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Mitigation Processes – Antecedents for building supply chain resilience

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Purpose – This study links the strategic literature based supply chain resilience capabilities and operational/ practitioner based disaster management processes to build an integrated generic supply chain resilience framework.

Design/ Methodology/ Approach – Utilising an in depth qualitative case of a collaborative agency in a well-developed country this paper explores their collaboration, communication, coordination and cooperation processes to better disaster management while building supply chain resilience.

Findings – The empirical data lead to the creation of an integrated supply chain resilience framework identifying the interplay of disaster management processes and critical capabilities required to build supply chain resilience over the four different disaster management phases. The critical importance of mitigation processes in building supply chain resilience is highlighted.

Practical Implications/ Social Implications – The proposed generic supply chain resilience framework represents an initial attempt to help management to direct resources and plan for building the capabilities required in each phase of disaster management, while remaining strategically focused.

Originality – This paper contributes to an advanced understanding of supply chain resilience in both commercial and humanitarian aid organisations by developing an integrated framework, depicting four distinct phases, associated capabilities and processes. By utilising the unique disaster supply chain management context a two way knowledge and learning flow between humanitarian and commercial organisations is established.

Keywords: Supply Chain Resilience, Disaster Management, Humanitarian Aid

Article Classification: Case Study

Introduction

The growing complexity of managing global supply chains and meeting exacerbating customer requirements has made organisations more aware of their operational and economic vulnerability to threats from the macro environment: every business activity has an inherent risk of unexpected disturbances which can lead to financial losses and in some cases firm closures (Skipper and Hanna, 2009). Building supply chain resilience can help to reduce and overcome exposure (vulnerability) to risks (Peck, 2005; Svensson, 2000; Tang, 2006; Wagner and Bode, 2006), through developing strategies which enable the supply chain to recover to its original (or an improved) functional state following a disruption (Jüttner and Maklan, 2011). However, despite growing requirement for firms to develop pro-active and comprehensive risk management processes, such as building resilience, theory offers little help or guidance (Hale and Moberg, 2005).

The academic supply chain management (SCM) literature fails to move beyond theory to offer management guidance on the implementation and operationalization of the supply chain resilience concept. There is limited empirical research on the topic to date, so the research picture is incomplete and lacks specific and important practitioner insights (Jüttner, 2005). In contrast, detailed practical guidance on how to manage disasters and inherent disruptions is provided by government agencies such as the Federal Emergency Management Agency (FEMA) in the US or the Humanitarian Aid and Civil Protection department of the European Commission (ECHO). This guidance is based on general, practitioner based disaster management processes and has developed independently of theory. The purpose of this research is to combine theory and practice to develop an integrated supply chain resilience framework by investigating the interdependencies between the theoretical frameworks of supply chain resilience and the operational practitioner based emergency management processes.

To, firstly, address this gap and, secondly, establish a greater understanding of how organisations can build supply chain resilience we consider an in depth qualitative case study in the disaster management context. There is a growing appreciation that unique contexts, often demonstrating extreme situations (Bamberger and Pratt, 2010), can provide critical insights that offer potent depictions of some of the target phenomenon's characteristics (here supply chain resilience). In addition, 'general' supply chain operations can benefit from research into disaster SCM (Christopher and Tatham, 2011): the unique context can provide insights for non-routine problem solving and risk management practices (Day et al., 2012) that lead to refinements and/ or development of theoretical frameworks for commercial operations.

This paper makes two key contributions: the first and major contribution is the development of a generic (for both commercial and disaster management context) integrated framework of supply chain resilience. Findings extend existing knowledge by identifying how different disruption phases link to theoretical supply chain capabilities and practitioner processes, highlighting that the integration of processes and capabilities for building supply chain resilience has to be iterative and staged. Secondly, we demonstrate the usefulness of our integrated framework and reveal its significant managerial implications through a retrospective analysis of aid operations in response to Hurricane Katrina. This analysis illustrates how mitigation processes are an integral part of building resilience antecedent to the ability of a supply chain to prepare for, respond to and recover from a disruption.

The article is organised as follows. We begin by deriving the strategic dimension on supply chain resilience from academic literature, and practitioner generated disaster management processes to capture the current operational perspective, establishing the state of the art in both disciplines. We then present our case study design, followed by a summary of the research findings for discussion in respect to existing literature. Through an analysis of

Hurricane Katrina we will show the usefulness of our framework. Finally, we elaborate on implications for theory and management practices, present limitations and identify suggestions for future research.

Literature Review

Supply Chain Resilience - The Strategic Dimensions

In today's interconnected world most organisations recognise the potential risk of experiencing a supply chain disruption (Skipper and Hanna, 2009) e.g. caused by a workforce strike, extreme weather conditions or a truck breaking down (Blackhurst et al., 2011). Such disruption can be related to any unplanned and unanticipated event that impacts the normal flow of goods, material and/ or services (Craighead et al., 2007). The vulnerability of supply chains to disruptions is evidenced by major events in the past e.g. the earthquake in Japan in 2012 not only impacted the Japanese and Asian economies, but led to shortages in the automobile and technology industry supply chains in Europe.

The apparent ability of some supply chains to recover from inevitable and unexpected supply chain disruptions more effectively than others (see e.g. Nokia and Ericsson case) triggered a debate about supply chain resilience (Jüttner and Maklan, 2011). Supply chain resilience is based on the underlying assumption that not all risks can be prevented (Jüttner and Maklan 2011). Resilience is a pro-active and holistic approach to managing supply chain risks enhancing traditional risk management strategies (i.e. risk assessment, vulnerability analysis, continuity planning): as it does not require risk identification and quantification supply chain resilience can deal with *unforeseeable* disruptions and events (Pettit et al., 2010). The concept refers to an organisation's capacity to survive, adapt and grow when confronted with change and uncertainty (Knemeyer et al., 2009) and has been defined in supply chain terms as 'the adaptive capability of the supply chain to *prepare* for unexpected events, *respond* to disruption and *recover* from them by maintaining continuity of operations

at the desired level of connectedness and control over structures and function' (Ponomarov and Holcomb, 2009, p. 131, emphasis added). It can be thought of in terms of 'shock absorption' between stages of the supply chain (Sheffi and Rice, 2005).

While there are few conceptual differences with regards to the definition of supply chain resilience in current literature (see e.g. Peck, 2005; Ponomarov and Holcomb, 2009; Sheffi and Rice, 2005), the formative elements needed to secure the adaptive capability of resilience are presented with significant disparity (Jüttner and Maklan, 2011). In this research we use the existing conceptualisation of a resilient supply chain from a system-level perspective as suggested by Christopher and Peck (2004). Their research identifies four primary capabilities for developing resilience: (1) supply chain (re-)engineering, (2) collaboration, (3) agility and (4) risk awareness. Additionally, after reviewing literature we consider knowledge management as a fifth system level element due to frequent references in literature to knowledge management practices (e.g. supply chain understanding (Blackhurst et al., 2011; Christopher and Peck, 2004)). Following we will explain the system-level approach in more detail incorporating other formative elements of resilience referred to in literature which we imply to be logical sub-categories of the five elements as per Table 1 in Appendix B.

Supply Chain (Re-)engineering

When a disruption happens, it is already too late to try to develop preventative solutions (Tomasini and Van Wassenhove, 2009). Resilience must be built into a supply chain in advance of a disturbance and incorporate readiness to enable an efficient and effective response (Ponomarov and Holcomb, 2009). Robust supply chain strategies enhance a firm's capability to sustain its operations when a major disruption hits (Tang, 2006) by preventing risks from having negative effects and enabling resistance to change without adapting its initial stable configuration (Wieland and Wallenburg, 2012). This requires all chain members

to have an understanding of the network (Christopher and Peck, 2004; Ponis and Koronis, 2012; Ponomarov and Holcomb, 2009) to be aligned in the event of a disruption occurring (Jüttner and Maklan, 2011). Mapping the supply network involves understanding who owns what, and what are the key measures that are currently in place (Harland et al., 2003). Such maps can then direct management attention and enable the prioritization of planning (Sheffi and Rice, 2005) as processes and structures to absorb risks are already in place when the risk event occurs (Wieland and Wallenburg, 2012). This is especially relevant to balancing efficiency of operations (Pettit et al., 2010, 2013) with the need for redundant capacity (Sheffi and Rice, 2005; Sheffi, 2005) to provide a buffer that can buy time for a firm to recover from a disruption (Zsidisin and Wagner, 2010), for example safety stocks or multiple suppliers. Obtaining a holistic understanding of cost/ benefit trade-offs when managing risks and understanding where inventory should be strategically placed, in what form it should be held and how much is necessary enables an effective handling of disruptions and increases resilience (Blackhurst et al., 2011). This can only be achieved through collaboration between the different members of the supply chain.

Collaboration

As SCM is essentially a network theory the management of risk must also be examined from a network perspective (Christopher and Peck, 2004). Collaboration among organisations in a supply chain network is what integrates the network as a whole and makes a holistic approach, needed to build supply chain resilience, possible (Sheffi, 2001); there is a consent in literature that collaboration is an essential element of building supply chain resilience (see also Table 1). The fundamental principle of supply chain collaboration is that the exchange of information and application of shared knowledge across the chain can decrease uncertainty (Christopher and Peck, 2004), increase visibility (Faisal et al., 2006), operational effectiveness and efficiency, and enhance customer service.

Collaboration amongst supply chain members can be vertical or horizontal, and can either be an operational matter - emphasising how working together can support supply chain efficiency - or involve strategic knowledge or innovation perspectives, as ways for members to access complementary skills to improve chain performance (Jüttner and Maklan, 2011). While vertical collaboration involves different members at different value chain stages (suppliers, manufacturers, customers, etc.), horizontal collaboration takes place between different organisations working at the same level, usually in partnerships or between different functional departments within an organisation. Collaboration is not only important before and during a disruption but also after a disruption, in order to share experiences among the parties to increase the ability of the system to deal with future risks (Jüttner and Maklan, 2011; Sheffi, 2005).

