

DECISION SCIENCES INSTITUTE

Natural disaster response and recovery and the relationship to disruption performance

Raveekarn Aiemwongnukul
University of Leeds
Email: ml13r2a@leeds.ac.uk

Chee Yew Wong
University of Leeds
Email: C.Y.Wong@leeds.ac.uk

Luisa Huaccho Huatuco
University of York
Email: luisa.huatuco@york.ac.uk

Ilias Vlachos
University of Leeds
Email: I.Vlachos@leeds.ac.uk

ABSTRACT

As the frequency of unpredictable natural disasters (ND) is intensifying, firms face increasing challenges of how to minimize its impacts. This paper explores and identifies the ND response and recovery capabilities and develops understanding of these mechanisms. Evidence from two comparative extreme cases of factories dealing with the Thailand 2011 flood is examined. A process framework is developed and does not only exhibit enabling ND capabilities, ND response and ND recovery, but also explicates ND disruption performance that results from being engaged in the response and recovery activities prior and post disruption.

KEYWORDS: Supply chain risk management, Supply chain resilience, Disaster management, Case studies, Performance

INTRODUCTION

Evidence shows that there is an increasing trend of natural disasters (ND) around the globe (Kleindorfer & Saad, 2005) and it has also been named as one of the top two risks for businesses globally (Wright, 2013, Business Continuity Institute, 2014). ND impact can affect business performance and the world economy. Disruptions of supply chain activities and operational systems have delayed product delivery, resulting in increases in costs, losses in sales (Chopra & Sodhi, 2004) and might take a long time to recover (Hendricks & Singhal, 2005). For example, one flood can lead to severe damage, such as Hurricane Floyd that flooded a Daimler Chrysler plant in North Carolina (USA) resulting in the closure of their plants for seven days (Norrman & Jansson, 2004). This pressing concern for firms calls for adapting and developing their supply chain capabilities for surviving in this volatile situations.

For example, the Thailand 2011 flooding, as it was a large-scale disaster occurring in a half century when the incident occurred, it appeared that some of businesses did not have ND plans in advance and they had enormous challenges in responding and recovering from the disruption.

Surely, the Thailand flooding impacts are tremendous and not all businesses managed to respond and recover properly for mitigating against natural disaster. Most of the businesses collapsed or even relocated to other countries. However, there were some businesses which responded successfully and survived. It is a wonder why some firms could do better than the others in the same situation. This paper will reveal these experience cases reflect their performance in dealing with ND situations. It also offers insights into how firms can overcome the supply chain constraints in the volatile situation caused by ND.

Three main research questions are addressed: (1) how do firms develop response and recovery capabilities required to mitigate the impacts due to ND disruption, (2) what are the measurements ND disruption performance? and (3) how do firms' response and recovery capabilities affect ND disruption performance? The effective response and recovery capabilities and their performance are exhibited in a framework for being a guideline to both practitioners and academics.

A body of literature is rapidly growing in resilience, mitigation (Wright, 2013), and risk management capabilities, however, not many of them answer how those firms actually acted during the ND disruptions. Many studies have acknowledged the need for capabilities in accordance with disaster phases: preparation, response and recovery (Ponomarov & Holcomb, 2009). So far, the literature has a small amount of contribution with respect to this aspect and much of the literature has focused mainly on recovery capabilities (Craighead et al., 2007) and preparation capabilities (Knemeyer et al., 2009). Traditionally extensive research e.g. disaster management and crisis management stresses on advance preparations. In real life, not all businesses manage to prepare for mitigation against ND as they are considered 'random phenomena' (Sheffi & Rice, 2005) and to have low-probability and high-impact risks (Trkman, & McCormack, 2009; Oke & Gopalakrishnan, 2009).

Though some supply chain risk literature discusses mitigation and monitoring capabilities, the majority of studies do not distinguish strategies for different types of threats (Oke & Gopalakrishnan, 2009). Different sources of risks should be addressed by different mitigation strategies (Oke & Gopalakrishnan, 2009). However, ND has been mixed up with other types of disruptions (e.g. financial crisis, demand risk, supply chain risks, etc.). In fact, the operations and supply chain literature knows little about ND. Understanding response and recovery capabilities are crucial for business as it is accounted as a significant role in reducing the impacts of disruptions (Runyan, 2006).

