruptions. In hindsight, reflecting on my experience of talking to several supply chain executives from various organizations, an obvious conclusion was that supply chain executives were constantly involved in firefighting issues originating out of behaviour or actions of others. Indeed, they were handling disruptions as suggested by Mulani and Hau (2002), but on closer inspection it was found that they were constantly battling with behavioural aspects of the humans associated with the network. Respondents openly accepted that problems were triggered and amplified due to the behaviours of other organizational functions, organization's top management, representatives of suppliers and members of logistics companies. This is evident from the fact that out of 167 cases of SCD discussed by the respondents, only 12 cases relate to natural catastrophes or genuine problems originating in the extended network. While all the other cases had a behavioural antecedent associated to events leading up to disruption. Respondents also expressed their disappointment that the supply chain function is always burdened with the responsibility to cover for the errors made by other people, teams or organizational functions.

Accepting the importance of agent behaviours, actions and interactions, this doctoral research highlights particular destabilizing agent behaviours and actions that may lead to supply chain disruption. The practitioner community can gain from the list of agent behaviours proposed by this research to understand and avoid particular kind of disruptions that are propelled by behavioural interaction of humans engaged in the

supply network. For instance if managers observe that organizational members are losing trust in organization and its management, supply network members are disregarding processes or showing signs of opportunism /dishonesty and there are frequent instances where people repeatedly commit careless mistakes or show a lack of vigour towards adhering to the process requirements, then these observations are signs of accruing behavioural tension in the supply chain. Using the findings from the investigation of 167 real cases of SCD, this doctoral research demonstrates that impact of such kind of behaviours and the resulting behavioural tension could amplify under complex and dynamic conditions and that such behaviours of micro agent interactions should not be discounted. If supply chain managers are willing to avoid disruptions, they need to cautiously monitor and timely address such behaviours.

Findings of this research also indicate that supply chain members connected with events of disruption had problems with organizational hierarchy and inter functional alignment, which often resulted in supply chain members loosing motivation and willingness to perform as per organizational expectations. The patterns in the data indicated that an aggregated impact of inter-functional misalignment and demotivated supply chain members was increasing the likelihood of disruptions and was also severely undermining a network's capability to respond to disruptions. The practitioners should view this finding as a guideline to evaluate the events in their supply network regarding burgeoning issues related to organizational members losing their motivation or willingness to be resilient towards possible disruption scenarios. The findings demonstrated that events like; pushing supply chain members to expedite dispatches, compelling supply chain members to work additional hours to support urgent requests or asking supply chain to resolve issues originating from forecasting or planning blunders done by marketing function, can negatively impact the mind set and behaviour of supply chain members. Patterns in the data also revealed that if the organization fails to sufficiently recognize or reward the efforts of supply chain members then this could further damages the willingness and motivation of supply chain members to be proactive towards disruption incidents.

Moreover, the insights from this research are important for supplier management practices. Managers and organizational members should be aware of the levels of

opportunism and false commitments made by people representing suppliers and such practices should be recognized at the earliest. The findings suggest that if such incidences or practices persist, then they have a potential to escalate into bitter tussles and in extreme circumstances culminate into disruptions. Managers should work towards reducing the effects and impact of such behaviours.

Patterns from the 167 cases of disruption discussed in the findings are also indicative that behaviour of organizational actors was more prone to cause disruption under some typical system and ongoing conditions such as, while launching a new product, products that have complex design or manufacturing requirements, product purchases that are either first time or one off purchase and asymmetry among network partners in terms of power , volume or turnover dependency. Organizations can gain from awareness of these conditions/ disruption context as these conditions have a strong bearing on people's behaviour and the outcomes of disruption events. Managers are advised to carefully consider the context of the procurement and judge the associated behaviours of stakeholders to evaluate the quality of the relationship.

This doctoral research further demonstrates that managerial behaviours and actions targeted at supporting struggling suppliers could improve disruption performance. Incidents reveal that behaviour of procurement and supply management teams could have a great impact on the completion of complex outsourced tasks. Based upon the task requirement, the supplier management team should establish their behaviours and degree of support rendered to their suppliers and this should not be just restricted to Tier 1 suppliers but should also be extended to key accounts on Tier 2 as well. A case connected to firm 2 demonstrated that going an extra mile to help a struggling Tier-2 supplier's manufacturing unit facing a labour strike helped firm 2 avoid a major disruption. Firm 18 also went beyond the contractually committed support to help a supplier avoid losses, while contrary to these examples, firm 21 followed a callous and apathetic attitude towards their suppliers which led to severe disruptions.

Finally, this study demonstrated that agent behaviours supporting resilience and robustness were contingent upon two aspects; (i) the prevailing organizational culture that supported decentralized decision making and out of the box thinking; and (ii) individual traits of the managers that prompts them to take bold decisions and go an

extra mile to pursue disruptions. In eight disruption cases related to firm 7 and three cases from firm 2, supply chain executives adopted out of the box thinking and over ambitious pursuit, resulting in avoidance of disruptions. This is a crucial finding for organizational decision makers responsible for harnessing organizational culture as a culture promoting such managerial traits could reinforce the performance of supply networks. In hierarchical organizations, there is a need to introspect the prevailing rigidity in organizational cultures and the prominence of a top down hierarchy and conventional decision making. The cases support the view that there is a need for decentralizing decision making and supporting innovative and creative approaches.

To summarise the implications for practice, the most important takeaway for organizations is that this study succeeds in providing organizations with an explanation for observed deviations in their operations performance using a behavioural aspect of human agents. Using the findings of the research, firms and managers will be able to look beyond normative supply chain models and operational procedures into the aspect of how these procedures are disposed in an operations environment. Being aware of agent behaviours and schemas relevant to SCD, firms will be able to draw better interventions and create more robust strategies to tackle events of disruption.

A summary of all the contributions is presented in table 31.

7.5 Limitations

Like all research, there are limitations that are to be noted. First, the research strategy of investigating cases related to SCD required to take some key design decisions which imposed certain limitations on the outcomes. The decision to adopt a purposeful sampling technique over a random or theoretical sampling could be argued to be influencing the patterns of outcomes observed in the findings; it was heavily biased towards manufacturing firms. Also, in pursuit to control both a sufficient degree of variety and of similarity among the investigated cases, the opportunity to evaluate the idiosyncratic possibilities associated with random sampling were compromised.

Data collection posed another limitation for the research. The interview data used in this research is reliant on a single respondent from each firm. Whilst, respondents were senior managers with first-hand experience of SCD, reliance on a single respondent

could add an element of personal bias and thus in future there is a need to include the viewpoints of other agents associated with the SCD events. Thirdly, SCD are temporal events and necessarily our study was reliant on retrospective accounts. This puts a limitation on the ability of the respondents to sufficiently and accurately account for elements associated with these historical events.

Table 31: Summary of contributions

Type of contribution	Description of the contribution
Primary contributions	• presents the conceptualization of supply chain emergence and self-organization from dissipative structures and adaptive tension based view of complexity. • Formalizes the agent perspective in SCD events and empirically validating it in a field based case study by presenting a set of agent behaviours contributing to the departure of supply chain from normal operating conditions and influencing network disruptions. • A model that can be used to explain the possible future pathways of a supply chain under crisis • affirms the complex adaptive system based conceptualization of supply chain networks by validating the claim that agent schemas and internal mechanism have an explanatory relevance for systemic phenomenon.
Secondary contributions	• establish the role of behavioural and cognitive element of human actions in a supply chain scenario • presents a conceptualization and explanation of agent behaviours leading to supply chain resilience and robustness and validates it by using qualitative case data. • presents a systematic data collection tool of Repertory Grids as a preferred technique to help respondents articulate and discover agent and agency aspect of a supply chain phenomenon. • presents the utility of having a critical realist research design for investigating complex system phenomenon, particularly the ones that require accounting for an agent perspective. It also proves the utility of abductive reasoning in supply chain theory building. • operationalise a modified version of grounded theory based inductive, qualitative analysis framework based upon Gioia methodology.
Contribution to practice	• provide organizations with an explanation for observed deviations in their operations performance using a behavioural aspect of human agents. Using the findings of the research, firms and managers will be able to look beyond meagre normative supply chain models and operation procedures into the aspect how these procedures are disposed in an operations environment. • help organizations to draw interventions and strategies. Being aware of agent behaviours and schemas relevant to SCD, firms will be able to draw better interventions and more robust strategies to tackle events of disruption.

Furthermore, in each case the data was collected from only the focal firm. The issues and concerns raised by respondents about their suppliers could neither be verified nor correlated with their partner's perspective. A one-sided analysis of relationships and behaviours could be argued to limit the possibility of developing deeper insights.

Lastly, in an effort to conceptualize causal mechanisms influencing the micro to macro transformation of agent behaviours, from a critical realist perspective, required a degree of creativity and theory matching which could be judged as subjective. Although, the

use of abductive logic for theory matching between the observed and available theoretical explanations is a proven research methodology for a critical realist perspective, yet it limits the possibility to comment on other possible mechanisms that may be active in the investigated cases.

7.6 Direction for future research

The outcomes of this research and the discussions of its limitations are suggestive of possible future research endeavours that could address unanswered questions related to this doctoral enquiry.

The theoretical model proposed in this thesis can be extended and refined by evaluating behavioural aspects from either side of a relationship. The escalation of adaptive tension due to agent interactions, in a supplier buyer context, can be better expressed if narratives of tension causing micro agent interactions are correlated from each side and inference drawn about accompanied agent schemas prompting such behaviours.

The theoretical model proposed in this thesis presents a very restrictive account of agent schemas and mindsets and that is an area that needs to be further extended. In the organizational behaviour literature, there are instruments available to account for cognitive and behavioural aspects of organizational members, for example empirical study on organizational citizenship behaviour and counter productive work behaviour by Dalal (2005). These proven instruments can be used to enrich our understanding of behavioural aspects of supply chains. It should be noted that this doctoral thesis came up with only negative and destabilizing agent behaviours, however there will be an abundance of agent behaviours that may be positively contributing to a supply chain's performance. This could include citizenship behaviour, positive deviance, creative deviance etc.

The concept of emergence and self-organization has been viewed in a positive light in new product development and entrepreneurship literature. There is a need to conceptualize the supply chain zone of emergent complexity from a positive viewpoint. Supply chains within a zone of emergent complexity that support positive adaptation and self-organization could provide useful insights for designing adaptable, resilient and

robust supply networks. This is an area that needs attention from micro interaction and adaptive tension perspective.