Agility

Resilience implies agility, or the flexibility and ability to speedily adapt (also referred to as velocity) to both positive and negative environmental influences (Ponomarov and Holcomb, 2009). The driver behind agility is the continuous search for the most appropriate response to change, uncertainty and unpredictability within the business environment (Lin et al., 2006). Flexibility facilitates coordination processes and enables organisations to cope with the high levels of environmental and operating uncertainty (Manuj and Mentzer, 2008). However, to do so, visibility, the ability to see from one end of the supply chain to the other, is of paramount importance (Christopher and Peck, 2004; Jüttner and Maklan, 2011; Pettit et al., 2013). Visibility ensures confidence in the supply chain preventing overreaction, unnecessary interventions and ineffective decision in a risk event situation (Christopher and Lee, 2004). Hence, in line with Christopher and Peck (2004) and Faisal et al. (2006) we capture visibility, velocity and flexibility as important building blocks and antecedents of agility, which are needed in a resilience supply chain.

Risk Awareness/ Knowledge Management

While agility is necessary to be able to react to uncertainty, a resilient supply chain also demands a supportive management culture (Christopher and Peck, 2004) and direct top management support (Ponomarov and Holcomb, 2009). As Sheffi and Rice (2005, p. 47) state "it is important not to underestimate the contribution of culture to an organisation's flexibility and resilience". To be resilient, organisations need to develop appropriate management policies and actions that assess risk continuously and coordinate the efforts of their supply network (Kleindorfer and Saad, 2005): supply chain partners must share a common understandings and awareness of the risks that could occur within their operations (Faisal et al., 2006).

The capacity to learn from past disruptions to develop better preparedness for future ones is a principal property of resilience (Ponomarov and Holcomb, 2009). Therefore, leading companies provide training to employees, suppliers and customers about security and supply network risks to raise awareness and reinforce the importance of supply chain resilience (Blackhurst et al., 2011; Rice and Caniato, 2003). Furthermore, knowledge and understanding of supply chain structures - both physical and informational - are important elements of supply chain resilience (Choi and Hong, 2002).

In summary, supply chain (re-)engineering, collaboration, agility, risk awareness and knowledge management capabilities underpin a supply network's resilience. These formative resilience elements are based on integrating and coordinating resources which often span functional areas and thus become manifested in supply chain processes (Jüttner and Maklan, 2011). However, it remains unclear which processes build resilience and how they are related to the supply chain resilience elements from literature. Therefore, we need to understand how the specific interplay of these capabilities can be operationalized and applied in practice simultaneously if we are to further our understanding of supply chain resilience, which is the

purpose of this paper. As it is often useful to take an extreme example for illustration (Bamberger and Pratt, 2010) the context and empirical case study for this research is the disaster management sector. This sector offers extremely potent depictions of processes that *deal* with risk as frequent breakdowns and interruptions in the material and information flow occur (Blecken, 2010). Therefore, we now look to best practices within disaster management for insights on the operationalization of supply chain resilience.

Disaster Management - Best Practices from an Extreme Context

The disaster management context represents an ideal opportunity for examining supply chain resilience given the exacerbating frequency, magnitude and impact of disasters threatening the sustainability of communities, businesses and their resources around the globe. While it is still difficult to forecast exactly when or where a low probability-high impact disaster, such as an earthquake or tsunami, is going to happen, identifying vulnerable areas that are at risk (Peck, 2005; 2006) makes it possible to put in place practices and resources to minimise the potential impact of disasters before they occur i.e. to build resilience. Disaster management addresses the organisation and management of resources and responsibilities for humanitarian aspects of emergencies to lessen the impact of disasters (The International Federation of Red Cross and Red Crescent Societies, 2013). In this context SCM underpins 80% of all activities contributing to cost savings as well as to increased operational efficiency in the planning, delivery and distribution of relief goods (Van Wassenhove, 2006).

Disaster SCM characteristics

While 'general' SCM is characterised by a predetermined set of suppliers, manufacturing sites and stable or at least more predictable demand, disaster SCM is represented by large scale operations, irregular demand, unusual constraints in major emergencies and unreliable, or non-existent supply and transportation information – primarily unforeseeable factors

(Kovács and Spens, 2007). Under these circumstances the *engineering* of a distribution network is challenging due to the nature of the unknown (locations, type, spread and magnitude of events, politics and culture) (Beamon, 2004; Holguín-Veras et al., 2012). Furthermore, disaster management organisations deal with (almost) zero lead time in their supply chain as there may be no advance warning of a crisis, which in turn affects inventory availability, procurement and distribution. This places a huge emphasize on the *agile* capabilities in their supply chain. Moreover, as no single actor has sufficient resources to respond effectively independently, (Balcik et al., 2010) *collaboration* in the disaster management sector is of paramount importance. The regular breakdowns and interruptions in the material and information flow (Blecken, 2010) during disaster management operations allow us to conclude that organisations active in disaster management have a high *risk awareness* and can be considered experts (*knowledgeable*) in working with uncertainty and risk - for them experiencing unpredictability in SCM is the norm. Therefore, exploring processes employed during disaster management holds great potential for general insights on building resilient supply chains.

Disaster Management Processes

Similarly to how supply chain resilience is defined, resilience in the disaster management sector refers to the ability of an individual, a household, a community, a country or a region to withstand, adapt, and quickly recover from stresses and shocks such as drought, violence, conflict or natural disaster (European Comission Humanitarian Aid and Civil Protection, 2012). However, in contrast to the high level strategic perspective of supply chain resilience in the academic literature, there is a large body of applied and more operationally focused research in practitioner and trade journals as well as reports by government funded agencies. Based on a comprehensive analysis of these papers, Helferich and Cook (2002) identified pro-active and re-active disaster management processes for the supply chain context (see

Figure 1). While traditionally disaster management tends to be re-active and disaster specific this four phase disaster management framework advocates long term strategic planning for effective and efficient disaster management. Widely accepted in the humanitarian SCM context (see e.g. Kovács and Spens, 2007; Natarajarathinam et al., 2009; Pettit and Beresford, 2005) the framework brings together the pro-active elements of mitigation and preparedness with the re-active elements of immediate response and recovery. Pro-active measures prepare for disruption response to contain and control potential risks (Tummala and Schoenherr, 2011). More specifically, while mitigation is the application of measures that will either prevent the onset of a disaster or reduce the impact should one occur, preparedness includes activities that prepare for an effective and efficient response (Altay and Green, 2006; Tomlin, 2006). Particularly, disaster risk reduction measures compromising preparedness, mitigation and prevention, aim to enhance resilience to disasters making use of information and communicate on technology and earth observation tools (The Montpellier Pane, 2012). Opposed to that are re-active processes that take place after a disruption has occurred including the employment of resources to preserve life, property, the environment, and the social, economic, and political structures (response) as well as actions taken in the long term after the immediate impact has passed to stabilize and restore some semblance of normalcy in structures (recovery) (Altay and Green, 2006). As displayed in Figure 1 these four phases are cyclical rather than linear and can operate concurrently: mitigation and reconstruction efforts often and ideally take place at the same time in parallel (Maon et al., 2009).[1]

[1] We would like to refer the reader to Maon et al. (2009) for an extensive list of SCM practices within the disaster management sector in each phase.

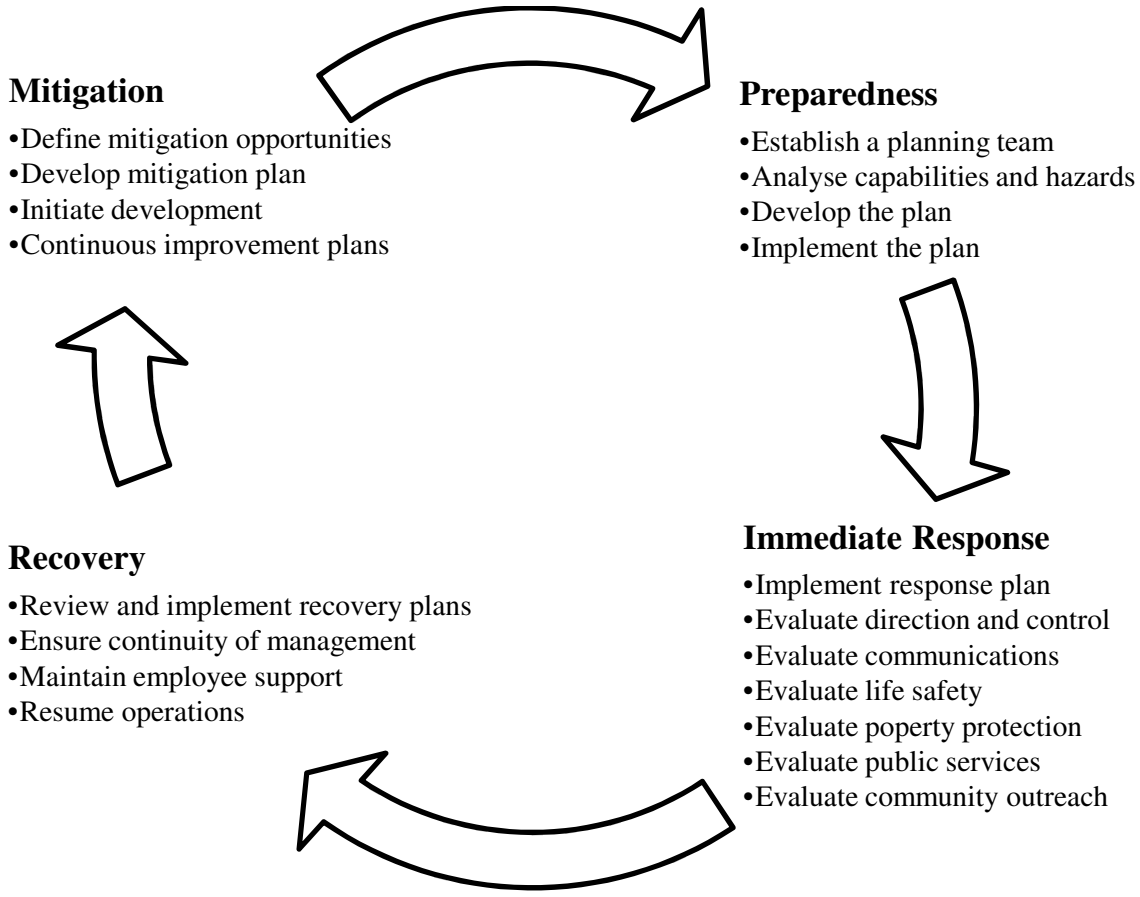

Figure 1 Disaster Management Processes
(Adapted from Helferich and Cook (2002, p.53))