The severity of damage relies on how they respond and recover. There is a need for both academics and practitioners in operations and supply chain to understand what effective response and recovery capabilities are required for ND and how we should measure their performance. Not only ignoring response and recovery, operations and supply chain area also overlook how those capabilities affect to their performance. Therefore, firms need to have a guideline to indicate their abilities to perform. This is important for general practitioners to understand, even though, ND is an ad-hoc event, it influences firms' normal targets.

Nowadays, ND increases in its frequency around the world, this becomes a part of normal operations, especially for multinational firms that need to adapt and manage their supply chain around the globe. As such in the case of UPS, the firm developed its own weather forecast station after facing unexpected severe blizzards (Sheffi & Rice, 2005). Without a doubt, having performance indicators will help them to monitor and improve their capabilities accordingly. Even though ND are unavoidable, firms can mitigate their impacts if they address the problems by

having appropriate response and recovery capabilities.

The study draws on several literature review streams. Research in the areas of supply chain resilience and supply chain risk management, disaster management has been integrated for understanding ND phenomena. In this paper, the response and recovery capabilities and their performance will be discussed with regards to aspects of private firms. This study believes that a level of ND disruption is resulted from response and recovery activities and if firms have an appropriate response, this will facilitate a fast recovery. The two cases will enhance our understanding of why the firms are successful and unsuccessful. Both cases will be integrated for finding the best performance in responding and recovering from ND. Finally, a theoretical framework will be presented in terms of a process perspective.

LITERATURE REVIEW

ND disruption performance

The literature suggests that there is an unresolved issue where disruption performance is concerned and what should be an indicator for reflecting firms' abilities in dealing with ND disruptions. There are implicitly two aspects of the indicators: (1) disruptions mitigation, which can be referred to as losses or damage, such as severity of disruption (Craighead et al., 2007), degree of recovery (Tang, 2006), magnitude and duration of the deviation minimization (Vugrin et al., 2010) and resisting losses from disruptions (Hendricks & Singhal, 2005); and (2) market responsiveness (Christopher et al., 2006) represents customer satisfaction and capture changing in the market needs (Carvalho et al., 2012). This category includes operational performance (e.g. delivery flexibility, on time delivery), and economic performance (e.g. procurement cost, redundancy cost) (Carvalho et al., 2012). Empirical studies have examined the relationships between performance and supply chain resilience capabilities, the first indicator involves customer's value in routine disruptions (Wieland & Wallenburg, 2012) and the second is a study of firm resilience to high and low severity impact in terms of reconfiguring resources (Ambulkar et al., 2015).

It is important to have an indicator for measuring the level of performance of ND response and recovery capabilities because previous studies did not fully consider what should be an indicator for ND response and recovery capabilities performance. In any emergency situation, every decision making process is crucial as it makes a critical impact and influence to unpredictable outcomes. This study focuses on defining the concept and detail of ND disruption performance in the context of ND response and recovery capabilities.

ND response and recovery

Supply chain resilience offers a system that helps reduce the severity of supply chain disruptions and enable operational continuity (Ponomarov & Holcomb, 2009), including those generated by natural disasters (ND). Several definitions stress on the ability in dealing with unexpected supply chain disruptions and ability to return after being disturbed (Rice & Caniato, 2003, Christopher and Peck, 2004). It is also considered as a "shock absorption" that reduces the likelihood of vulnerability and avoids interruption (Sheffi & Rice, 2005). A broader set of known concepts such as flexibility (Sheffi & Rice, 2005; Vugrin et al., 2010), redundancy (Sheffi & Rice, 2005; Jüttner & Maklan, 2011), collaboration (Christopher & Peck, 2004) and agility (Wieland & Wallenburg, 2012) is offered to help businesses to respond and have a quick recovery on different levels

such as a return to the original or to a better state (Christopher & Peck, 2004). Several researchers seek to explain what capabilities are important for ND. For example, Petit et al. (2013) identified recognition of early warning signals, crisis management, resource mobilization, demand pool, etc. However, which ways and when managers should apply these capabilities if ND occur are less known.

Response and recovery capabilities have been addressed as the components of supply chain resilience (Tukamuhabwa et al., 2015). Several scholars encourage building in the resilience capabilities in advance to facilitate firms' ability to respond and recover (Christopher & Peck, 2004; Ponomarov & Holcomb, 2009). To date these papers ignore what ND response and recovery capabilities are and how to achieve them.