Future studies could further examine the contextual conditions that contribute to destabilization, particularly using configurational approaches that stress nonlinear relationships and conjunctural causality and identify the combinations of factors that shape particular outcomes (Ragin, 1987; Fiss, 2007). Whether and why certain behaviours cause greater magnitude SCD events than others. The findings here also raise questions about how micro level actions might generate other macro level outcomes. An adaptive tension based explanation of more supply chain phenomenon could be investigated. These future studies could focuses on how these outcomes are produced, and the agent schemas that give rise to action, how acts, activities and interactions are undertaken and how these actions have transformational effects.

7.7 Summary

This chapter presented a discussion of the contributions of this research to both the academic and practitioner community, accounted for its limitations and lastly provided future directions that could further extend or enrich the findings of this research contribution. This formally concludes this doctoral research and this thesis.

REFERENCES

Aastrup, J. and Halldórsson, Á. (2008) 'Epistemological role of case studies in logistics: A critical realist perspective', *International Journal of Physical Distribution & Logistics Management*, 38(10), pp. 746–763. doi: 10.1108/09600030810926475.

Adamides, E. D. (2012) 'Critical realism in supply chain research: Understanding the dynamics of a seasonal goods supply chain', *International Journal of Physical Distribution & Logistics Management*, 42(10), pp. 906–930. doi: 10.1108/09600031211281420.

Adenso- Diaz, B., Mena, C., García- Carbajal, S. and Liechty, M. (2012) 'The impact of supply network characteristics on reliability', *Supply Chain Management: An International Journal*, 17(3), pp. 263–276. doi: 10.1108/13598541211227108.

Albino, V., Garavelli, A. and Okogbaa, O. (1998) 'Vulnerability of production systems with multi-supplier network: A case study', *International Journal of Production Research*, 36(11), pp. 3055–3066. doi: 10.1080/002075498192283.

Allen, P. M. and Varga, L. (2006) 'A co-evolutionary complex systems perspective on information systems', *Journal of Information Technology*, 21(4), pp. 229–238. doi: 10.1057/palgrave.jit.2000075.

Amaral, L. a. N. and Ottino, J. M. (2004) 'Complex networks', *The European Physical Journal B - Condensed Matter*, 38(2), pp. 147–162. doi: 10.1140/epjb/e2004-00110-5.

Anderson, P. J. J. (2006) 'Understanding Mechanisms in Organizational Research: Reflections From a Collective Journey', *Journal of Management Inquiry*, 15(2), pp. 102–113. doi: 10.1177/1056492605280231.

Anderson, P. W. (1999) 'Perspective: Complexity theory and organization science', *Organization Science*, 10(3), pp. 216–232.

Archer, M. S. (1995) *Realist social theory: The morphogenetic approach*. Cambridge University Press.

Ashby, W. R. (1956) *An introduction to cybernetics*. London: Chapman and Hall.

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*. Elsevier B.V., 227(1), pp. 199–215. doi: 10.1016/j.ejor.2012.12.017.

Bak, P. (1996) *How nature works: The science of self-organized criticalit*. New York: Copernicus.

Bartunek, J. M. (1983) 'Changing interpretive schemes and organizational restructuring : The example of a religious order'.

Benbya, H. and McKelvey, B. (2006) 'Toward a complexity theory of information systems development', *Information Technology & People*. Edited by E. Jacucci, 19(1), pp. 12–34. doi: 10.1108/09593840610649952.

Bendoly, E., Croson, R., Goncalves, P. and Schultz, K. (2009) 'Bodies of knowledge for research in behavioral operations', *Production and Operations Management*, 19(4), pp. 434–452. doi: 10.1111/j.1937-5956.2009.01108.x.

Bendoly, E., Donohue, K. and Schultz, K. L. (2006) 'Behavior in operations management: Assessing recent findings and revisiting old assumptions', *Journal of Operations Management*, 24(6), pp. 737–752. doi: 10.1016/j.jom.2005.10.001.

Bertalanffy, L. Von (1972) 'The history and status of general systems theory', *Academy of Management Journal.*, 15(4), pp. 407–426. doi: 10.2307/255139.

Beyer, J. M. and Trice, H. M. (1984) 'A field study of the use and perceived effects of discipline in controlling work performance', *Academy of Management Journal*, 27(4), pp. 743–764. doi: 10.2307/255876.

Bhaskar, R. (1975) *A realist theory of science*. Leeds: Leeds Books.

Bhaskar, R. (1989) 'Reclaiming reality', *A critical introduction to contemporary philosophy*.

Bhaskar, R. (1998) 'The possibility of naturalism: a philosophical critique of the contemporary human sciences', *Critical Realism--Interventions*.

Bhaskar, R. (2010) *Reclaiming reality: A critical introduction to contemporary*

philosophy. Taylor and Francis.

Blackhurst, J., Craighead, C. W., Elkins, D. and Handfield, R. B. (2005) 'An empirically derived agenda of critical research issues for managing supply-chain disruptions', *International Journal of Production Research*. Taylor & Francis Ltd, 43(19), pp. 4067–4081. doi: 10.1080/00207540500151549.

Bode, C. and Wagner, S. M. (2015) 'Structural drivers of upstream supply chain complexity and the frequency of supply chain disruptions', *Journal of Operations Management*, 36, pp. 215–228. doi: 10.1016/j.jom.2014.12.004.

Bode, C., Wagner, S. M., Petersen, K. J. and Ellram, L. M. (2011) 'understanding responses to supply chain disruptions: insights from information processing and resource dependence perspectives', *Academy of Management Journal*. Academy of Management, 54(4), pp. 833–856. doi: 10.5465/AMJ.2011.64870145.

Bradshaw, J. . ., Ford, K. M., Adams-Webber, J. R. and Boose, J. H. (1993) 'Beyond the repertory grid. New approaches to constructivist knowledge acquisition tool development', *International Journal of Intelligent Systems*, 8(2), pp. 287–333.

Braunscheidel, M. J. and Suresh, N. C. (2009) 'The organizational antecedents of a firm's supply chain agility for risk mitigation and response', *Journal of Operations Management*, 27(2), pp. 119–140. doi: 10.1016/j.jom.2008.09.006.

Buckley, W. F. (1998) *Society - A complex adaptive system: Essays in social theory*. Taylor and Francis.

Bygstad, B. and Munkvold, B. (2011) 'In search of mechanisms. Conducting a critical realist data analysis', *ICIS*, 9.

Cantor, D. E., Blackhurst, J. V and Cortes, J. D. (2014) 'The clock is ticking: The role of uncertainty, regulatory focus, and level of risk on supply chain disruption decision making behavior', *Transportation Research Part E: Logistics and Transportation Review*, 72, pp. 159–172. doi: 10.1016/j.tre.2014.10.007.

Chen, K. and Xiao, T. (2015) 'Outsourcing strategy and production disruption of supply chain with demand and capacity allocation uncertainties.', *International Journal of*

Production Economics, 170, pp. 243–257. Available at: http://10.0.3.248/j.ijpe.2015.09.028.

Chiles, T. H., Meyer, A. D. and Hench, T. J. (2004) 'Organizational emergence: the origin and transformation of Branson Missouri's musical theatres', *Organization Science*, 15(5), pp. 499–519. doi: 10.1287/orsc.

Chiva-Gomez, R. (2004) 'Repercussions of complex adaptive systems on product design management', *Technovation*, 24(9), pp. 707–711. doi: 10.1016/S0166-4972(02)00155-4.

Choi, T. Y., Dooley, K. J. and Rungtusanatham, M. (2001) 'Supply networks and complex adaptive systems: control versus emergence', *Journal of Operations Management*, 19(3), pp. 351–366. doi: 10.1016/S0272-6963(00)00068-1.

Chopra, S. and Sodhi, M. (2004) 'Managing risk to avoid supply-chain breakdown', *MIT Sloan Management Review*, pp. 53–62. Available at: http://sloanreview.mit.edu/article/managing-risk-to-avoid-supplychain-breakdown/ (Accessed: 12 August 2013).

Christopher, M. and Lee, H. (2004) 'Mitigating supply chain risk through improved confidence', *International Journal of Physical Distribution & Logistics Management*, 34(5), pp. 388–396. doi: 10.1108/09600030410545436.

Christopher, M. and Peck, H. (2004) 'Building the resilient supply chain', *International Journal of Logistics …*, (2004). Available at: http://www.emeraldinsight.com/journals.htm?articleid=1527548&show=abstract (Accessed: 12 August 2013).

Clemons, R. and Slotnick, S. A. (2016) 'The effect of supply-chain disruption, quality and knowledge transfer on firm strategy.', *Intern. Journal of Production Economics*, 178, pp. 169–186. doi: 10.1016/j.ijpe.2016.05.012.

Cohen, J. and Stewart, I. (1994) *The collapse of chaos: Discovering simplicity in a complex world*. New York.: Viking.

Cohen, M. D. and Axelrod, R. (1984) 'Coping with complexity: The adaptive value of

changing utility', *The American Economic Review*, 74(1), pp. 30–42.

Colicchia, C., Dallari, F. and Melacini, M. (2010) 'Increasing supply chain resilience in a global sourcing context', *Production Planning & Control*, 21(7), pp. 680–694. Available at: http://www.tandfonline.com/doi/abs/10.1080/09537280903551969 (Accessed: 26 May 2013).

Cook, D., Mulrow, C. and Haynes, R. B. (1997) 'Synthesis of best evidence for clinical decisions', *Annals of Internal Medicine*, 126, pp. 376–380. doi: 10.7326/0003-4819-126-5-199703010-00006.

Craighead, C. W., Blackhurst, J., Rungtusanatham, M. J. and Handfield, R. B. (2007) 'The severity of supply chain disruptions: design characteristics and mitigation capabilities', *Decision Sciences*. Wiley-Blackwell, 38(1), pp. 131–156. doi: 10.1111/j.1540-5915.2007.00151.x.

Cramer, F. (1993) *Chaos and order: the complex structure of living things (trans. DL Loewus)*. New York: VCH.

Creswell, J. W. (2013) *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. 4th edn. Sage, Thousand Oaks.