Figure 1 captures how the essence of effective and efficient disaster management is the application of a long term perspective to the processes of making *pro-active* decisions to lessen the impact of unforeseeable events combined with *re-active* decisions to overcome the impact (Natarajarathinam et al., 2009) analogous to definitions of resilience in academic research. In line with Ponomoarov and Holcomb (2009), who recognise resilience as an emerging field within emergency management research, we propose that these four disaster phases are directly related to resilience. We therefore expect supply chain resilience capabilities and disaster management processes/ phases to also be interrelated. To explore the specific relationships and interdependencies between the theoretical frameworks of supply chain resilience and the operational practitioner based emergency management we undertook

a detailed qualitative case study in the disaster management sector.

Methodology

To empirically investigate the relationship between the disaster management processes and supply chain resilience capabilities we adopted an explanatory single case study design (Eisenhardt and Graebner, 2007; Eisenhardt, 1989). Case study research is particularly suited to developing a holistic and in-depth understanding of a complex, unique and exploratory phenomena in a real-life context (Yin, 2009) while allowing questions of why, what and how to be answered (Voss et al., 2002; Yin, 2009). Our study analyses the Voluntary Organizations Active in Disaster (VOAD) group in El Paso, Texas and its disaster management processes across the four disaster phases in relation to the supply chain resilience framework outlined in the literature review.

Introducing the Case

VOAD provides a particularly appropriate research site as it was founded specifically to improve disaster management operations following inadequate preparation for Hurricane Camille in 1970. It is a national organisation (with 50 members) which coordinates efforts among organisations at both national (US) and State/Territory levels. The organisations involved have the stated aims of reducing potential suffering by increasing supply chain resilience through their commitment to communication, collaboration, cooperation and coordination. They share knowledge and resources to better serve those impacted by each disaster phase, so the organisation offers an excellent setting in which to examine how disaster management processes can be linked to supply chain resilience. Our in-depth study was based on the local VOAD group in El Paso, Texas, which was originally formed to incorporate 25 local organisations after unprecedented levels of rainfall in late July/early August 2006 damaged at least 1500 homes and 100 roadways, at a cost of approximately US

$200 million (Crowder, 2006).

When the disaster occurred, local aid agencies were under enormous pressure to respond. Damage and recovery across the county were uneven (Collins, 2010), as there was no engineered system via which the different government, private and not-for profit sector agencies could coordinate their services or identify resources they needed (from other agencies) to improve their responsiveness. Most community agencies and groups knew very little about how to respond to a disaster, or how to collaborate to meet urgent client needs. This resulted in some neighbourhoods receiving a great amount of public and private attention, while other communities struggled with little support; unnecessary duplication of efforts meant some needs gained adequate attention while others went unmet. This is not a new phenomenon, and has happened on larger scales with devastating impact in ill-prepared disaster zones such as the Indian ocean Tsunami 2004 and the Darfur crises 2004/2005 (Jahre and Jensen, 2010).

While conscious that examining a single organisation limits the transferability of findings, a single case study can offer convincing results, especially when the situation is deliberately selected to provide certain insights that alternative cases may not reveal (Siggelkow, 2007). Our chosen setting is of particular value as its supply chain network had been formed relatively recently and there was plenty of information available about its evolution and how its resilience capabilities and disaster management processes had been established and developed. In addition, the geographically remote location of the chain in the far South West of the country places more emphasis on its ability to prepare for and respond to any disaster independently, highlighting the importance of supply chain linkages.

Data Collection

To achieve internal triangulation (Voss et al., 2002), we used a range of techniques to collect

data: (1) nine interviews in three different VOAD lead member organisations, (2) observation of a 60 min VOAD meeting attended by 15 members, and (3) study of archival sources such as internal reports, memos and strategy documents.

We organised individual semi-structured interviews (of approximately 45 minutes) from multiple viewpoints within the VOAD group (3 directors, 4 functional managers and 2 volunteers) contributing to the richness and variety of the data collected (Alvarez et al., 2010). All interviews took place face to face in the office buildings of the interviewees in July 2011, and were recorded and transcribed verbatim; as was the VOAD group meeting. Based on the initial literature review, an interview protocol was developed providing the structure for the data collection process. Accordingly, the interviews with participants followed a standard core (to facilitate data comparison – see Appendix A) organised under broadly defined themes, with open-ended questions and probes to encourage detailed responses to uncover material on specific aspects directly relating to disaster events and the VOAD group, as well as a range of general issues relating to the interviewee's organisation: the group's history and size, and descriptions of the specific roles of each supply chain partner's manager. We asked respondents to recall examples of disasters that happened in their region, to describe their organisation's role and the extent of their involvement, and to evaluate the effectiveness of their actions. The interviews were followed by informal discussions with participants which provided additional context for our analysis, but further background information about interviewees has been excluded from this paper as anonymity was a condition of their involvement. The VOAD meeting gave us additional data on how the pro-active dimensions of preparedness and mitigation are operationalized and how these could fit into the supply chain resilience framework.

In a last step we reviewed archival sources, such as internal reports, strategy documents and newspaper reports. This allowed for triangulation as well as supplementation

to the background of the information collected through the interviews. Table 2 lists the titles and types of documents included in the research.

Table 2 Types of documents analysed

	Document Name	Type of Document	Year
1	Emergency Management Guide for Businesses and Industry	Report	1993
2	Emergency Response in the Community	Report	2003
3	Grant Narrative	Application	2006
4	Executive Summary	Report	2008
5	Empowerment Evaluation Matrix	Report	2008
6	Annual Report of Specific Project	Report	2009
7	Texas VOAD – Active Members and Services Provided	Report	2010
8	Disaster Preparedness Plan	Strategic Document	2011
9	Long Term Recovery Guide	Report	2012

Data Analysis

In analysing the data we firstly applied a data reduction approach coding data items ranging in length from a few words up to several paragraphs, using *in vivo* codes (Miles and Huberman, 1994) to filter out data truly applicable to the disaster management context (first order codes). In doing so, we were very careful to only code situations influencing the disaster processes based on specific actions and interactions rather than beliefs of the respondents (see quotations in Table 3 and 4, Appendix B for representative examples of first order codes). To increase the reliability of our data, where necessary, we followed up with e-mails and calls to fill in missing details e.g. if the length of a project was unclear or the scope of collaboration between different organisations. Following, the data analysis progressed through multiple phases. First we examined first order codes in relation to the disaster management processes. We deducted second order categories guided by Helferich and Cook's (2002) disaster management framework (Figure 1) (see Table 3 in Appendix B for representative data). Next, we examined first order codes in relation to Christopher and Peck's (2004) framework deducting second order categories under the headings of supply

chain (re-)engineering, collaboration, agility, risk awareness and knowledge management (see Table 4 in Appendix B for representative data). In doing so, we incorporated data in relation to the different resilience aspects that we grouped under the system level headings as per Table 1. In a third step, as our primary objective was to close the gap between theory and practice by establishing an integrated approach to supply chain resilience, we sought out and analysed patterns juxtaposing the data from Table 3 (disaster management processes) and Table 4 (supply chain resilience capabilities). This allowed us to generate Table 5 displaying the congruence between disaster management processes and supply chain resilience capabilities (illustrated via check marks). Where we only found partial confirmation for congruence i.e. only one or two informants' codes in a category we refer to 'possibly required' processes/ capabilities (illustrated via check marks in brackets).

Our initial understanding of the data (comparing pre-VOAD examples with post- VOAD examples of interviewees) pointed to a more complex relationship between supply chain capabilities and disaster management processes than anticipated. Therefore, to achieve a more in-depth exploration of the relationship between the two constructs we searched for patterns between disaster management processes, supply chain resilience capabilities and the four disaster phases. The triangulation of the interview data with archival data and literature brought us to the conclusion that a high emphasis on mitigation processes is essential to building supply chain resilience capabilities. In turn, preparedness, response and recovery processes cannot take place without having established supply chain resilience capabilities. This finding led to the re-coding of some of the disaster management processes differently to Helferich and Cook (2002), specifically in relation to preparedness and mitigation (compare Figure 1 with Table 5).

NVivo9 was used to manage the data analysis process in a systematic and consistent manner (Alvarez et al., 2010). Although the data was coded manually, the software was

especially useful for fragmenting, re-assembling and re-coding the data so as to generate findings progressively. Overall, we followed a recursive iterative process to relate our data and findings to existing theoretical frameworks and literature (Eisenhardt and Graebner, 2007); an overview of the methodological process can be seen in Figure 2 below.