Supply chain risk management

Research on supply chain risk management aligns with the resilience literature. The research has been investigating resources, methods and processes that can be designed and implemented within supply chain to alleviate supply chain risks (Jüttner, 2005). Supply chain risk management can be viewed as one of the significant capabilities (Elahi, 2013) for mitigating disruptions caused by many sources including natural disaster. The literature mainly offers normative steps to mitigate risk by understanding risk and developing ways to reduce harms. The literature typically provides guidance to understand sources of vulnerability (Kleindorfer & Saad, 2005) and assess risks (Sheffi & Rice, 2005) and evaluation of risk and risk mitigation strategies (Manuj & Mentzer, 2008). Typically, it is suggested to identify risk using probabilities of occurrences and impacts (Sheffi & Rice, 2005, Petit et al., 2010), categorizing risk sources into impacts on particular supply chain operations (Christopher & Peck, 2004; Kleindorfer & Saad, 2005, Elahi, 2013). This allows us to understand sources of threats and how to minimize the risk impacts in advance (Knemeyer et al., 2009).

The literature has also offered a combination of approaches that most of them involve advanced planning for minimizing impacts from disruptions, such as a process of proactive planning which implies the essential need for disaster management phases (Knemeyer et al., 2009); mitigation capabilities that are involved with proactive recovery and warning capabilities (Craighead et al., 2007); business continuity that directs business attention to prepare advanced plans for future recovery (Jüttner, 2005). Park et al. (2013) conducted a case study of supply chain disruption from the Japan earthquake emphasized on restoration process. The study offered a model regarding to supply chain information design and business continuity planning aspects.

The supply chain risk management literature is set in a context of advance preparation and over-emphasis on probability and impacts over the ways a natural disaster disrupts or interrupts the supply chains instead of focusing on the advance preparation. This paper focuses on how firms immediately respond to and recover from flooding, and what the relationship is between them.

Disaster management

The disaster management literature provides knowledge for understanding, controlling and managing disasters. The International Federation of Red Cross and Red Crescent Societies (IFRC, 2014) considers disaster management as "*the organization and management of resources and responsibilities for dealing with all humanitarian aspects of emergencies*". The disaster

management literature typically offers different phases for organizations to understand its nature (Lettieri et al., 2009). Scholars commonly adapt these phases lens, and then appropriately design capabilities for disaster relief that fit into each phase (Kovacs & Spens, 2007).

The disaster management literature seeks to explain how people in non-profit organizations, government and private organizations manage disaster management activities, planning and resources. To integrate with the phases: (1) pre-disaster: involves mitigating the risk by conducting plans, predicting, providing early warning, and preparing necessary resources; (2) during phase: the activities relevant with emergency management in activating plans, securing people and facilities, establishing command center; and (3) post-disaster: the activities emphasize on recovery , reconstruction and resolution of damages infrastructure and business (Faulkner, 2001; Moe & Pathranarakul, 2006; Altay, 2006; Beckon & Hughey, 2013). It is understood that these capabilities are designed for humanitarian and non-profit-organizations, with regards to ND. Perhaps, the supply chain literature can learn from these strands of literature. There is a need to enhance our knowledge and understanding of how to respond in emergency and recover from ND effectively.

METHOD

Research setting

This study examines firms' responses to the 2011 flooding in Thailand focusing on response to and recovery from extreme ND. The 2011 floods are the most expensive in terms of loss of life and economic damages ever recorded (Guha-Sapir et al., 2011). The industrial zones were concentrated in the central region of the country and were submerged by the floods. 14,000 factories collapsed causing more than 500 deaths (BBC, 2017) with Damages estimated at circa \$45 billion (World Bank, 2011). Thailand accounted for 25% of global production of computer hard drives, making it one of the largest sources (Financial Times, 2017). The flooding caused extensive and long term impacts to firms around the world (Wright, 2013) and increased consumer prices (BBC, 2017).