Daft, R. L. and Weick, K. E. (1984) 'Toward a model of organizations as interpretation systems', *Academy of Management Review*, 9(2), pp. 284–295. doi: 10.5465/AMR.1984.4277657.

Dalal, R. S. (2005) 'A meta-analysis of the relationship between organizational citizenship behavior and counterproductive work behavior', 90(6), pp. 1241–1255. doi: 10.1037/0021-9010.90.6.1241.

Datta, P. P., Christopher, M. and Allen, P. (2007) 'Agent-based modelling of complex production/distribution systems to improve resilience', *International Journal of Logistics Research and Applications*, 10(3), pp. 187–203. doi: 10.1080/13675560701467144.

Dawson, C. (2002) *Practical research methods: a user-friendly guide to mastering research techniques and projects*. Oxford:How to books.

Denyer, D., Tranfield, D. and van Aken, J. E. (2008) 'Developing design propositions through research synthesis', *Organization Studies*, 29(3), pp. 393–413. Available at: http://oss.sagepub.com/cgi/doi/10.1177/0170840607088020.

Depew, D. J. and Weber, B. H. (1995) *Darwinism Evolving: Systems Dynamics and the Genealogy of Natural Selection*. Cambridge, MA.: MIT Press.

DiMaggio, P. J. (2010) 'Culture and Cognition', 23(1997), pp. 263–287.

Dooley, K. (1996) 'A Nominal Definition of Complex Adaptive Systems', *Chaos Network*, 8(1), pp. 2–3. Available at: http://www.mendeley.com/research/complex-adaptive-systems-nominal-definition/.

Dooley, K. J., Johnson, T. L. and Bush, D. H. (1995) *TQM, Chaos and Complexity*, *Human Systems Management*. doi: 10.3233/HSM-1995-14403.

Dowty, R. A. and Wallace, W. A. (2010) 'Implications of organizational culture for supply chain disruption and restoration', *International Journal of Production Economics*, 126(1), pp. 57–65. doi: 10.1016/j.ijpe.2009.10.024.

Dubois, A. and Gadde, L. E. (2002) 'Systematic combining: An abductive approach to case research', *Journal of Business Research*, 55(7), pp. 553–560. doi: 10.1016/S0148-2963(00)00195-8.

Easterby-Smith, Mark Thorpe, R. and Jackson, P. (2012) *Management Research*. 4th edn. Sage.

Easton, G. (2010) 'Critical realism in case study research', *Industrial Marketing Management*, 39(1), pp. 118–128. doi: 10.1016/j.indmarman.2008.06.004.

Edmondson, A. C. and McManus, S. E. (2007) 'Methodological fit in management field research', *Academy of Management Review*, 32(4), pp. 1155–1179. doi: 10.5465/AMR.2007.26586086.

Eigen, M. and Schuster, P. (1979) *The Hypercycle: A Principle of Natural Self-Organization*. New York: Simon and Schuster.

Eisenhardt, K. . M. and Sull, D. N. (2001) 'Strategy as Simple Rules', *Havard Business Review*.

Eisenhardt, K. M. (1989) ‘Building Theories From Case Study Research’, *The Academy of Management Review*, 14(4), pp. 532–550.

Emirbayer, M. and Mische, A. (1998) ‘What Is Agency?’, *Amaerican Journal of Sociology*, 103(4), pp. 962–1023.

Eve, R. A., Horsfall, S. and Lee, M. E. (1997) *Chaos, complexity, and sociology: Myths, models, and theories*. Sage.

Faisal, M. N., Banwet, D. K. and Shankar, R. (2006) ‘Supply chain risk mitigation: modeling the enablers’, *Business Process Management Journal*, 12(4), pp. 535–552. doi: 10.1108/14637150610678113.

Fiksel, J. (2006) ‘Sustainability and resilience: toward a systems approach’, *Sustainability: Science Practice and Policy*, 2(2). Available at: http://sspp.proquest.com/static_content/vol2iss2/0608-028.fiksel-print.html (Accessed: 16 April 2014).

Fiss, P. C. (2007) ‘A set-theoretic approach to organizational configurations’, *Academy of Management Review*, 32(4), pp. 1190–1198. doi: 10.5465/AMR.2007.26586092.

Fleetwood, S. (2005) ‘Ontology in organization and management studies: a critical realist perspective’, 12(2), pp. 197–222. doi: 10.1177/1350508405051188.

Fredendall, L. D., Craig, J. B., Fowler, P. J. and Damali, U. (2009) ‘Barriers to swift, even flow in the internal supply chain of perioperative surgical services department: A case study’, *Decision Sciences*, 40(2), pp. 327–349. doi: 10.1111/j.1540-5915.2009.00232.x.

Friesz, T. L., Lee, I. and Lin, C.-C. (2011) ‘Competition and disruption in a dynamic urban supply chain’, *Transportation Research: Part B*, 45(8), pp. 1212–1231. Available at: http://10.0.3.248/j.trb.2011.05.005.

Gell-Mann, M. (1994) *The Quark and the Jaguar*. New York: W H Freeman and Company.

Gell-Mann, M. (2002) ‘What is Complexity?’, in *Complexity and industrial clusters*, pp. 13–24.

George, E., Chattopadhyay, P., Sitkin, S. B. and Barden, J. (2006) 'Cognitive Underpinnings of Institutional and Change : Persistence a Framing', *Academy of Management Review*, 31(2), pp. 347–365. doi: 20159206.

Giddens, A. (1984) *The constitution of society: Outline of the theory of structuration*. Univ of California Press.

Gino, F. and Pisano, G. P. (2008) 'Toward a theory of behavioral operations', *Manufacturing and Service Operations Management*, 10(4), pp. 676–691. doi: 10.1287/msom.1070.0205.

Gioia, D. a., Corley, K. G. and Hamilton, A. L. (2013) 'Seeking Qualitative Rigor in Inductive Research', *Organizational Research Methods*, 16(1), pp. 15–31. doi: 10.1177/1094428112452151.

Giri, B. C. and Bardhan, S. (2015) 'Coordinating a supply chain under uncertain demand and random yield in presence of supply disruption.', *International Journal of Production Research*, 53(16), pp. 5070–5084. Available at: http://10.0.4.56/00207543.2015.1030469.

Glaser, Barney, and A. S. (1967) *The discovery grounded theory: strategies for qualitative inquiry*. Chicago: Aldin.

Glaser, B. G. and Strauss, A. L. (2009) *The discovery of grounded theory: Strategies for qualitative research*. Transaction publishers.

Glaser, B. and Strauss, A. (1967) *The Discovery of Grounded Theory: Strategies For Qualitative Research*. London: Wiedenfeld and Nicholson.

Gligor, D. M. and Holcomb, M. (2013) 'The role of personal relationships in supply chains', *The International Journal of Logistics Management*, 24(3), pp. 328–355. doi: 10.1108/IJLM-07-2012-0067.

Goetschalckx, M., Huang, E. and Mital, P. (2012) 'Robust global supply network design', *Information, Knowledge, Systems …*, 11, pp. 119–130. Available at: http://iospress.metapress.com/index/Y8388X3712652725.pdf (Accessed: 26 June 2014).

Goffin, K., Raja, J. Z., Claes, B., Szwejczewski, M. and Martinez, V. (2012) 'Rigor in qualitative supply chain management research', *International Journal of Physical Distribution & Logistics Management*. Edited by D. Flint, 42(8/9), pp. 804–827. doi: 10.1108/09600031211269767.

Goldspink, C. and Kay†, R. (2003) 'Organizations as self-organizing and sustaining systems: a complex and autopoietic systems perspective', *International Journal of General Systems*, 32(5), pp. 459–474. doi: 10.1080/0308107031000135017.

Golgeci, I. and Ponomarov, S. Y. (2013) 'Does firm innovativeness enable effective responses to supply chain disruptions? An empirical study.', *Supply Chain Management*, 18(6), pp. 604–617. doi: 10.1108/SCM-10-2012-0331.

Greening, P. and Rutherford, C. (2011) 'Disruptions and supply networks: a multi-level, multi-theoretical relational perspective', *The International Journal of Logistics Management*, 22(1), pp. 104–126. doi: 10.1108/09574091111127570.

Hair, N., Rose, S. and Clark, M. (2009) 'Using qualitative repertory grid techniques to explore perceptions of business-to-business online customer experience', *Journal of Customer Behaviour*, 8(1), pp. 51–65. Available at: http://openurl.ingenta.com/content/xref?genre=article&issn=1475-3928&volume=8&issue=1&spage=51.

Handfield, R. B. and Nichols, E. . (1999) *Introduction to supply chain management*. Englewood Cliffs, NJ: Prentice Hall.

Hannah, D. R. and Robertson, K. (2015) 'Why and how do employees break and bend confidential information protection rules?', *Journal of Management Studies*, 52(3), pp. 381–413. doi: 10.1111/joms.12120.

Hanson, N. R. (1958) 'The logic of discovery', *The Journal of Philosophy*, 55(25), pp. 1073–1089.

Harland, C., Brenchley, R. and Walker, H. (2003) 'Risk in supply networks', *Journal of Purchasing and Supply Management*, 9(2), pp. 51–62. doi: 10.1016/S1478-4092(03)00004-9.

Hendricks, K. B. and Singhal, V. R. (2003) 'The effect of supply chain glitches on shareholder wealth', *Journal of Operations Management*, 21(5), pp. 501–522.

Hendricks, K. B. and Singhal, V. R. (2005) 'An Empirical Analysis of the Effect of Supply Chain Disruptions on Long-Run Stock Price Performance and Equity Risk of the Firm.', *Production & Operations Management*. Wiley-Blackwell, 14(1), pp. 35–52.

Henfridsson, O. and Bygstad, B. (2013) 'The generative mechanisms of digital infrastructure evolution', *Mis Quarterly*, 37(3), pp. 907–931. Available at: http://www.academia.edu/download/30291507/Henfridsson_and_Bygstad_accepted_distribution_version.pdf (Accessed: 1 September 2014).

Holland, J. (2006) 'Studying complex adaptive systems', *Journal of Systems Science and Complexity*, (November 2005), pp. 1–8. Available at: http://link.springer.com/article/10.1007/s11424-006-0001-z (Accessed: 22 January 2014).

Holland, J. H. (1993) 'Echoing Emergence', *Santa Fe, NM*.