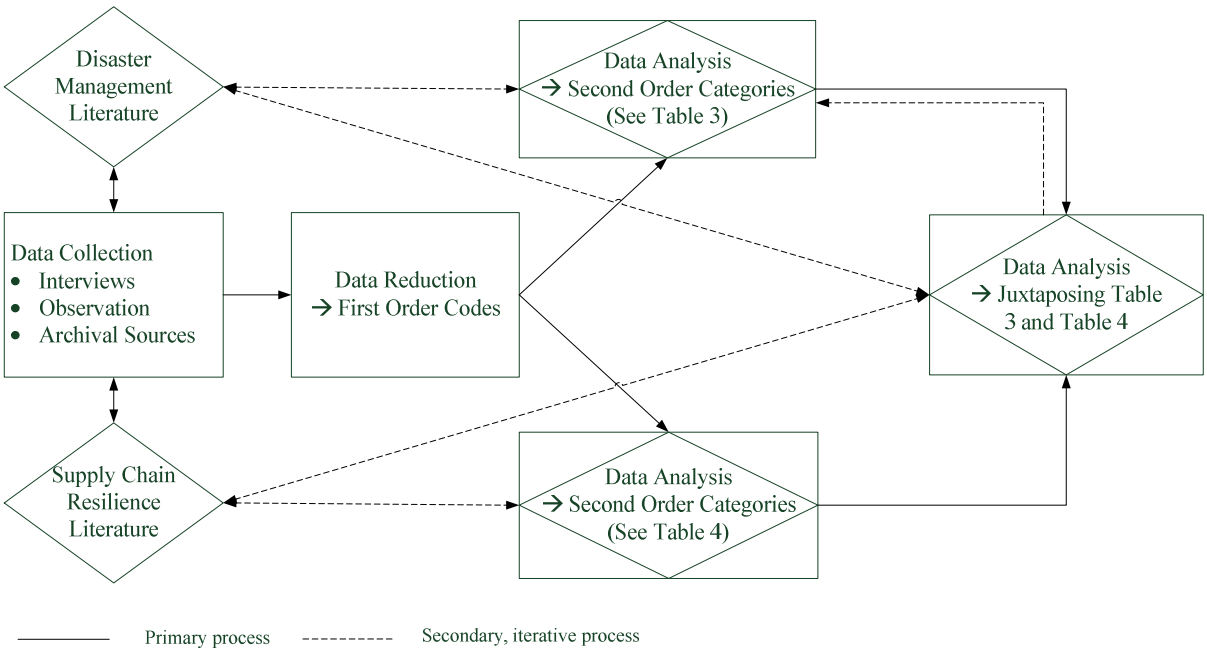

Figure 2 Methodological Process

Overall, multiple measures were employed to ensure the trustworthiness of the qualitative data and their analysis: multiple iterations of data analysis, constant moving between data and theory and confirming the validity of preliminary analyses with respondents to identify and correct any misunderstandings or omissions (Voss et al., 2002). Similar to Jüttner and Maklan (2011) our aim is to generalise to the theoretical concepts and not to populations or universes, therefore our emphasis is on analytical generalisation rather than statistical generalisation.

Findings and Discussion

Applying the insights from our analysis enabled us to build an integrated supply chain resilience framework depicting the relationship between specific processes and capabilities

needed in the different disruption phases. Findings are presented by showing how VOAD builds resilience with the help of the theoretical supply chain capabilities and application of specific disaster management processes (summarised in Table 5). While we discuss each disaster phase separately for ease of reference, in reality these phases are linked and overlap naturally (Van Wassenhove and Pedraza Martinez, 2012).

Mitigation Phase

The ability of different organisations or internal business departments to work together to develop a collective strategy often determines the success or failure of managing a disaster and/ or supply chain disruption (Chandes and Paché, 2010). Therefore, a planning team with *"effective leadership"* acting as *"a resource centre and communication hub" (Document 8)* is critical to be able to start building a resilient supply chain and lessen the possible impact of disasters/ supply chain disruptions. This first step is essential and requires top management support and risk awareness throughout the supply network (including beneficiaries), without which all of the following processes in the different disaster phases for building a resilient supply chain cannot take place.

As formative resilience capabilities are based on integrating and coordinating resources which often span functional areas (Jüttner and Maklan, 2010), this team needs to be made up from intra- and inter-organizational supply chain members. The analysis of data suggests that members of such a team should be deliberately chosen to make use of complementary capabilities while being *"geared towards filling individual agencies resource gaps" (Director 2).* Thus for the set-up of a resilient supply chain, strong strategic horizontal and vertical collaboration as well as knowledge management (transfer, store, create and apply) capabilities throughout the mitigation phase have to be built between all team/ supply chain members.

To ensure the most current evaluation of existing supply chain (resilience) capabilities, resources and possible hazards, routine meetings and reviews among the planning team are essential, as is the case in VOAD El Paso. Demand satisfaction, alternative sources of supplies (supplier and supplier's supplier's) as well as inventory and capacity levels in the supply chain have to be known prior to an event to prevent further complications during a disaster/ disruption that could have been avoided, both in terms of aid delivery as well as products/ services to consumers; as literature suggest (see e.g. Christopher and Peck, 2004), supply chain resilience is a network theory and necessitates an according approach. Furthermore, our data indicates that such an analysis coupled with considerations of different scenarios can be the basis for the development of strategic plans for implementation during preparedness, immediate response and recovery along with measurements and metrics, that will need to be evaluated throughout all phases. Examples of measurements and metrics are monitoring of level of threats, pre-identification and pre-categorization of vulnerabilities, prioritization and sequencing plans (Oloruntoba, 2010). Such information has to be shared throughout the supply network so that every employee of every organization involved is familiar with the plans and what to expect once plans kick into action (van Vactor, 2011).

While the above mentioned processes support the engineering of the necessary communication, collaboration, coordination and cooperation structure and infrastructure among the planning team, our findings show that they also help to identify, avoid and eliminate supply network inefficiencies prior to an event taking place. An example of such continuous improvements is the establishment of an updated preparedness plan (Document 8, discussed and evaluated during the observation of the VOAD meeting).

It can be concluded that mitigation processes incorporating continuous improvement build the strategic capabilities of horizontal and vertical collaboration, risk awareness, supply chain (re-)engineering and knowledge management capabilities as suggested by the supply

chain literature, which form the basis for all other phases and an overall resilient supply chain.

Preparedness Phase

A prepared supply chain is ready to enable an efficient and effective response (Ponomarov and Holcomb, 2009) in line with the definition of supply chain resilience. Our data analysis suggests that during the preparedness phase strategic horizontal and vertical collaborative agreements set out in the mitigation phase are translated into operational plans. During that process all involved parties get ready for action; in case of an emergency they then know about their specific roles and can respond effectively to the disruption (Natarajarathinam et al., 2009). *"We always have to make sure we are prepared for anything" (Functional Manager 2).* Our findings indicate that routines established through learning exercises and simulations as well as the evaluation of pre-agreed metrics are critical components of the preparedness processes as they identify supply chain links and the institutional roles required to build resilience. Due to the rarity of actual opportunities for managers to acquire emergency experience literature suggests the inclusions of stress risk management and/ or assessment centres (Paton and Jackson, 2002; Paton, 2003). These simulate disaster scenarios and develop critical decision making as well as necessary collaboration capabilities (Hale and Moberg, 2005). A table top exercise during the observed VOAD meeting illustrated one example of such learning.

Furthermore, our data analysis indicates that implementing and executing preparedness plans might also require agile supply chain capabilities: *"We had to set up in a matter of hours to expect what we thought might be 5-7000 people." (Director 2).* While some events happen out of the blue e.g. a fire in a plant, other events such as weather conditions are unavoidable, yet somewhat foreseeable and give more time to put the preparedness plan into action. To be able to do so, findings indicate that the preparedness

plan should outline each member's specific role in a disaster/ supply chain disruption and their resources as well as network activities and includes the *"set up of supplies in strategic locations"* and "*memorandums of understanding for supplies with other businesses […] to activate more resources" (Director 1).*

In conclusion, our findings suggest that the emphasis for building supply chain resilience through preparedness should be on the planning processes enabled by the strategic capabilities of knowledge management, collaboration and agility, rather than on the plan itself. Therefore, constant information exchange and learning from horizontal and vertical supply chain partners to "*keep skill levels up" (Functional Manager 1)*, so as to be prepared, are essential.

Immediate Response Phase

Our analysis shows that high levels of horizontal and vertical collaboration capabilities are required when implementing the developed disaster plan, evaluating its direction and control, and ensuring communication. Pre-established lines of communication and knowledge of different expertise within the collaborative network enable e.g. the evaluation of life safety, property protection, public services and supply chain disruption outreach in a standardised and unified way. This is in line with previous research by Blackhurst et al. (2011) identifying communication protocols as a critical enabler for supply chain resilience. Furthermore, it appears that services and resources (human, physical and organisational) through vertical collaboration, upstream and downstream, can be incorporated better as network wide gaps are known immediately.

While having direction and control as well as a permanent communication infrastructure for action during disasters is important, our data indicates that the adaptability and agility of the network structure to different situations and needs, that might occur during any emergency, is equally as essential: *"there is no routine, every disaster is different"*

(Functional Manager 1). It can be assumed that gaps in work flow and interruptions will occur during the immediate response (van Vactor, 2011) possibly necessitating re-engineering of the supply chain. Therefore, organizations need to be able to adapt to changing needs, whether it is due to one of its members (or their resources) being affected (such as a local warehouse being destroyed) or other unforeseen circumstances.

Overall our findings lead to the conclusion that horizontal and vertical collaboration and possible re-engineering capabilities during an emergency enable processes that help to get aid to people/ products to consumers effectively and efficiently while avoiding duplications of efforts. Furthermore, flexibility and agility are key capabilities for building supply chain resilience in the immediate response phase.