FIRMS (IN 2011)	POLYCO	FOODCO
Business Unit	Polyester product	Ready to eat Food
Number of Employees (at disaster site)	~ 450	~ 4000
Primary suppliers	20% import, 80% domestics (main raw materials were from affiliated firms)	100% Domestic
Primary customers	55% export, 45% domestic	90% domestic, 10% exports (85% affiliated company that owns more than 4,000 convenient stores, 15% external)
Production locations in Thailand	2 locations, 3 plants	1 location

ND plans	Yes, but limited (was first developed in 2010)	No
Number of interviewees	9 (administration, production, purchasing, power & Utilities, HRD, utilities, vice president of manufacturing, Director)	6 (Logistics, production, purchasing, safety, assistant general manager (export / risk management))
Risk management	Yes, Initiated by head quarter	Yes, Initiated by head quarter
Operations discontinuity	~ 7 months	~ 1 1/2 month
Severity of the flooding damages	70-80% of physical assets	Minor losses
Height of flooding	~ 2 meters	~ 1 meter

Case selection

The study employed a purposive sampling strategy to set criteria for case selection. The study focused on two sectors of manufacturing firms in Thailand which had experienced in dealing with the floods. Those two cases represented two polarised examples that the first case, PolyCo had high ND disruption performance (unsuccessful in response, but became successful in recovery). The second case, FoodCo had low ND disruption performance (successful in both response and recovery). The both cases aim to enhance the understanding of what the processes and activities in prior and post disruption and how these influence to different performance. Table 1 shows the summary of the firms.

The firm size was controlled because it might have an influence on different capabilities and performance, so both cases were selected based on the criteria of being large factories which had number of staff in Thailand more than 500 people. Table 2 provides an overview of firms' description.

Table 2: Firms' description in the year 2011

- PolyCo

PolyCo was a leading world producer of petrochemicals operated as a group of companies. The firm was operated under the policy of multiple production locations for serving their customers in different areas. One of PolyCo's sites was located in the flooding area with another business unit. In 2011 this site had total staff of around 450 people and mainly focused on production functions. The main purchasing department, marketing, and sales departments were based in the Bangkok head office. Due to the nature of products, the production operation relied on heavy machines and were less labour intensive. The production focused on high efficiency operations with standard products, but mainly dealt with planning and forecasting rather than making to order. Due to Thai manufacturing safety standards and corporate risk management, the firm arranged emergency drills for the staff in their operations.

Their sourcing was approximately 20% imports and 80% domestic; of which majorities were from their own affiliated plants. The purchasing department at the flooding site was mainly responsible for sourcing plant equipment e.g. spare parts. The strategic raw materials were mainly obtained from the affiliated firms which were a major producer in this field. The outbound logistics functions and warehouse were operated on their own by providing the transports services from 3rd party logistics providers. Prior to the 2011 flood, PolyCo was almost flooded, as the surrounding areas were submerged by water. In response to that situation, the company initiated flood plans.

- FoodCo

FoodCo was a subsidiary of a large Thai conglomerate company, it operated in the ready-to-eats food industry. In 2011 FoodCo production and main operations were operated in one geographic location with three main production plants. This industry relies on labour and it had approximately 4,000 employees on the site.

The raw materials were sourced domestically with more than a thousand units of raw materials and several hundred suppliers. The logistics transport was operated under the collaboration of around 400 transport subcontractors. The warehouses were owned and operated by themselves with several distribution hubs around the country.

The firm had no record of being flooded, neither had it previously experienced dealing with any ND. The company had emergency response plans and conducted emergency drills in a case of fires and chemical accidents. Prior the event the company had implemented supplier risk management, but this was not specific to flooding. The suppliers' risks were analysed and mitigations were made to alleviate the risk from single sources to multiple sources. The food quality control and RD department tested the potential raw materials in advance before an emergency occurs. Nowadays, the company has expanded their business in various geographical location in Thailand to mitigate the risks with several modification of their system.

Data collection

Semi-structured interviews were conducted with the relevant actors in operations and supply chain and relevant people who engaged in a task against the Thailand flooding. The interviewees

included directors and managers in operations, supply chain, risk management and related positions. The interviews were the main source of data collection and were conducted in the years 2015 and 2016 by using face-to-face, telephone interview, and site visits with follow-up questions. In total fifteen, interviews generally lasted between 60-120 minutes. Fifteen interviews were conducted across 6 from FoodCo and 9 from PolyCo from two firms and some of them were interviewed more than one time. Based on the first round, some initial ideas and concepts were identified, in the second round, follow-up interviews helped refine the concepts and gain in-depth understanding of the ND response. The questions were a mixture between open and specific questions to ask about how/why they dealt with the flood in the different phases and the results in doing those things. All interviews covered prior and post flooding disruption (only short-term). The interviews were done in English or Thai with a voice recorder, then transcribed and translated into English where required. These processes were crossed checked for enhancing validity. As this is a retrospective case study, triangulation of interview data from multiple interviewees, documents and relevant websites helped ensure validity and rigor of the analysis.