Holland, J. H. (1995) *Hidden Order: How Adaptation Builds Complexity*. USA: Addison Wesley Publishing Company.

Huang, Y., Zhang, Z. and Zhang, X. (2010) 'Assessment and management vulnerability of supply networks structure based on social networks analysis', in *2010 IEEE International Conference on Advanced Management Science(ICAMS 2010)*, pp. 128–132. doi: 10.1109/ICAMS.2010.5553272.

Hung, K.-T., Ro, Y. K. and Tangpong, C. (2009) 'Agent Characteristics and Compliance Behavior in Supply Chain Disruptions.', *Journal of Business & Management*. Journal of Business & Management, 15(1), pp. 51–71. Available at: https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=51003317&site=ehost-live.

Ivanov, D., Sokolov, B. and Dolgui, A. (2014) 'The Ripple effect in supply chains: trade-off "efficiency-flexibility-resilience" in disruption management.', *International Journal of Production Research*. Taylor & Francis Ltd, 52(7), pp. 2154–2172. doi: 10.1080/00207543.2013.858836.

Jankowicz, D. (2005) *The Easy Guide to Repertory Grids*. UK: John Wiley & Sons.

Jüttner, U. and Maklan, S. (2011) 'Supply chain resilience in the global financial crisis: an empirical study', *Supply Chain Management: An International Journal*, 16(4), pp. 246–259. Available at: http://www.emeraldinsight.com/10.1108/13598541111139062 (Accessed: 6 November 2012).

Juttner, U., Peck, H. and Christopher, M. (2003) 'Supply chain risk management: outlining an agenda for future research', *International Journal of Logistics Research and Applications*, 6(4), pp. 197–210. doi: 10.1080/1367556031000162701 6.

Kauffman, S. A. (1993) *The Origins of Order: Self-Organization and Selection in Evolution*. New York: Oxford University Press.

Kaye, B. (1993) *Chaos & Complexity*. New York: VCH.

Kelly, G. A. (1955) *The Psychology of Personal Constructs*. New York: Norton.

Kempster, S. (2006) 'Leadership learning through lived experience: A process of apprenticeship?', *Journal of Management and Organization*, 12(1), pp. 4–22. doi: 10.5172/jmo.2006.12.1.4.

Kempster, S. and Parry, K. (2014) 'Critical Realism and Grounded Theory', in Edwards, P. K., Mahoney, J. O., and Vincent, S. (eds) *Studying Organizations Using Critical Realism. A Practical Guide*. Oxford, UK: Oxford University Press, pp. 86–108.

Kempster, S. and Parry, K. W. (2011) 'Grounded theory and leadership research: A critical realist perspective', *Leadership Quarterly*. Elsevier B.V., 22(1), pp. 106–120. doi: 10.1016/j.leaqua.2010.12.010.

Kim, Y., Chen, Y.-S. and Linderman, K. (2015) 'Supply network disruption and resilience: A network structural perspective', *Journal of Operations Management*. Falls Church: Elsevier Sequoia S.A., 33–34, p. 43. Available at: http://search.proquest.com/docview/1655113641?accountid=10297.

Kleindorfer, P. R. and Saad, G. H. (2009) 'Managing Disruption Risks in Supply Chains', *Production and Operations Management*. Wiley-Blackwell, 14(1), pp. 53–68. doi: 10.1111/j.1937-5956.2005.tb00009.x.

Kumar, S., Liu, J. and Demirag, O. C. (2015) 'National Culture's Impact on Effectiveness of Supply Chain Disruption Management', *The Journal of Applied Business and Economics*. Thunder Bay: North American Business Press, 17(4), pp. 11–29. Available at: http://search.proquest.com/docview/1764139199?accountid=10297.

Layder, D. (1990) *The Realist Image in Social Science*. New York: St. Martin's Press.

Lee, T. W. (1993) *Using Qualitative Methods in Organizational Research*. Sage.

Levin, S. a. (1998) 'Ecosystems and the Biosphere as Complex Adaptive Systems', pp. 431–436. doi: 10.1007/s100219900037.

Levy, D. (1994) 'Chaos theory and strategy: theory, application. And managerial implication', *Strategic Management Journal*, 15, pp. 167–178.

Lichtenstein, B. (2000) 'Self-organized transitions: A pattern amid the chaos of transformative change.', *Academy of Management Perspectives*, 14(4), pp. 128–141. doi: 10.5465/AME.2000.3979821.

Lichtenstein, B. B., Carter, N. M., Dooley, K. J. and Gartner, W. B. (2007) 'Complexity dynamics of nascent entrepreneurship', *Journal of Business Venturing*, 22(2), pp. 236–261. doi: 10.1016/j.jbusvent.2006.06.001.

Lichtenstein, B. B. and Plowman, D. A. (2009) 'The leadership of emergence: A complex systems leadership theory of emergence at successive organizational levels', *Leadership Quarterly*. Elsevier Inc., 20(4), pp. 617–630. doi: 10.1016/j.leaqua.2009.04.006.

Mainemelis, C. (2010) 'Stealing fire: Creative deviance in the evolution of new ideas', *Academy of Management Review*, 35(4), pp. 558–578. doi: 10.5465/AMR.2010.53502801.

Mainzer, K. (1997) *Thinking in Complexity: The Complex Dynamics of Matter, Mind, and Mankind*. 3rd edn. New York: Springer- Verlag.

Manuj, I. and Mentzer, J. T. (2008a) 'Global Supply Chain Risk Management', *Journal of Business Logistics*, 29(1), pp. 133–155. doi: 10.1002/j.2158-1592.2008.tb00072.x.

Manuj, I. and Mentzer, J. T. (2008b) 'Global supply chain risk management strategies',

International Journal of Physical Distribution & Logistics Management, 38(3), pp. 192–223. Available at: http://www.emeraldinsight.com/10.1108/09600030810866986 (Accessed: 27 February 2013).

Manuj, I. and Pohlen, T. L. (2012) 'A reviewer's guide to the grounded theory methodology in logistics and supply chain management research', *International Journal of Physical Distribution & Logistics Management*. Edited by D. Flint, 42(8/9), pp. 784–803. doi: 10.1108/09600031211269758.

Marley, K. A., Ward, P. T. and Hill, J. A. (2014) 'Mitigating supply chain disruptions – a normal accident perspective.', *Supply Chain Management*, 19(2), pp. 142–152. Available at: http://10.0.4.84/SCM-03-2013-0083.

McAdam, D. and Scott, W. . (2005) *Organizations and movements, Social movements and organization theory*.

Mccarthy, I. P., Tsinopoulos, C., Allen, P. and Rose-anderssen, C. (2006) 'New Product Development as a Complex Adaptive System of Decisions', pp. 437–456.

McClelland, P. L., Xin Liang and Barker, V. L. (2010) 'CEO Commitment to the Status Quo: Replication and Extension Using Content Analysis', *Journal of Management*, 36(5), pp. 1251–1277. doi: 10.1177/0149206309345019.

McKelvey, B. (1999a) 'Avoiding Complexity Catastrophe in Coevolutionary Pockets: Strategies for Rugged Landscapes', *Organization Science VO - 10*, 10(3), pp. 294–321. doi: 10.1287/orsc.10.3.294.

McKelvey, B. (1999b) 'Self-Organization, Complexity Catastrophe, and Microstate Models at the Edge of Chaos', in *Variations in Organization Science. In Honor of Donald T. Campbell*, pp. 279–307.

McKelvey, B. (2001) 'Energising Order-Creating Networks of Distributed Intelligence: Improving the Corporate Brain', *International Journal of Innovation Management*, 5(2), pp. 181–212. doi: 10.1142/S1363919601000348.

McKelvey, B. (2002) 'Emergent order in firms : complexity science vs . The entanglement trap', *Complex Systems and Evolutionary Perspectives of Organizations:*

Applications of Complexity Theory to Organizations, (1), pp. 1–15.

McKelvey, B. (2004) 'Toward a complexity science of entrepreneurship', *Journal of Business Venturing*, 19(3), pp. 313–341. doi: 10.1016/S0883-9026(03)00034-X.

Meepetchdee, Y. and Shah, N. (2007) 'Logistical network design with robustness and complexity considerations', *International Journal of Physical Distribution & Logistics Management*, 37(3), pp. 201–222. doi: 10.1108/09600030710742425.

Miles, M. B. and Huberman, A. M. (1984) *Qualitative Data Analysis: A Source Book of New Methods*. Newbury Park, CA: Sage.

Mingers, J. (2000) 'The contribution of critical realism as an underpinning philosophy for OR/MS and systems', *Journal of the Operational Research Society*, 51(11), pp. 1256–1270. doi: 10.1057/palgrave.jors.2601033.

Mingers, J. (2006) 'A critique of statistical modelling in management science from a critical realist perspective: its role within multimethodology', *Journal of the Operational Research Society*, 57(2), pp. 202–219. doi: 10.1057/palgrave.jors.2601980.

Mo, Y. and Harrison, T. P. (2005) 'A Conceptual Framework for Robust Supply Chain Design Under Demand Uncertainty', in Panos, M. P. and Geunes, J. (eds) *Supply chain optimization*. Springer, pp. 243–263.

Morcol, G. (2001) 'What Is Complexity Science? Postmodernist or Psotpositivist?', *Emergence*, 3(1), pp. 104–119. doi: 10.1207/S15327000EM0301_07.

Morçöl, G. and Wachhaus, A. (2009) 'Network and Complexity Theories: A Comparison and Prospects for a Synthesis', *Administrative Theory & Praxis*, 31(1), pp. 44–58. doi: 10.2753/ATP1084-1806310103.

Mulani, N. and Hau, L. (2002) 'New business models for supply chain excellence', *Achieving supply chain excellence through technology*, 4.

Nair, A., Narasimhan, R. and Choi, T. Y. (2009) 'Supply Networks as a Complex Adaptive System: Toward Simulation-Based Theory Building on Evolutionary Decision Making', *Decision Sciences*, 40(4), pp. 783–815. doi: 10.1111/j.1540-5915.2009.00251.x.

Nair, A. and Vidal, J. M. (2011) 'Supply network topology and robustness against disruptions – an investigation using multi-agent model', *International Journal of Production Research*, 49(5), pp. 1391–1404. Available at: http://www.tandfonline.com/doi/abs/10.1080/00207543.2010.518744 (Accessed: 8 October 2012).