Recovery Phase

The implementation of pre-established recovery plans for crisis management begins the minute an emergency occurs (van Vactor, 2011). Consequently the planning team has to ensure the continuity of risk and resilience management while maintaining employee support to be able resume operations at the desired level, which possible involves re-engineering the supply chain. Analysis of findings show that this is only possible if risk awareness is spread throughout the supply chain. Additionally, horizontal and vertical collaboration capabilities help to use resources and complementary skills in the supply chain in the most effective and efficient way. Our data indicates that to do so all supply chain members need to have access to information and knowledge about the resources held by the different organizations: "*We have lists of resources that we could provide for them. So we send out referrals for them. These are three different companies that are actually handing out what they need (Functional Manager 3).*"

We conclude that horizontal and vertical collaborative capabilities in the recovery phase of a

disruption help to establish processes enabling a network where resources and complementary skills can be used in the most effective and efficient way. Furthermore, risk awareness and knowledge management capabilities throughout the supply chain are needed to be able to achieve recovery while re-engineering nodes along the chain and maintaining continuity of operations at the desired level of connectedness and control over structures and function in line with the definition of supply chain resilience.

Table 5 Integrative Framework for Building Supply Chain Resilience

Phase/ Process (2nd Order Categories)		Supply Chain Resilience Capabilities (2nd Order Categories)				
		Horizontal & Vertical Collaboration	*Supply Chain (Re-) engineering*	*Agility*	*Risk Awareness*	*Knowledge Management*
Mitigation	Establish a cross-functional planning team	√	√		√	√
	Analyse supply chain capabilities and hazards	√			√	√
	Develop and communicate plan for preparedness, response and recovery	√	√		√	√
	Agree measurements and metrics for preparedness, response and recovery	√	√		√	√
	Develop continuous improvement and supply chain risk mitigation plans	√	(√)		√	√
Preparedness	Implement preparedness plan: Translate strategic agreements into operational matters	√	(√)	(√)		√
	Evaluate based on measurements and metrics	√		(√)		√
	Establish routines through training and simulation	√	√	(√)		√
Response	Implement response plan, measurements and metrics	√	(√)	√		√
	Evaluate direction and control	√		(√)		(√)
	Evaluate communications throughout the supply chain	√		(√)		(√)
	Evaluate supply chain disruption outreach	√	(√)	√		(√)
Recovery	Review and implement recovery plans	√	(√)			√
	Ensure continuity of risk and resilience management	√			√	
	Maintain employee support	√			√	
	Resume operations	√		(√)		√

(√) = possibly required

√ = required

An illustrative case of the integrated framework

We now undertake a retrospective analysis of Hurricane Katrina to illustrate the analytical usefulness of our proposed integrative framework. Hurricane Katrina hit New Orleans on the morning of August 29th 2005. One of the most destructive natural disaster to occur in the United States, it caused the death of circa 1,330 people and displaced over 770,000, destroyed an estimated 300,000 homes with over $96 billion in property damage, and left 118 million cubic yards of debris (Samaan and Verneuil, 2009). The disaster management for Katrina has been heavily criticised, mainly for the ineffective logistical response (Holguin-Veras et al., 2007).

At the time of the hurricane striking, disaster plans for New Orleans were still under development and inconsistent (Committee on Homeland Security and Governmental Affairs, 2006). The hurricane protection system had never been quantified, so the actual risk and vulnerability of the city was unknown (American Society of Civil Engineers, 2007). Therefore, the plans that were in place could not realistically judge the requirements and consequences of such an event (Holguin-Veras et al., 2007). Furthermore, no single agency was in charge of hurricane protection in New Orleans, there was no cross-functional planning team in place, and FEMA was not ready for the magnitude of the disaster (Qamar et al., 2007). While the destructive strength of the hurricane is undeniable officials preparing for the disaster were fully aware of critical deficiencies in their plans and gaping holes in their resources (Committee on Homeland Security and Governmental Affairs, 2006): it was known that FEMA lacked 20% of its workforce (Holguin-Veras et al., 2007) and that its logistics system suffered from significant and long-standing problems (Committee on Homeland Security and Governmental Affairs, 2006). Processes to develop continuous improvement and supply chain risk mitigation plans to address these identified gaps were not in place.

These examples show that the mitigation processes identified in our framework were

absent or problematic regarding the operations of Hurricane Katrina. Therefore, important and necessary supply chain resilience capabilities were not built pro-actively. This adversely impacted horizontal and vertical collaboration, supply chain (re-)engineering, agility, risk awareness as well as knowledge management and learning throughout the other phases of the disaster. In line with our findings this highlights that the necessary supply chain resilience capabilities must be built during the mitigation phase to enable the essential processes during preparedness, response and recovery that allow for effective and efficient disaster management. Table 6 in the Appendices shows a more detailed analysis of Hurricane Katrina in relation to the developed framework, identifying which specific interplay of capabilities and processes was adequate, problematic or non-existent. [2]

Conclusions

In today's interconnected globalised world supply chain resilience is of increasing relevance as it enables an organisation to prepare for, respond to and recover successfully from disruptions. Yet our review of the literature indicates that while theory has identified the capabilities required to achieve supply chain resilience, it fails to provide guidance on how these capabilities apply within the different phases entailed in the supply chain resilience definition. Our detailed qualitative investigation of the practices of a sophisticated disaster management supply chain enables the major contribution of this paper, the development of an integrative framework for building supply chain resilience, as depicted in Table 5. This framework extends current theory as it bridges the gap between theory and practice. Furthermore, our findings highlight that the integration of processes and capabilities for building supply chain resilience has to be iterative and staged; creating and maintaining resilience is not a one-time event, but rather a process in itself (Pettit et al., 2013).

[2] For details on a contrasting well executed disaster management we would like to refer the reader to Oloruntoba (2010) who describes the response to Cyclone Larry in 2006.

Supply chain resilience is considered a pro-active risk management strategy, however, the concept also captures the re-active elements of being able to respond to a disruption and recover to the same or an improved state of functioning (Jüttner and Maklan, 2011). While Helferich and Cooks' (2002) framework places equal importance on the different phases of disaster management we show that the adaptive capability to prepare for, respond to and recover from disruption (definition of resilience) is foremost about mitigation processes. Our findings highlight that mitigation processes are of paramount importance as they are the antecedents to building supply chain resilience capabilities which in turn enable the execution of the necessary processes during preparedness, response and recovery. This important link has been missing to date, but is critical if we are to build relevant theory which advises organisations on the appropriate application and deployment of resources to build supply chain resilience.

While there is no one size fits all model for supply chain resilience - each organization will have idiosyncratic requirements (van Vactor, 2001) in terms of time, human, physical and organisational resources– our framework contributes to the development of an awareness of the value of the strategic capabilities involved in the different disruption phases and of how they interact with each other through specific processes. Determining the appropriate practices to manage supply chain vulnerabilities and risk appears to be context specific, dependent amongst other things on the supply chain's response to the need for operational excellence (Peck et al., 2003). Therefore, our integrated framework is not to be seen as a specific set out route to supply chain resilience but more as a road map that can guide individual, context specific supply chains (commercial and disaster management businesses) in improving and building up their supply chain resilience and disruption management capabilities.

Managerial Implications

Our study's findings also translate into several important practice implications for supply chain managers. Many aid agencies specialise in disaster management, so it can be taken as a given that one of their great strengths is that they know what to do in emergencies; hence, there is great potential for commercial businesses to learn from their practices. By analysing the collaboration efforts of the El Paso VOAD group to develop an integrated supply chain resilience framework our study explores how to support managers in implementing strategies to build supply chain resilience. In particular, the need for management to be pro-active in developing resilience is clearly demonstrated: mitigation processes are essential to building supply chain resilience, irrespective of the type of organisation. Setting up networks and infrastructures in advance creates knowledge and resilience capabilities prior to the event that can reduce the vulnerability of the supply chain. By moving from a high level theoretical awareness of the need for resilience to building awareness of specific mitigation processes that develop the adaptive capabilities to prepare for, respond to and recover from a disruption/ disaster allows management to direct and prioritise resources accordingly while reducing the vulnerability of the supply chain for unforeseeable events.

The subtleties in collaboration which we have identified have significant implications for how supply network members communicate at different stages of disaster management (see processes during mitigation, preparedness, immediate response and recovery), reinforcing the need for managers to be aware of the importance of cross-functional teams. Fostering continuous commitment to communication and collaboration at different levels of management within and between organizations, involving staff from different departments, supply chain members and organisational levels in strategic planning and establishing risk awareness via training and education is the first step to becoming more resilient.

Limitations and Research Implications

This paper identifies the connection between disaster management processes and strategic capabilities needed at each phase as a disaster/ disruption strikes to achieve a resilient supply network. Our proposed integrated framework combines key concepts from disaster management and supply chain resilience to develop an integrated view that shows the interdependencies between disruption phases, capabilities and processes that can be synchronized via a strategic and synchronized approach.

While this paper reports the findings for research into just one VOAD group in the United States it is based on a central US government initiative supported by a pool of available information. Therefore, we believe other VOAD groups operate on a similar basis. However, as interviewees could choose which disaster example to talk about there may be some concerns in relation to the reliability of what participants recalled depending on the time elapsed since that particular event took place. While our work aimed for analytical rather than statistical generalizability, further work is needed to establish the transferability of our single case study findings to different organisational contexts and industries. Replicating our study in developing country or commercial contexts would clearly expand our insights. Furthermore, studies in relation to the involvement of the diverse stakeholders in the disaster management context such as beneficiaries, the public, media, military and governments for building resilience could provide additional important insights.

The richness of the data from the extreme case analysed here indicates the benefits from future studies adopting this approach. As expressed by Bamberger and Pratt (2010, p. 665) ‘we should remind ourselves that some of the most significant contributions to management theory emerged from what might best be labeled “unconventional” organisational research’. For some critical but complex aspects of organisational activity,

particularly supply chain resilience as our initial step shows, such approaches may yield rich insights.