Nair, A. and Vidal, J. M. J. M. (2011) 'Supply network topology and robustness against disruptions – an investigation using multi-agent model', *International Journal of Production Research*. Taylor & Francis Ltd, 49(5), pp. 1391–1404. doi: 10.1080/00207543.2010.518744.

Narasimhan, R., Swink, M. and Kim, S. W. (2006) 'Disentangling leanness and agility: An empirical investigation', *Journal of Operations Management*, 24(5), pp. 440–457. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0272696305001543 (Accessed: 17 December 2013).

Narasimhan, R. and Talluri, S. (2009) 'Perspectives on risk management in supply chains', *Journal of Operations Management*, 27(2), pp. 114–118.

Newman, M. E. J. (2011) 'Complex Systems: A Survey', *American Journal of Physics*, 79(8), p. 800. doi: 10.1119/1.3590372.

Nicolis, G. and Prigogine, I. (1977) *Self-Organization in Nonequilibrium Systems*. New York: Wiley.

Nicolis, G. and Prigogine, I. (1989) *Exploring Complexity: An Introduction*. New York: Freeman.

Nilsson, F. and Darley, V. (2006) 'On complex adaptive systems and agent-based modelling for improving decision-making in manufacturing and logistics settings: Experiences from a packaging company', *International Journal of Operations & Production Management*, 26(12), pp. 1351–1373. doi: 10.1108/01443570610710588.

Oke, A. and Gopalakrishnan, M. (2009) 'Managing disruptions in supply chains: A case study of a retail supply chain', *International Journal of Production Economics*, 118(1), pp. 168–174. doi: 10.1016/j.ijpe.2008.08.045.

Pal, B., Sana, S. S. and Chaudhuri, K. (2012) ‘A multi-echelon supply chain model for reworkable items in multiple-markets with supply disruption’, *Economic Modelling*, 29(5), pp. 1891–1898. Available at: http://10.0.3.248/j.econmod.2012.06.005.

Papadakis, L. S. (2003) ‘On the sensitivity of configure -to - order supply chains for personal computers after component market disruptions.’, *International Journal of Physical Distribution & Logistics Management*, 33(10), pp. 934–950. Available at: https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=12331533&site=ehost-live.

Park, K., Min, H. and Min, S. (2016) ‘Inter-relationship among risk taking propensity, supply chain security practices, and supply chain disruption occurrence.’, *Journal of Purchasing & Supply Management*, 22(2), pp. 120–130. Available at: http://10.0.3.248/j.pursup.2015.12.001.

Parry, K. W. (1998) ‘Grounded theory and social process: A new direction for leadership research’, *The Leadership Quarterly*, 9(1), pp. 85–105. doi: 10.1016/S1048-9843(98)90043-1.

Pathak, S. D., Day, J. M., Nair, A., Sawaya, W. J. and Kristal, M. M. (2007) ‘Complexity and Adaptivity in Supply Networks: Building Supply Network Theory Using a Complex Adaptive Systems Perspective*’, *Decision Sciences*, 38(4), pp. 547–580. doi: 10.1111/j.1540-5915.2007.00170.x.

Pathak, S. D., Dilts, D. M. and Mahadevan, S. (2009) ‘Investigating Population and Topological Evolution in a Complex Adaptive Supply Network’, *Journal of Supply Chain Management*, 45(3), pp. 54–57. doi: 10.1111/j.1745-493X.2009.03171.x.

Pathak, S., Dilts, D. and Biswas, G. (2007) ‘On the evolutionary dynamics of supply network topologies’, *... , IEEE Transactions on*, 54(4), pp. 662–672. Available at: http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=4344967 (Accessed: 26 June 2014).

Patton, M. Q. (2002) ‘Two Decades of Developments in Qualitative Inquiry: A Personal, Experiential Perspective’, *Qualitative Social Work*, 1(3), pp. 261–283. doi: 10.1177/1473325002001003636.

Pawson, R. and Tilley, N. (1997) *Realistic Evaluation*. CA: London and Thousand Oaks, Sage.

Peck, H. (2005) 'Drivers of supply chain vulnerability: an integrated framework', *International Journal of Physical Distribution & Logistics Management*, 35(4), pp. 210–232. doi: 10.1108/09600030510599904.

Peck, H. (2006) 'Reconciling supply chain vulnerability, risk and supply chain management', *International Journal of Logistics*, 9(2), pp. 127–142. doi: 10.1080/13675560600673578.

Peirce, C. S. (1955) *Philosophical writings of Peirce*. Edited by J. Buchler. New York: Dover.

Perrow, C. (1999) *Normal accidents: Living with high risk technologies*. Princeton, NJ: Princeton University Press.

Peters, L. D., Pressey, A. D., Vanharanta, M. and Johnston, W. J. (2013) 'Constructivism and critical realism as alternative approaches to the study of business networks: Convergences and divergences in theory and in research practice', *Industrial Marketing Management*. Elsevier Inc., 42(3), pp. 336–346. doi: 10.1016/j.indmarman.2013.02.003.

Peterson, M. F. and Lewin, A. Y. (1998) 'Embedded Organizational Events : The Units of Process in Organization Science', (1).

Pettit, T., Fiksel, J. and Croxton, K. (2010) 'Ensuring supply chain resilience: development of a conceptual framework', *Journal of Business Logistics*, 31(1), pp. 1–21. Available at: http://onlinelibrary.wiley.com/doi/10.1002/j.2158-1592.2010.tb00125.x/full (Accessed: 3 July 2013).

Pettit, T. J., Croxton, K. L. and Fiksel, J. (2013) 'Ensuring supply chain resilience: Development and implementation of an assessment tool', *Journal of Business Logistics*, 34(1), pp. 46–76. doi: 10.1111/jbl.12009.

Pettit, T. J., Fiksel, J. and Croxton, K. L. (2010) 'Ensuring supply chain resilience: development of a conceptual framework', *Journal of Business Logistics*, 31(1), pp. 1–

21. doi: 10.1002/j.2158-1592.2010.tb00125.x.

Plowman, D. A., Baker, L. T., Beck, T. E., Kulkarni, M., Solansky, S. T. and Travis, D. V. (2007) 'Radical Change Accidentally: The Emergence and Amplification of Small Change', *Academy of Management Journal*, 50(3), pp. 515–543. doi: 10.5465/AMJ.2007.25525647.

Ponomarov, S. Y. and Holcomb, M. C. (2009) 'Understanding the concept of supply chain resilience', *The International Journal of Logistics Management*, 20(1), pp. 124–143. Available at: http://www.emeraldinsight.com/10.1108/09574090910954873 (Accessed: 9 November 2012).

Poole, M. S., Van de Ven, A. H., Dooley, K. and Holmes, M. E. (2000) *Organizational change and innovation processes: Theory and methods for research*. Oxford University Press.

Poulis, K. and Poulis, E. (2016) 'Problematizing Fit and Survival: Transforming the Law of Requisite Variety Through Complexity Misalignment', *Academy of Management Review*, 41(3), pp. 503–527. doi: 10.5465/amr.2014.0073.

Prigogine, I. and Stengers, I. (1984) *Order out of chaos: Man's new dialogue with nature*. New York: Bantam books.

Ragin, C. (1987) *The comparative method*. Berkeley: University of California Press.

Reason, J. (1990) 'Human error.', *Human error.*, pp. 1056–1057. doi: 10.1017/CBO9781139062367.

Reason, J. (1997) *Managing the Risks of Organizational Accidents*. Aldershot: Ashgate Publishing Ltd.

Reason, J. (1998) 'Achieving a safe culture: Theory and practice', *Work & Stress 2 star*, 12(3), pp. 293–306. doi: 10.1080/02678379808256868.

Robson, C. and McCartan, K. (2016) *Real World Research*. fourth. John Wiley & Sons.

Rogers, B. and Ryals, L. (2007) 'Using the repertory grid to access the underlying realities in key account relationships', *International Journal of Market Research*, 49(5), pp. 595–613. Available at: http://dspace.lib.cranfield.ac.uk/handle/1826/3161.

Romar, E. J. (2004) ‘Globalization, ethics, and opportunism: a Confucian view of business relationships’, *Business Ethics Quarterly*, 14(4), pp. 663–678.

Rotaru, K., Churilov, L. and Flitman, A. (2014) ‘Can critical realism enable a journey from description to understanding in operations and supply chain management?’, *Supply Chain Management : An International Journal*, 19(2), pp. 117–125. doi: 10.1108/SCM-11-2013-0417.

Sachan, A. and Datta, S. (2005) ‘Review of supply chain management and logistics research’, *International Journal of Physical Distribution & Logistics Management*, pp. 664–705. doi: 10.1108/09600030510632032.

Sarkar, S. and Kumar, S. (2015) ‘A behavioral experiment on inventory management with supply chain disruption.’, *International Journal of Production Economics*, 169, pp. 169–178. Available at: http://10.0.3.248/j.ijpe.2015.07.032.

Sawik, T. (2015) ‘On the fair optimization of cost and customer service level in a supply chain under disruption risks.’, *Omega*, 53, pp. 58–66. Available at: http://10.0.3.248/j.omega.2014.12.004.

Sayer, A. (1992) *Method in Social Science: A Realist Approach*. London: Routledge.

Sayer, A. (2000) *Realism and Social Science*. Thousand Oaks, Sage Publications Inc.

Schrödinger, E. (1944) *What is Life: The Physical Aspect of the Living Cell*. Cambridge, UK: Cambridge University Press.

Shah, R., Goldstein, S. M., Unger, B. T. and Henry, T. D. (2008) ‘Explaining Anomalous High Performance in a Health Care Supply Chain*’, *Decision Sciences*, 39(4), pp. 759–789. doi: 10.1111/j.1540-5915.2008.00211.x.

Sheffi, Y. (2001) ‘Supply chain management under the threat of international terrorism’, *International Journal of Logistics Management, The*. Available at: http://www.emeraldinsight.com/journals.htm?articleid=1527503&show=abstract (Accessed: 24 August 2013).

Sheffi, Y. (2005) *The Resilient Enterprise: Overcoming Vulnerability for Competitive Advantage*. Cambridge, MA: The MIT Press.

Sheffi, Y. and Rice, J. (2005) ‘A supply chain view of the resilient enterprise’, *MIT Sloan Management Review*, 47(1). Available at: http://sloanreview.mit.edu/article/a-supply-chain-view-of-the-resilient-enterprise/ (Accessed: 12 August 2013).

Simchi-Levi, D., Schmidt, W., Wei, Y., Yun Zhang, P., Combs, K., Ge, Y., Gusikhin, O., Sanders, M. and Zhang, D. (2015) ‘Identifying Risks and Mitigating Disruptions in the Automotive Supply Chain.’, *Interfaces*, 45(5), pp. 375–390. Available at: http://10.0.5.7/inte.2015.0804.

Skipper, J. B. and Hanna, J. B. (2009) ‘Minimizing supply chain disruption risk through enhanced flexibility’, *International Journal of Physical Distribution & Logistics Management*, 39(5), pp. 404–427. Available at: http://www.emeraldinsight.com/10.1108/09600030910973742 (Accessed: 3 June 2013).

Sminia, H. (2009) ‘Process research in strategy formation: Theory, methodology and relevance’, *International Journal of Management Reviews*, 11(1), pp. 97–125. Available at: http://doi.wiley.com/10.1111/j.1468-2370.2008.00253.x (Accessed: 4 August 2014).

Smith, M. L. (2006) ‘Overcoming theory-practice inconsistencies: Critical realism and information systems research’, *Information and Organization*, 16(3), pp. 191–211. doi: 10.1016/j.infoandorg.2005.10.003.

Speier, C., Whipple, J. M., Closs, D. J. and Voss, M. D. (2011) ‘Global supply chain design considerations: Mitigating product safety and security risks’, *Journal of Operations Management*, 29(7–8), pp. 721–736. doi: 10.1016/j.jom.2011.06.003.

Stacey, R. D. (1996) *Complexity and Creativity in Organizations*. San Francisco: Berrett-Koehler Publishers.

Staw, B. M. and Boettger, R. D. (1990) ‘Task Revision: a Neglected Form of Work Performance.’, *Academy of Management Journal*, 33(3), pp. 534–559. doi: 10.2307/256580.

Stecke, K. E. and Kumar, S. (2009) ‘Sources of Supply Chain Disruptions, Factors That Breed Vulnerability, and Mitigating Strategies’, *Journal of Marketing Channels*, 16(3), pp. 193–226. doi: 10.1080/10466690902932551.

Sterman, J. D. (1989) ‘Modeling Management Behavior - Misperceptions of Feedback in a Dynamic Decision-Making Experiment’, *Management Science*, 35, pp. 321–339.

Strauss, A. L. and Corbin, J. M. (1990) *Basics of Qualitative Research*. Vol 15. Newbury Park, CA: Sage.

Surana, A., Kumara *, S., Greaves, M. and Raghavan, U. N. (2005) ‘Supply-chain networks: a complex adaptive systems perspective’, *International Journal of Production Research*, 43(20), pp. 4235–4265. doi: 10.1080/00207540500142274.

Sutcliffe, K. M. (2011) ‘High reliability organizations (HROs)’, *Best Practice and Research: Clinical Anaesthesiology*. Elsevier Ltd, 25(2), pp. 133–144. doi: 10.1016/j.bpa.2011.03.001.

Svensson, G. (2000) ‘A conceptual framework for the analysis of vulnerability in supply chains’, *International Journal of Physical Distribution & Logistics Management*, 30(9), pp. 731–750. doi: 10.1108/09600030010351444.

Svensson, G. (2000) ‘A conceptual framework for the analysis of vulnerability in supply chains’, *International Journal of Physical Distribution & Logistics Management*, 30(9), pp. 731–749. Available at: http://www.emeraldinsight.com/journals.htm?articleid=846778&show=abstract (Accessed: 23 July 2013).

Svensson, G. (2002a) ‘A conceptual framework of vulnerability in firms’ inbound and outbound logistics flows’, *International Journal of Physical Distribution & Logistics Management*, 32(2), pp. 110–134. doi: 10.1108/09600030210421723.

Svensson, G. (2002) ‘A conceptual framework of vulnerability in firms’ inbound and outbound logistics flows’, *... Journal of Physical Distribution & Logistics Management*, 32(2), pp. 110–134. Available at: http://www.emeraldinsight.com/journals.htm?articleid=846828&show=abstract (Accessed: 23 July 2013).

Svensson, G. (2002b) ‘A typology of vulnerability scenarios towards suppliers and customers in supply chains based upon perceived time and relationship dependencies’, *International Journal of Physical Distribution & Logistics Management*, 32, pp. 168–

187. doi: 10.1108/09600030210426511.

Svensson, G. (2002c) ‘A typology of vulnerability scenarios towards suppliers and customers in supply chains based upon perceived time and relationship dependencies’, *International Journal of Physical Distribution & Logistics Management*, 32(3), pp. 168–187. Available at: http://www.emeraldinsight.com/10.1108/09600030210426511 (Accessed: 16 July 2013).

Svensson, G. (2002d) ‘Dyadic Vulnerability in Companies’ Inbound and Outbound Logistics Flows’, *International Journal of Logistics Research and Applications*, 5(1), pp. 13–43. doi: 10.1080/13675560110114261.

Tang, C. (2006a) ‘Perspectives in supply chain risk management’, *International Journal of Production Economics*, 103(2), pp. 451–488. doi: 10.1016/j.ijpe.2005.12.006.

Tang, C. (2006b) ‘Robust strategies for mitigating supply chain disruptions’, *International Journal of Logistics*, 9(1), pp. 33–45. doi: 10.1080/13675560500405584.

Tang, C. and Tomlin, B. (2008) ‘The power of flexibility for mitigating supply chain risks’, *International Journal of Production Economics*, 116(1), pp. 12–27. doi: 10.1016/j.ijpe.2008.07.008.

Tashakkori, A. and Teddlie, C. (1998) *Mixed methodology: Combining qualitative and quantitative approaches. Applied social research methods series, Vol. 46.* Sage.

Thadakamaila, H. (2004) ‘Survivability of multiagent-based supply networks: a topological perspect’, *Intelligent Systems, IEEE*, 19(5), pp. 24–31. Available at: http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1347065 (Accessed: 22 January 2014).

Thiétart, R. A. and Forgues, B. (1995) ‘Chaos Theory and Organization’, *Organization Science*, 6(1), pp. 19–31. doi: 10.1287/orsc.6.1.19.

Thornton, L. ., Esper, T. . and Morris, M. . (2013) ‘Exploring the impact of supply chain counterproductive work behaviors on supply chain relationships’, *International Journal of Physical Distribution & Logistics Management*, 43(9), pp. 786–804. doi: 10.1108/IJPDLM-09-2012-0298.

Tokar, T. (2010) ‘Behavioural research in logistics and supply chain management’, *The International Journal of Logistics Management*, 21(1), pp. 89–103. doi: 10.1108/09574091011042197.

Tomlin, B. (2006) ‘On the Value of Mitigation and Contingency Strategies for Managing Supply Chain Disruption Risks’, *Management Science*. INFORMS: Institute for Operations Research, 52(5), pp. 639–657. doi: 10.1287/mnsc.1060.0515.

Tranfield, D., Denyer, D. and Smart, P. (2003) ‘Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review’, *British Journal of Management*, 14(3), pp. 207–222. Available at: http://doi.wiley.com/10.1111/1467-8551.00375.

Varga, L., Allen, P. M., Strathern, M., Rose-Anderssen, C., Baldwin, J. S. and Ridgway, K. (2009) ‘Sustainable Supply Networks: A Complex Systems Perspective’, *Emergence: Complexity & Organization*, 11(3), pp. 16–36. Available at: http://search.ebscohost.com/login.aspx?direct=true&db=buh&AN=45035356&site=ehost-live%5Cnhttp://0-content.ebscohost.com.wam.leeds.ac.uk/ContentServer.asp?T=P&P=AN&K=45035356&S=R&D=buh&EbscoContent=dGJyMNLe80Sep684yOvsOLCmr02eprRSs6u4S7KWxWXS&ContentCustomer.

Vaughan, D. (1996) *The Challenger launch decision: Risky technology, culture and deviance at NASA*. Chicago: University of Chicago Press.

Vogus, T. J. and Welbourne, T. M. (2003) ‘Structuring for high reliability: HR practices and mindful processes in reliability-seeking organizations’, *Journal of Organizational Behavior*, 24(SPEC. ISS. NOV.), pp. 877–903. doi: 10.1002/job.221.

Volkoff, O., Strong, D. M. and Elmes, M. B. (2007) ‘Technological Embeddedness and Organizational Change’, *Organization Science*, 18(5), pp. 832–848. doi: 10.1287/orsc.1070.0288.

Wagner, S. and Bode, C. (2008) ‘An empirical examination of supply chain performance along several dimensions of risk’, *Journal of Business Logistics*, 29(1), pp. 307–325. Available at: http://onlinelibrary.wiley.com/doi/10.1002/j.2158-

1592.2008.tb00081.x/full (Accessed: 25 October 2012).

Wagner, S. M. and Bode, C. (2006) 'An empirical investigation into supply chain vulnerability', *Journal of Purchasing and Supply Management*, 12(6), pp. 301–312. doi: 10.1016/j.pursup.2007.01.004.

Wagner, S. M. and Neshat, N. (2010) 'Assessing the vulnerability of supply chains using graph theory', *International Journal of Production Economics*. Elsevier, 126(1), pp. 121–129. doi: 10.1016/j.ijpe.2009.10.007.

Wagner, S. M. and Neshat, N. (2012) 'A comparison of supply chain vulnerability indices for different categories of firms', *International Journal of Production Research*, 50(11), pp. 2877–2891. doi: 10.1080/00207543.2011.561540.

Weick, K. E. (1987) 'Organizational Culture as a Source of High Reliability', *California Management Review*, 29(2), pp. 112–127. doi: 10.2307/41165243.

Weick, K. and Roberts, K. (1993) 'Collective mind in organizations: Heedful interrelating on flight decks', *Administrative Science Quarterly*, 38(3), pp. 357–381. Available at: http://www.jstor.org/stable/10.2307/2393372.

Wilding, R. D. (1998) 'The Supply Chain Complexity Traingle: uncertainty generation in the supply chain.' doi: 10.1108/09600039810247524.

Williamson, O. E. (1985) *The Economic Institutions of Capitalism Firms*. New York: The Free Press.