References

Altay, N. and Green, W.G. (2006), "OR/MS research in disaster operations management", *European Journal of Operational Research*, Vol. 175 No. 1, pp. 475–493.

Alvarez, G., Pilbeam, C. and Wilding, R. (2010), "Nestlé Nespresso AAA sustainable quality program: an investigation into the governance dynamics in a multi-stakeholder supply chain network", *Supply Chain Management: An International Journal*, Vol. 15 No. 2, pp. 165–182.

American Society of Civil Engineers. (2007), *Hurricane protection system: What went wrong and why*, Reston, Virigina.

Balcik, B., Beamon, B.M., Krejci, C.C., Muramatsu, K.M. and Ramirez, M. (2010), "Coordination in humanitarian relief chains: Practices, challenges and opportunities", *International Journal of Production Economics*, Elsevier, Vol. 126 No. 1, pp. 22–34.

Bamberger, P. and Pratt, M. (2010), "Moving forward by looking back: Reclaiming unconventional research contexts and samples in organizational scholarships", *Academy of Management Journal*, Vol. 53 No. 4, pp. 665–671.

Beamon, B.M. (2004), "Humanitarian relief chains: Issues and challenges", *Proceedings of the 34th International Conference on Computers & Industrial Engineering*, San Francisco, CA, pp. 77–82.

Blackhurst, J., Dunn, K.S. and Craighead, C.W. (2011), "An Empirically Derived Framework of Global Supply Resiliency", *Journal of Business Logistics*, Vol. 32 No. 4, pp. 374–391.

Blecken, A. (2010), "Supply chain process modelling for humanitarian organizations", *International Journal of Physical Distribution & Logistics Management*, Vol. 40 No. 8, pp. 675–692.

Brand, A.L. and Seidman, K. (2009), *Assessing Post Katrina Recovery*, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Chandes, J. and Paché, G. (2010), "Investigating humanitarian logistics issues: from operations management to strategic action", *Journal of Manufacturing Technology Management*, Vol. 21 No. 3, pp. 320–340.

Choi, T.Y. and Hong, Y. (2002), "Unveiling the structure of supply networks: case studies in Honda, Acura, and Daimler Chrysler", *Journal of Operations Management*, Vol. 20 No. 5, pp. 469–493.

Christopher, M. and Lee, H. (2004), "Mitigating supply chain risk through improved confidence", *International Journal of Physical Distribution & Logistics Management*, Vol. 34 No. 5, pp. 388–396.

Christopher, M. and Peck, H. (2004), "Building the Resilient Supply Chain", *International Journal of Logistics Management*, Vol. 15 No. 2, pp. 1–13.

Christopher, M. and Tatham, P. (2011), *Humanitarian Logistics: Meeting the Challenge of Preparing for and Responding to Disasters*, Kogan Page, London.

Collins, T.W. (2010), "Marginalization, Facilitation, and the Production of Unequal Risk: The 2006 Paso del Norte Floods", *Antipode*, Vol. 42 No. 2, pp. 258–288.

Committee on Homeland Security and Governmental Affairs. (2006), *Hurricane Katrina: A nation still unprepared*, Washington, Washington DC.

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*, Vol. 38 No. 1, pp. 131–156.

Crowder, D. (2006), "City street repairs to take time, money", *El Paso Times*, Vol. September No. 6.

Day, J.M., Melnyk, S.A., Larson, P.D., Davis, E.W. and Whybark, D.C. (2012), "Humanitarian disaster relief supply chains: A matter of life and death", *Journal of Supply Chain Management*, Vol. 48 No. 2, pp. 21–36.

Eisenhardt, K.M. (1989), "Building Theories from Case Study Research", *The Academy of Management Journal*, Vol. 14 No. 4, pp. 532–550.

Eisenhardt, K.M. and Graebner, M.E. (2007), "Theory building from cases: Opportunities and challenges", *Academy of Management Journal*, Vol. 50 No. 1, pp. 25–32.

Ellram, L.M. (1996), "The use of the case study method in logistics research", *Journal of Business Logistics*, Vol. 17 No. 2, pp. 93–138.

European Comission Humanitarian Aid and Civil Protection. (2012), *The EU approach to resilience: Learning from food security crises.*, Brussels, Belgium.

Faisal, M.N., Banwet, D.K. and Shankar, R. (2006), "Supply chain risk mitigation: modeling the enablers", *Business Process Management*, Vol. 12 No. 4, pp. 535–552.

Francis, V. (2008), "Supply chain visibility: lost in translation?", *Supply Chain Management: An International Journal*, Emerald Group Publishing Limited, Vol. 13 No. 3, pp. 180–184.

Hale, T. and Moberg, C.R. (2005), "Improving supply chain disaster preparedness - A decision process for secure site location", *International Journal of Physical Distribution & Logistics Management*, Vol. 35 No. 3, pp. 195–207.

Harland, C., Brenchley, R. and Walker, H. (2003), "Risk in supply networks", *Journal of Purchasing and Supply Management*, Vol. 9 No. 2, pp. 51–62.

Helferich, O.K. and Cook, R.L. (2002), *Securing the supply chain: Management report*, CLM Publications, Oak Brook, Illinios.

Holguín-Veras, J., Jaller, M.M., Van Wassenhove, L.N., Pérez, N. and Wachtendorf, T. (2012), "On the unique features of post-disaster humanitarian logistics", *Journal of Operations Management*, Vol. 30 No. 7-8, pp. 494–506.

Holguin-Veras, J., Perez, N., Ukkusuri, S. V, Wachtendorf, T. and Brown, B. (2007), "Emergency Logistics Issues Affecting the Response to Katrina: A Synthesis and Preliminary Suggestions for Improvement", *Transportation Research Record: Journal of the Transportation Research Board*, No. 2022, pp. 76–82.

Jahre, M. and Jensen, L.-M. (2010), "Coordination in humanitarian logistics through clusters", *International Journal of Physical Distribution & Logistics Management*, Emerald, Vol. 40 No. 8, pp. 657–674.

Jüttner, U. (2005), "Supply chain risk management: Understanding the business requirements from a practitioner perspective", *The International Journal of Logistics Management*, Vol. 16 No. 1, pp. 120–141.

Jüttner, U. and Maklan, S. (2011), "Supply chain resilience in the global financial crisis: an empirical study", *Supply Chain Management: An International Journal*, Vol. 16 No. 4, pp. 246–259.

Kleindorfer, P.R. and Saad, G.H. (2005), "Managing Disruption Risks in Supply Chains", *Production & Operations Management*, Vol. 14 No. 1, pp. 53–68.

Knemeyer, A.M., Zinn, W. and Eroglu, C. (2009), "Proactive planning for catastrophic events in supply chains", *Journal of Operations Management*, Vol. 27 No. 2, pp. 141–153.

Kovács, G. and Spens, K.M. (2007), "Humanitarian logistics in disaster relief operations", *International Journal of Physical Distribution & Logistics Management*, Vol. 37 No. 2, pp. 99–114.

Lin, C.-T., Chiu, H. and Chu, P.-Y. (2006), "Agility index in the supply chain", *International Journal of Production Economics*, Vol. 100 No. 2, pp. 285–299.

Manuj, I. and Mentzer, J.T. (2008), "Global Supply Chain Risk Management Strategies", *International Journal of Physical Distribution & Logistics Management*, Vol. 38 No. 3, pp. 192–223.

Maon, F., Lindgreen, A. and Vanhamme, J. (2009), "Developing supply chains in disaster relief operation through cross-sector socially oriented collaborations: A theoretical model", *Supply Chain Management: An International Journal*, Vol. 14 No. 2, pp. 149–164.

Naim, M., Lalwani, C., Fortuin, L., Schmidt, T., Taylor, J. and Aronsson, H. (2000), "A model for logistics systems engineering management education in Europe", *European Journal of Engineering Education*, Vol. 25 No. 1, pp. 65–82.

Natarajarathinam, M., Capar, I. and Narayanan, A. (2009), "Managing supply chins in times of crises: a review of literature and insights", *International Journal of Physical Distribution & Logistics Management*, Vol. 39 No. 7, pp. 535–573.

Oloruntoba, R. (2010), "An analysis of the Cyclone Larry emergency relief chain: Some key success factors", *International Journal of Production Economics*, Vol. 126 No. 1, pp. 85–101.

Paton, D. (2003), "Stress in disaster response: A risk management approach", *Disaster Prevention and Management*, Vol. 12 No. 3, pp. 203–209.

Paton, D. and Jackson, D. (2002), "Developing disaster management capability: An assessment centre approach", *Disaster Prevention and Management*, Vol. 11 No. 2, pp. 115–122.

Peck, Helen. (2005), "Finding better ways to deal with disasters", *Logistics & Transport Focus*, Vol. 7 No. 10, pp. 19–21.

Peck, H. (2005), "Drivers of supply chain vulnerability: An integrated framework", *International Journal of Physical Distribution and Logistics Management*, Vol. 35 No. 4, pp. 210–232.

Peck, H. (2006), "Reconciling supply chain vulnerability, risk and supply chain management", *International Journal of Logistics: Research & Applications*, Vol. 9 No. 2, pp. 127–142.

Peck, H., Abley, J., Christopher, M., Haywood, M., Saw, R., Rutherford, C. and Strathern, M. (2003), "Creating resilient supply chains: A practical guide", University Cranfield, UK.

Pettit, S.J. and Beresford, a. K.C. (2005), "Emergency relief logistics: an evaluation of military, non-military and composite response models", *International Journal of Logistics: Research & Applications*, Vol. 8 No. 4, pp. 313–331.

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*, Vol. 34 No. 1, pp. 46–76.

Pettit, T.J., Fiksel, J. and Croxton, K.L. (2010), "Ensuring supply chain resilience: Development of a conceptual framework", *Journal of Business Logistics*, Vol. 31 No. 1, pp. 1–21.