Williamson, O. E. (1998) 'Transaction cost economics: how it works; where it is headed**', (1), pp. 23–58.

Wu, T., Blackhurst, J. and O'grady, P. (2007) 'Methodology for supply chain disruption analysis', *International Journal of Production Research*. Taylor & Francis Ltd, 45(7), pp. 1665–1682. doi: 10.1080/00207540500362138.

Wynn, J. D. and Williams, C. K. (2012) 'Principles for Conducting Critical Realist Case Study Research in Information Systems', *MIS Quarterly*, 36(3), pp. 787–810.

Xiao, R., Yu, T. and Gong, X. (2012) 'Modeling and Simulation of Ant Colony'S Labor Division With Constraints for Task Allocation of Resilient Supply Chains',

International Journal on Artificial Intelligence Tools, 21(3), p. 1240014. doi: 10.1142/S0218213012400143.

Xiao, T. and Qi, X. (2008) 'Price competition, cost and demand disruptions and coordination of a supply chain with one manufacturer and two competing retailers', *Omega*, 36(5), pp. 741–753. doi: 10.1016/j.omega.2006.02.008.

Xiao, T. and Yu, G. (2006) 'Supply chain disruption management and evolutionarily stable strategies of retailers in the quantity-setting duopoly situation with homogeneous goods', *European Journal of Operational Research*, 173(2), pp. 648–668. Available at: http://10.0.3.248/j.ejor.2005.02.076.

Yang, T., Wen, Y.-F. and Wang, F.-F. (2011) 'Evaluation of robustness of supply chain information-sharing strategies using a hybrid Taguchi and multiple criteria decision-making method', *International Journal of Production Economics*. Elsevier, 134(2), pp. 458–466. doi: 10.1016/j.ijpe.2009.11.018.

Yin, R. . (1994) *Case study research: Design and methods*. 2nd edn. CA: Thousand Oaks, Sage.

Yin, R. . (2009) *Case Study Research: Design and Methods*. Sage Publications, inc.

Zeeman, E. C. (1977) *Catastrophe theory: Selected papers , 1972--1977*. Addison-Wesley.

Zhao, K., Kumar, A., Harrison, T. and Yen, J. (2011) 'Analyzing the resilience of complex supply network topologies against random and targeted disruptions', *Systems Journal, IEEE*, 5(1), pp. 28–39.

Zimmerman, B. J. and Hurst, D. K. (1993) 'Breaking the Boundaries: The Fractal Organization', *Journal of Management Inquiry*, 2(4), pp. 334–355. doi: 10.1177/105649269324006.

Zimmerman, B., Lindberg, C. and Plsek, P. (1998) *Edgeware*. Irving, TX: VHA.

Zsidisin, G. A., Melnyk, S. A. and Ragatz, G. L. (2005) 'An institutional theory perspective of business continuity planning for purchasing and supply management', *International Journal of Production Research*, 43(16), pp. 3401–3420.

Zsidisin, G. A. and Wagner, S. M. (2010) ‘Do Perceptions Become Reality? The Moderating Role of Supply Chain Resiliency on Disruption Occurrence’, *Journal of Business Logistics*. Wiley-Blackwell, 31(2), pp. 1–20. doi: 10.1002/j.2158-1592.2010.tb00140.x.

APPENDICES

Appendix A Details of Data Sample

Firm code	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8	Event 9	Event 10	Event 11	Event 12	Total events	Emergent events
Firm 1	Japan Tsunami (E)	Thai Flood (E)	Regional Agitation	Broken transport links	Political agitation	Thai monarchy	Japan vs China	Tax litigation	Fire at vendor	IR issue (E)			10	3
Firm 2	Spare part clutches	Supplier end strike (E)	Alkaline battery supplier (E)	Repeated failure of alternative supplier (E)	Quality check bottle neck	Changes in testing specs	S&OP issues						7	3
Firm 3	Flooded transport routes	Transport strike	Truck availability	Load clubbing	Material availability	Financial block on credit limit	Govt delay	Driver related issues					8	
Firm 4	Consolidation related delay	Process of signing PO	Frequency of shipping	A misplaced PO	Human error in S&OP	Financial delay							6	
Firm 5	Packaging quality disruption	Packaging shortfall in expansion	Utility supply issues	Bureaucratic or political interventions	Port strike	Machine spares	New product launch disruption due to design issues	New flavour quantity issues	Unorganised sector procurements				9	
Firm 6	License issue	Label issue	Airlift issue	One off purchase incident	ERP integration issue	Split PO consolidation	Chinese counterpart issues						7	
Firm 7	Packaging supply disruption (E)	conveyer belt	Molten sulphur (E)	Transport cartel (E)	Sulphuric short fall in market	Monopoly vendor close down (E)	Work contract related issues	European unit stopped production of a key component (E)	False commitment by resin supplier (E)	False test certificate related disruption (E)	Quality people creating bottleneck (E)	Acid purity related issue (E)	12	9
Firm 8	Stress film disruption	UDM machine break down (spare camera also	A critical low volume additive (the company acquisition	Shortage of reuse material scrap	Newly developed supplier now asking price rise (	Stress film and 1st may close down							6	2

		did not word) (E)	coincided with the event)		it was developed as a low cost moderate quality supplier) (E)									
Firm 9	Pirate attack	Weather at sea	Que up for birthing	Discharge hose leak	Supplier default on delivery date	Diesel dilemma	Traders change schedules	Policy changes at user end					8	
Firm 10	Train schedule and delays	Freight bill lost	Interstate documentation	Whirlpool events	LG delay								5	
Firm 11	Netwback issues	KSA asset stabilization	Variation in product output bleeding into supply chain issues (E)	Long lead time and sale on water (E)	2000 grades of PVCMA forecasting issue	Forced measure related disruption	Finance block						7	1
Firm 12	Port delay	No entry timings	Supplier break downs (once a year)	Transport issues	Quality issues with suppliers								5	
Firm 13	Part supply to customers	Quality and quantity issues	Vessel availability	Offload pumps on ports	Pooling of tank resource at ports	PR to PO cycle	SKU level forecasting error	Tempering with tracking device	Financial crunch	Shift in supplier location and port			10	
Firm 14	Reactor supply delay	Technical specification not agreed bottling plant	Dust collector	Temperature and fire proofing	Design modification due to a concrete column								5	
Firm 15	Warehouse stackers	Agri pipping system	Tractor in European plant	UPS manufacturer	Joint venture specialized machine with a world leading firm	Specialized piping (E)							6	1
Firm 16	Forecasting granularity related	Product proliferation	SAP as a blackbox	KPI and forecasting calculations	DC and RDC neither optimally	Inter nodal issues	Second guessing, trust and	System and personal excel files	GM sales personality and identify	Marketing not clear of	Incorrect or absent matrices		11	

	issues			wrong	located nor inventoriall y optimised		alignment	had various versions	issues	logistics priorities in new product launch	for lost sale accountin g			
Firm 17	Low Quotation ss fabrication (E)	Quality Culture (E)	Theft with no rider on contract	Reluctant to reserve till testing	Iteration of skilled manpower								5	2
Firm 18	Port low tide	Thai rice	Thai port feeder vessel	Rice weavers	Yemen port	Agent death in war	Redirect KSA cargo	Transport links inaccessibl e due to floods					8	
Firm 19 Man u	Barrel explosion	Snow blizzard kerosene oil disruption	Land slide cut off a post for 8 months with 2000 men brigade	Disruptive floods	Kingfisher disruption	Vendor going out of business	Cash replenishmen t issue						7	
Firm 20	Laminate Rejection on line	Short fall butter scotch	Laminate Start up	Glucose lumping	Cashew shortfall	Jar rejection (E)	Hair contaminatio n	Cartoon short fall	Sugar rejection	Corrugate box			10	1
Firm 21	Skin panel disruption	TRS disruption	Cage free wheel disruption	Bottom stretch	Dyna Tech (E)	Supporter tube	Legend disruption	Frame 9	MGB				9	1
Firm 22	Finance block	Outsourced equipment delay	New product launch disruption	Govt sector suppliers	Customers ask newer versions	Channel partner discontinued							6	
												Total	167	23

Coloured boxes demonstrate events that were either natural calamity or disruptions not caused directly by human behaviours

(E) symbol demonstrates that these events resulted in network emergence; either due to a change in network structure or a change in system's process, priorities or goals

Appendix B Repertory Grids

Firm 1

Construct (Likert Scale Ranking 5)	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8	Event 9	Event 10
Sudden impact	3	3	5	4	3	3	3	5	5	4
Production was not possible	5	5	5	1	2	2	2	1	5	5
Quick evaluation of alternative supplier	1	1	1	5	3	4	4	5	1	5
Multi location advantage	1	1	5	4	5	4	4	5	2	4
Long pipe line of material in transit	5	5	1	2	2	5	5	1	1	1
Logistics disruption	4	4	5	1	1	1	3	5	5	5
Political influence	5	5	1	1	1	1	1	3	5	5
Man-made	5	5	1	1	1	1	1	3	5	1
Government failure	5	5	1	2	1	1	1	4	5	5
Involvement of top management	2	2	1	2	2	3	1	5	5	1
Lobbying was required	5	5	3	3	3	3	1	2	5	1
Truck driver issues	5	5	2	1	1	4	5	5	5	3

Firm 2

Construct (Likert Scale Ranking 5)	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8
Very close cooperation with supplier	2	5	1	1	1	5	3	3
70% dependency of supplier on us	2	5	1	1	1	3	3	3
Opportunistic supplier behaviour	1	1	5	5	5	3	1	1
Monoploistic supplier behaviour	1	1	5	5	5	3	1	1
Market effect	5	1	4	3	1	1	1	5
Product not fit for lean still Management forcing a lean approach	5	1	4	4	4	4	5	5
Inflated demand	5	1	1	1	1	1	1	5
Design and supply chain impact not considered	5	1	5	5	5	5	5	5
Supply chain not involved in decision making	5	1	1	1	1	5	5	4
Supply chain priorities and concerns not understood	5	1	5	5	5	5	5	5

Firm 3

Construct (Likert Scale Ranking 5)	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8
Material available but not billed	3	5	5	3	1	5	1	1
Visibility related issue between us and customers	1	1	4	5	5	5	1	1
Required better internal planning	2	4	4	5	5	5	1	3
Transporter were forced to search for an alternative or invasive plan	5	5	2	1	1	1	4	3
Convince the customer for a particular volume	4	4	1	5	5	2	1	1
customer forecast are inaccurate	1	1	3	5	5	4	1	1

Firm 4

Construct (Likert Scale Ranking 5)	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6
Process difference between countries	5	5	1	1	1	1
forecast issues	5	1	4	1	5	1
Buyer does not disclose the real cause	5	1	1	1	1	5
Human error	1	4	1	5	5	3
financial viability issues with half container	5	1	5	1	1	1
multiple buying by the buyer	5	5	3	1	1	5

Firm 5

Construct (Likert Scale Ranking 5)	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_9	E_8
Sole Supplier	5	3	5	5	2	5	5	1	4
Unexpected Supplier Behaviour	5	3	4	3	1	5	5	2	5
Non Substitutable product	5	2	5	1	5	5	4	2	5
Relevance Of Supplier Flexibility	4	5	5	5	1	5	5	4	2
Incorrect Supplier Capability Assessment	5	5	5	4	1	2	5	5	4
Abuse Of Bargaining Power By Supplier	5	1	4	1	1	5	1	5	2
Dyadic Relationship	5	5	5	1	1	5	1	1	1
Low Influence Of Product Price	1	4	5	5	5	1	2	1	5
Process Or Procedure Fault	1	5	5	5	5	1	1	3	3
Government And Policy Issue	1	1	5	5	4	1	1	3	2
Low Cost of Negotiation	3	4	2	2	5	1	1	1	5

Firm 6

Construct (Likert Scale Ranking 5)	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8
narrow or inconsiderate view	5	1	4	5	3	1	5	5
Did not consider our priorities or urgency	5	4	2	5	1	1	5	5
carless behaviour of supplier	1	5	5	5	1	1	1	5
lot of unnecessary energy and money waste	3	5	5	5	1	5	5	2
we payed for someone else's fault	5	5	1	1	1	5	4	4
stock was unavailable	5	1	5	5	1	5	5	1
forecast was not there	1	1	5	4	1	1	5	1
to support a marketing activity	1	1	5	1	1	1	5	1

Firm 7

Construct (Likert Scale Ranking 5)	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8	Event 9	Event 10	Event 11	Event 12
Opportunistic behaviour and cartel	5	1	5	5	3	1	5	2	5	5	1	1
Internal people with fixed mind and lack of innovation	1	3	3	2	2	4	4	5	1	4	5	5
Unwilling to try alternatives	3	1	3	3	3	4	5	5	1	4	5	5
Quality was unsure of product specification or alternatives	1	3	1	1	1	1	1	5	1	3	5	5
Technical Myopia	1	1	1	1	1	4	3	5	1	4	5	5
internal team alignment	1	1	1	1	2	5	3	5	1	4	5	5
unwilling to adopt or be flexible	1	1	1	1	3	4	4	4	1	5	5	5
ego and intentional behaviours	5	1	5	5	1	1	4	4	5	5	3	3
lack of practical perspective	1	1	3	3	3	1	1	5	1	4	5	5

Firm 8

Construct (Likert Scale Ranking 5)	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6
regular high volume	5	1	1	5	4	1
no spare or stock	2	5	5	1	1	1
single source	3	5	5	1	1	1
performance measure motivated issue	1	1	1	1	5	5
market related issue	4	1	5	5	4	1
forecast error	1	1	5	5	4	4

Firm 9

Construct (Likert Scale Ranking 5)	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8	Event 9
Sudden change in outlook	1	1	5	1	5	4	5	5	3
Trading desk overrides all decision	1	1	5	1	5	3	5	5	3
Beneficial delay and que up of vessels	1	1	5	1	4	2	3	4	3
Opportunistic behaviour of suppliers	1	1	3	1	4	5	4	5	5
Availability of higher margin elsewhere	1	1	4	2	5	4	5	5	5
Have no control over it	5	5	2	5	3	5	5	1	5

Firm 10

Construct (Likert Scale Ranking 5)	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6
competitors pressure	1	1	1	5	5	3
forecasting error by customer	4	1	1	5	5	5
customer changing plans at the last moment	3	1	1	4	5	5
Save money on logistics	5	3	1	3	2	1
transporters are careless	5	5	5	1	1	1
careless truck driver	1	4	4	1	1	1

Firm 11

Construct (Likert Scale Ranking 5)	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7
Alignment of Forecasting, sales and production	3	4	5	4	5	5	1
Production related issues	5	5	5	1	5	5	1
Dynamic pricing and market forces	5	3	2	4	5	5	5
Low volumes with high demand fluctuation	1	1	5	3	5	3	1
Profitability forced us to change product or grade mix which lead to a loss of few grades	4	2	3	3	5	5	1
Lack of skill resulted in disruption	1	5	3	3	4	4	1
Additional warehouse setup to support variation in demand	1	5	4	2	1	5	1
Top management strategy to delay	5	4	3	1	5	5	1

Firm 12

Construct (Likert Scale Ranking 5)	Event 1	Event 2	Event 3	Event 4	Event 5
Government Rules regulation and processes	5	5	1	3	1
Machinery issues	4	1	5	4	4
irresponsible and uncaring attitude	5	3	1	5	3
unskilled and temporary workers	1	1	3	4	5

Firm 13

Construct (Likert Scale Ranking 5)	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8	Event 9	Event 10
internal alignment	4	5	3	1	1	5	5	1	2	1
lack of trust on others	1	5	1	1	1	5	5	1	1	1
unscientific forecast methods	4	1	1	4	1	3	5	1	4	1
mischief by transport or logistics firms	3	5	1	1	1	1	1	5	1	1
change in circumstances or market	1	1	5	4	4	1	4	1	4	5
forecast granularity error	5	1	3	1	4	4	5	1	1	3

Firm 14

Construct (Likert Scale Ranking 5)	Event 1	Event 2	Event 3	Event 4	Event 5
change in technical specification	5	5	5	3	5
internal routines were not followed	4	4	1	4	5
fabrication related issues	5	3	5	5	3
late involvement of other functions	4	1	5	5	1
careless mistake	3	3	2	1	5

Firm 15

Construct (Likert Scale Ranking 5)	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6
Vendor apathy	5	4	5	5	5	5
Attitude issues	5	1	5	5	3	5
Financial stability of vendor	1	5	1	1	2	5
over commitment	1	3	1	5	5	5
higher management intervention	5	4	5	4	1	1
opportunistic behaviour	1	1	4	5	4	5
ego issues	4	1	5	4	4	3
False information about capacity	1	4	4	5	4	5
careless handling	5	2	2	5	4	1

Firm 16

Construct (Likert Scale Ranking 5)	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8	Event 9	Event 10	Event 11	Event 12
Blindly trust the system	3	1	5	5	3	3	5	2	1	5	1	1
Considered themselves to be right and others wrong	4	1	2	4	2	1	4	5	5	5	5	4
faulty supply chain strategy	5	5	3	5	5	4	5	2	2	2	2	5
Product proliferation	5	5	1	1	4	4	4	2	3	1	4	2
interventional conflicts	5	5	1	1	1	1	3	5	5	2	4	5
SKU level planning (granularity) is a issue	5	5	5	2	5	4	3	5	5	1	1	1
Lack of trust on others	3	4	2	1	2	1	4	5	5	4	5	1
Wrong data on system or local files	2	2	4	4	3	1	5	2	5	5	2	1
Ego or personality issues	4	4	1	1	1	1	1	5	5	5	5	1

Firm 17

Construct (Likert Scale Ranking 5)	Event 1	Event 2	Event 3	Event 4	Event 5
Had Competency	5	3	5	2	3
Loss making deal / low profitability	5	1	5	3	2
Reallocation of resource due to delay	5	1	5	5	1
Need for a top management intervention	5	5	5	1	5
Material + labour contract	1	5	1	5	2
High motivation due to high stake	1	5	1	1	3
Required persisting external motivation to complete the job	5	4	5	2	4

Firm 18

Construct (Likert Scale Ranking 5)	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8
Least care attitude	5	5	1	5	3	4	4	5
Ego	5	5	1	1	1	1	2	3
Redirect the consignment	1	1	1	5	1	1	5	1
Was not in our hand	5	5	5	1	1	1	5	1
Over optimization of cost	5	2	2	5	1	1	5	5
Greedy for profitability	3	2	2	5	3	3	3	5

Firm 20

Construct (Likert Scale Ranking 5)	Event1	Event2	Event3	Event4	Event5	Event6	Event7	Event8	Event9	Event10
Stock Out	5	5	5	1	5	1	1	5	1	4
Collaboration Error	3	5	5	1	5	1	1	5	1	1
Transport Miss Handelling	1	1	1	5	1	1	1	1	5	5
Wrong Supplier Selection	5	1	1	1	1	5	1	1	1	1
Complex Product Design	5	1	1	1	1	1	1	1	1	1
CiloWorking Design And Procurement	5	1	1	1	1	1	1	1	1	1
Work Culture And Personality Conflicts	3	1	4	1	3	3	4	3	2	2
Quick fix Solution	1	1	1	1	1	4	3	1	4	4
New Product Development Failure	3	4	2	1	4	1	1	1	1	1
Lack Of Clarity Of Network Lead time	3	4	3	1	1	4	2	4	3	3

Firm 21

	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8	Event 9
Vendor assessment/ competence	3	1	1	1	1	5	3	1	4
Single tier	5	1	5	2	5	5	1	5	5
No internal competency	5	4	5	1	5	3	1	5	5
Single part	4	4	5	5	5	5	1	5	5
(Complex procedure job	5	5	5	1	5	5	4	4	5
Always outsourced	5	1	5	1	5	5	1	5	5
Contract Breach	1	1	1	1	5	1	1	1	1
Technical knowledge was not adequately shared	1	3	4	5	1	3	4	1	4
Low quotation **Penalty clauses of contract were not clearly understood**	5	1	5	2	1	4	2	3	1

Firm 22

Construct (Likert Scale Ranking 5)	**Event 1**	**Event 2**	**Event 3**	**Event 4**	**Event 5**	**Event 6**
Finance rotation and management	5	5	5	5	1	1
short product lifespan	1	1	3	4	5	5
Custom issues	3	5	3	1	4	1
Stiff competition in segment	1	5	5	4	5	5