Ponis, S.T. and Koronis, E. (2012), "Supply chain resilience: Definition of concept and its formative elements", *The Journal of Applied Business Research*, Vol. 28 No. 5, pp. 921–930.

Ponomarov, S.Y. and Holcomb, M.C. (2009), "Understanding the concept of supply chain resilience", *The International Journal of Logistics Management*, Vol. 20 No. 1, pp. 124–143.

Qamar, I., Mehler, K. and Bayram Yildirim, M. (2007), *Comparison of disaser logistics planning and execution for 2005 hurricane season*, Midwest Transportation Consortium, Iowa.

Rice, J.B. and Caniato, F. (2003), "Building a secure and resilient supply network", *Supply Chain Management Review*, Vol. 7 No. 5, p. 22.

Samaan, J.-L. and Verneuil, L. (2009), "Civil-Military relations in Hurricane Katrina: A case study on crisis management in natural disaster response", in Steets, J. and Hamilton, D.S. (Eds.),*Humanitarian Assistance: Improving U.S.-European Cooperation*, Center for Transatlantic Relations, The Johns Hopkins University/Global Public Policy Institute, pp. 413–432.

Sheffi, Y. (2001), "Supply Chain Management under the Threat of International Terrorism", *International Journal of Logistics Management*, Vol. 12 No. 2, pp. 1–11.

Sheffi, Y. (2005), "A Supply Chain View of the Resilient Enterprise A Supply Chain View of the Resilient Enterprise", Vol. 47 No. 1.

Sheffi, Y. and Rice, J.B. (2005), "A Supply Chain View of the Resilient Enterprise", *MIT Sloan Management Review*, Vol. 47 No. 1, pp. 41–48.

Siggelkow, N. (2007), "Persuasion with case studies", *Academy of Management Journal*, Vol. 50 No. 1, pp. 20–24.

Skipper, J B and Hanna, J.B. (2009), "Minimizing supply chain disruption risk through enhanced flexibility", *International Journal of Physical Distribution and Logistics Management*, Vol. 39 No. 5, pp. 404–427.

Skipper, Joseph B. and Hanna, J.B. (2009), "Minimizing supply chain disruption risk through enhanced flexibility", *International Journal of Physical Distribution and Logistics Management*, Vol. 39 No. 5, pp. 404–427.

Svensson, G. (2000), "A conceptual framework for the analysis of vulnerability in supply chains", *International Journal of Physical Distribution & Logistics Management*, Vol. 30 No. 9, p. 731.

Tang, C.S. (2006), "Robust strategies for mitigating supply chain disruptions", *International Journal of Logistics: Research & Applications*, Vol. 9 No. 1, pp. 33–45.

The International Federation of Red Cross and Red Crescent Societies. (2013), "About disaster management". Retrieved May 16, 2013, from http://www.ifrc.org/en/what-we-do/disaster-management/about-disaster-management/

The Montpellier Pane. (2012), *Growth with resilience: Opportunities in African argriculture*, London, UK.

Tomasini, R.M. and Van Wassenhove, L.N. (2009), "From preparedness to partnerships: case study research on humanitarian logistics", *International Transactions in Operational Research*, Vol. 16 No. 5, pp. 549–559.

Tomlin, B. (2006), "On the Value of Mitigation and Contingency Strategies for Managing Supply Chain Disruption Risks", *Management Science*, Vol. 52 No. 5, pp. 639–657.

Van Vactor, J.D. (2011), "Cognizant healthcare logistics management: Ensuring resilience during crisis", *International Journal of Disaster Resilience in the Built Environment*, Vol. 2 No. 3, pp. 245–255.

Voss, C., Tsikriktsis, N. and Frohlich, M. (2002), "Case research in operations management", *International Journal of Operations & Production Management*, Vol. 22 No. 2, pp. 195–219.

Wagner, S.M. and Bode, C. (2006), "An empirical investigation into supply chain vulnerability", *Journal of Purchasing and Supply Management*, UK, Vol. 12 No. 6, pp. 301–312.

Van Wassenhove, L.N. (2006), "Blackett Memorial Lecture Humanitarian aid logistics: supply chain management in high gear", *Journal Operational Research Society*, Nature Publishing Group, Vol. 57 No. 5, pp. 475–489.

Wieland, A. and Wallenburg, C.M. (2012), "Dealing with supply chain risks: Linking risk management practices and strategies to performance", *International Journal of Physical Distribution & Logistics Management*, Vol. 42 No. 10, pp. 887–905.

Yin, R.K. (2009), *Case Study Research: Design and Methods*, *Essential guide to qualitative methods in organizational research*, Sage Publications, London, Vol. 5.

Zsidisin, G.A. and Wagner, S.M. (2010), "Do perceptions become reality? The moderating role of supply chain resiliency on disruption occorrence", *Journal of Business Logistics*, Vol. 31 No. 2, pp. 1–20.

Appendix A: Interview Guide

1. General Information

- Career, educational background, work experience (commercial or not for profit)
- Current department and role, job description
- Responsibilities, role in relation to organisation

2. Role of SCM

- Where do you see SCM in the organisation in relation to importance and recognition?
- Can you tell me how your position is related to daily supply chain activities?
  - Typical supply chain
  - Routine operations
  - Role of IT
  - Role of partnerships/ collaboration, time frame

3. Disaster Management

- Please recall a specific example of a disaster in this region (before and after VOAD)
  - Slow onset vs. fast onset
  - Preparation, Immediate Response, Recovery
  - Organisation's role and involvement
- Can you think of an example where from your perspective many things went wrong?
- How did you learn from it to make sure it won't happen again?
- Did it impact sustainability of operations? How?

4. VOAD

- Can you tell me about the establishment of VOAD EL Paso?
- What processes and procedures do you have in place?
- How do you prepare and mitigate risks and possible disasters?
  - Contingency planning / Mitigation
  - Techniques
  - Parties involved
- How do you collaborate?

5. If money wasn't an issue would there be anything you would like to improve in your supply network?

Appendix B

Table 1 Supply Chain Resilience Overview (Adapted from Pettit et al. (2010)) – Support for System Level Resilience Approach

System Level Resilience Capabilities	Resilience Elements	Christopher and Peck (2004)	Rice and Caniato (2003)	Sheffi (2005), Sheffi and Rice (2005)	Blackhurst et al. (2005)	Tang (2006)	Ponomarov and Holcomb (2009)
Supply Chain (re-)engineering:		**X**	**X**	**X**	**X**	**X**	**X**
The conceptualisation, design, implementation, operation and re-engineering of the supply chain (Naim et al., 2000)	*Efficiency:* The ability to produce outputs with minimum resource requirements (Pettit et al., 2010).	X		X	X	X	X
	Redundancy: Limiting or mitigating the negative consequences of change by keeping resources in reserve, such as having safety stock, maintaining multiple supplier and running operations at a low capacity utilization rates (Blackhurst et al., 2005; Sheffi and Rice, 2005).	X	X	X		X	X
	Robustness: The ability of a supply chain to resist change without adapting its initial stable configuration (Wieland and Wallenburg, 2012).				X	X	
Collaboration:		**X**	**X**	**X**	**X**	**X**	**X**
The level of joined decision making & working together at a tactical, operational or strategic level between two or more supply chain member (horizontal or vertical). Scalable through the magnitude of relationship strength, quality & closeness. (Jüttner and Maklan, 2011)	*Visibility*: The identity, location and status of entities transiting the supply chain, captured in timely messages about events, along with the planned and actual dates/times for these events (Francis, 2008).	X	X	X	X	X	X
Agility (Flexibility):		**X**	**X**	**X**	**X**	**X**	**X**
The ability to rapidly respond to change by adapting its initial stable configuration (Wieland and Wallenburg, 2012).	*Velocity*: The speed in which a supply chain can react to changes in demand, upwards or downwards (Christopher and Peck, 2004).	X	X	X	X	X	X
	Visibility: see above	X	X	X	X	X	X
Risk Awareness: Making supply chain risk assessment a formal part of the decision making process at every level (Christopher and Peck, 2004).		**X**		**X**	**X**		**X**
Knowledge Management: Knowledge and understanding of supply chains structures- both physical & informational and its ability to learn from changes (Adapted from Ponomarov and Holcomb, 2009).		**X**	**X**	**X**	**X**	**X**	**X**

System Level Resilience Capabilities	Resilience Elements	Pettit et al. (2010, 2013)	Zsidisin and Wagner (2010)	Jüttner and Maklan (2011)	Blackhurst et al. (2011)	Ponis (2012)	Wieland and Wallenburg (2012, 2013)
Supply Chain (re-)engineering:		**X**			**X**		
The conceptualisation, design, implementation, operation and re-engineering of the supply chain (Naim et al., 2000)	*Efficiency:* The ability to produce outputs with minimum resource requirements (Pettit et al., 2010).	X			X		
	Redundancy: Limiting or mitigating the negative consequences of change by keeping resources in reserve, such as having safety stock, maintaining multiple supplier and running operations at a low capacity utilization rates (Blackhurst et al., 2005; Sheffi and Rice, 2005).	X	X		X	X	
	Robustness: The ability of a supply chain to resist change without adapting its initial stable configuration (Wieland and Wallenburg, 2012).						X
Collaboration:		**X**	**X**	**X**	**X**	**X**	**X**
The level of joined decision making & working together at a tactical, operational or strategic level between two or more supply chain member (horizontal or vertical). Scalable through the magnitude of relationship strength, quality & closeness. (Jüttner and Maklan, 2011)	*Visibility*: The identity, location and status of entities transiting the supply chain, captured in timely messages about events, along with the planned and actual dates/times for these events (Francis, 2008).	X		X	X	X	X
Agility (Flexibility):		**X**	**X**	**X**		**X**	**X**
The ability to rapidly respond to change by adapting its initial stable configuration (Wieland and Wallenburg, 2012).	*Velocity*: The speed in which a supply chain can react to changes in demand, upwards or downwards (Christopher and Peck, 2004).	X	X	X	X	X	X
	Visibility: see above	X		X	X	X	X
Risk Awareness: Making supply chain risk assessment a formal part of the decision making process at every level (Christopher and Peck, 2004).		**X**			**X**		
Knowledge Management: Knowledge and understanding of supply chains structures- both physical & informational and its ability to learn from changes (Adapted from Ponomarov and Holcomb, 2009).		**X**			**X**	**X**	

Table 3 Progression of Coding I (excerpt)

Second Order Categories	*First Order Codes*
Disaster Management Processes	Representative Data
Immediate Response	
Implement response plan, measurements and metrics	"A response plan includes effective leadership, a resource centre and communication hub." (Document 8) "CERT went out to shut off the electricity. So that others can continue to do their primary job, which is staying and assisting in the event of large emergency situation." (Volunteer 1) "We got, maybe 12hours notice and we were ready. We were ready within 3 hours." (Functional Manager 1) "During our ice storm in February we had a shelter open at the Convention Centre, we were told that there were 100s if not 1000s of people coming." (Director 1)
Evaluate direction and control	"We responded quickly, we made sure that they had water and a place to stay and verified that the damaged really was only bad to 2 or 3 homes." (Functional Manager 2) "The critical step is called disaster assessment. During the flooding we had helicopters going out, city vehicles going around looking to see how many roof tops were sticking up out of the water." (Director 1)
Evaluate communication	"Collaboration with the Chamber of Commerce to activate more resources." (Director 1) "Partners with government emergency management agencies to facilitate communication and coordination."(Document 9)
Evaluate supply chain disruption outreach	"We responded quickly, we made sure that they had water and a place to stay and verified that the damaged really was only bad to 2 or 3 homes." (Functional Manager 2) "Many houses developed black mold which can have serious health problems. In trying to assist residents with housing, appliances, clothing and food agencies working with flood victims often had to call multiple agencies to find what they needed."(Document 3)
Recovery	
Review and implement recovery plan	"We formed a recovery comity. We said ok remember when we were planning? Now it has happened, now we need to take care of these residence." (Director 3)
Ensure continuity of risk and resilience management	"Three months after the floods agencies are still identifying and responding to long term needs of flood victims such as repairs to houses, mental health issues, and replacement of household goods." (Document 3) "We said we need to bring people together and we worked with FEMA representatives and we all came together and said 'What can we do to help people that are not going to be able to fix their houses?'. So we worked together for about 3 years." (Director 3)
Maintain employee support	"The group developed by-laws, elected officers and established committees to solicit donations, coordinate volunteers, determine client needs, and coordinate case management." (Document 3)
Resume Operations	"We had lists of resources that we could provide for them. We send out referrals for them: these are 3 different companies that are handing out what you need." (Volunteer 2) "We were providing cleaning items, personal care items, blankets. And then saying 'ok, now that you have all your necessities, your basic necessities, what else do you need." (Functional Manager 3) "They give them the referrals they need to other agencies who will help them on a longer term basis with e.g. new furniture, refer to." (Functional Manager 4)

Table 4 Progression of Coding II (excerpt)

Second Order Categories	*First Order Codes*
Resilience Capabilities	Representative Data
Supply Chain (Re-)engineering	
	"Identify what agencies store furniture, equipment, appliances, food and clothing. Identify capacity to storing additional materials." (Document 5)
	"Memorandums of understanding for supplies with commercial business." (Director 1)
	"Set up of supplies in strategic locations." (Director 1)
	"We plan, we do strategic planning and training. It involves evacuation, sheltering, we have plans in place and people to respond in situations like that." (Functional Manager 1)
	"A key part of the program is to reach the underserved areas and populations." (Document4)
	"They give them the referrals they need to other agencies who will help them on a longer term basis with e.g. new furniture, refer to." (Functional Manager 4)
	"A response plan includes effective leadership, a resource centre and communication hub." (Document 8)
Agility	
	"We got, maybe 12hours notice and we were ready. We were ready within 3 hours." (Functional Manager 1)
	"During our ice storm in February we had a shelter open at the Convention Centre, we were told that there were 100s if not 1000s of people coming." (Director 1)
	"The critical step is called disaster assessment. During the flooding we had helicopters going out, city vehicles going around looking to see how many roof tops were sticking up out of the water." (Director 1)
	"We responded quickly, we made sure that they had water and a place to stay and verified that the damaged really was only bad to 2 or 3 homes." (Functional Manager 2)
	"We had to set up in a matter of hours to expect what we thought might be 5, 6, 7000 people. They were evacuating about 20000." (Director 2)
Knowledge Management	
	"Learning from passed events." (Director 2)
	"We plan, we do strategic planning and training. It involves evacuation, sheltering, we have plans in place and people to respond in situations like that." (Functional Manager 1)
	"Practice plans in place." (Volunteer 1)
	"The way we prepare for disasters is that we keep up our skills." (Functional Manager 1)
	"In the event of an emergency situation it is very apparent that people want to step up and help. Unfortunately we can't have them do that unless they are trained." (Functional Manager 2)
	"We do community education: get an emergency kit, make a plan, be informed." (Director 1)
	"The 20h course training teaches fire safety, life search and rescue, we teach them some medical operations, how to handle a mass medical operations, like how to get the most people out of a disaster emergency situation and save as many people as they possibly can and then we teach cribbing, which is cribbing is how to remove a victim off from a heavy object and then we teach them disaster psychology, terrorism." (Functional Manager 3)
	"It is a local take care of yourself, prepare yourself, assist yourself, be able to shut of your water, your electricity, your gas etc. Also take care of your neighbours, assist your neighbours and then in the event of a larger scale you go out and assist the community." (Functional Manager 3)
	"We do what we call dry runs, we do practices, e.g. what if a pipe line bursts." (Functional Manager 1)
	"To provide assistance to businesses, non-profits and institutions in developing their own disaster plan." (Document 5)
	"We need more liaisons to interface with other agencies that we work with, do training, make sure that we practice our plans." (Director 2)
	"We said we need to bring people together and we worked with FEMA representatives and we all came together and said 'What can we do to help people that are not going to be able to fix their houses?'. So we worked together for about 3 years." (Director 3)

Table 6 **Integrated Resilience Framework applied to Hurricane Katrina** (based on information supplied by American Society of Civil Engineers, 2007; Brand and Seidman, 2009; Committee on Homeland Security and Governmental Affairs, 2006; Holguin-Veras et al., 2007; Qamar et al., 2007)

Phase/ Process		**Situation in relation to Katrina**	**Supply Chain Resilience Capabilities**				
			Horizontal & Vertical Collaboration	*Supply Chain (Re-) engineering*	*Agility*	*Risk Awareness*	*Knowledge Management*
Mitigation	Establish a (cross-functional) planning team	Absence of defined responsibilities and lack of leadership - Delays in aid response due to official lack of understanding of problems	↯	X		↯	X
	Analyse supply chain capabilities and hazards	Absence of risk assessment - New Orleans's hurricane protection system had never been quantified	X			X	X
	Develop and communicate plan for preparedness, response & recovery	Haphazard and underdeveloped plans– plans for New Orleans were still in the development phases and internally inconsistent	↯	↯		√	↯
	Agree measurements and metrics for preparedness, response & recovery	Inadequate metrics and measurements available due to underdeveloped plans – only some measures were available that were not implemented	X	X		X	X
	Develop continuous improvement & supply chain risk mitigation plans	Failure to address identified problem areas - it was known that FEMA (1) lacked staff and (2) its logistics system suffered from significant and long-standing problems.	↯	X		√	↯
Preparedness	Implement preparedness plan: Translate strategic agreements into operational matters	Poor implementation of plans and commitments – absence of transport for people without cars	↯	X	↯		↯
	Evaluate based on measurements and metrics	Inadequate evaluation - only initial pre-positioning of supplies, supplies were not enough	↯		↯		↯
	Establish routines through training and simulation	Unidentified constraints in achieving responsiveness – funding delays, last minute cutbacks, long approval processes for simulation exercise → unfamiliar processes and policies hampering response	↯	X	↯		↯

Phase/ Process		Situation in relation to Katrina	Supply Chain Resilience Capabilities				
			Horizontal & Vertical Collaboration	*Supply Chain (Re-) engineering*	*Agility*	*Risk Awareness*	*Knowledge Management*
Response	Implement response plan, measurements and metrics	Failure in execution of response plans - Orders, requests and efforts were duplicated, left unfilled, unchecked or misdirected	↯	X	X		↯
	Evaluate direction and control	Inadequate continuous assessment - Adequate supplies were not received until 12 days after landfall; inadequate staff resourcing	↯		↯		X
	Evaluate communications throughout the supply chain	Failure to communicate resource availabilities - delayed state and federal officials' learning about where rescues were slowed shipments of food and water	↯		X		↯
	Evaluate supply chain disruption outreach	Misjudgement of local impact of disaster - inappropriate aid distribution points that could not be reached by everyone	↯	X	X		↯
Recovery	Review and implement recovery plans	Recovery plans were established but not thought through - ineffective policies & systems to deliver services and resources across neighbourhood boundaries	↯	↯			↯
	Ensure continuity of risk and resilience management	Continuity of problems from response - poor communication and responsiveness, especially between City Hall and neighbourhoods; Strategic and coordinated planning and investment has been absent.	↯			√	
	Maintain employee support	Constant support - Today different volunteer groups & FEMA are still helping residences to recover	√			√	
	Resume operations	Delays, slow rebuilding - 3 years after the storm, many aspects of New Orleans' recovery have not improved since the immediate aftermath of Katrina	↯	X			

X = not existent ↯ = Problems √ = Adequate