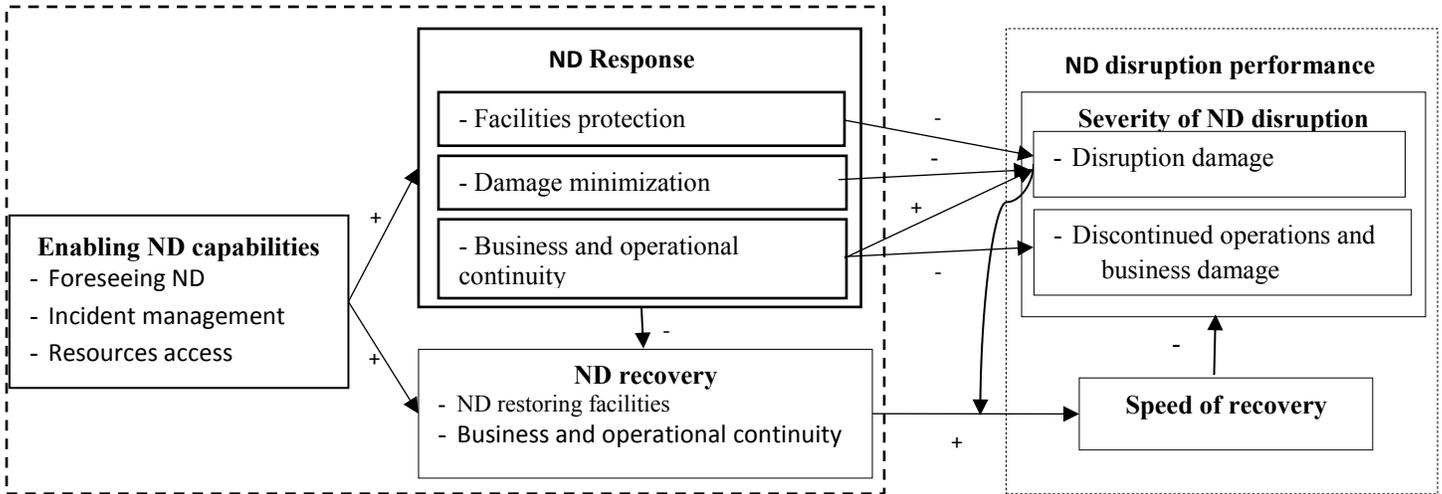
Qualitative data analysis

The research is based on an approach for theory building from comparative case studies (Eisenhardt, 1989; Ketokivi & Choi, 2014) for enhancing generalizability. The data was analyzed thematically by using NVIVO 9 and MS Excel. The theoretical themes emerged through using an inductive approach to data analysis. The aim of the first round of analysis was having an initial idea to capture what capabilities the firms used for dealing with the flood. Then the second round data were analysed and converged with the first phase interview transcripts, documents, and the website while allowing the code to be flexible and modified. The different phases of capabilities and their performance were coded and identified, and the relationships between the themes were established by using mixed techniques using both causation coding and domain and taxonomic coding (Saldaña, 2015). The cases were first analyzed within case studies for understanding the commonalities and differences between the two cases, and then followed by a comparative case study to integrate the patterns into a framework. The different literature streams were employed at the last stage for making a connection and to help understand the analysis.

FINDINGS

The theoretical framework in Figure 1 emerged from the empirical data. The coding identified three types of capabilities: 1) enabling ND capabilities, 2) ND response, and 3) ND recovery clustered into mitigation capabilities. The findings will be presented in terms of what the firms did prior flooding and after flooding (short-term). ND disruption performance highlights two main categories that the firms normally used to measure their performance. The text will be discussed on each capability and their performance, as well as the links to how those capabilities influence to the different levels of performance.

Fig. 1. Framework of ND response and ND recovery to a ND disruption



ND disruption performance

ND disruption performance consists of two main dimensions that are used to evaluate ND response and recovery; severity of ND disruptions and speed of recovery.

Severity of ND disruption

Severity of disruption was used to measure the magnitude of ND impacts to the firms, including tangible and intangible losses. This dimension consisted of disruption damages and discontinued operations and business damages.

- Disruption damage

Disruption damage was used to measure the impacts of ND in terms of loss of human life and monetary value. Both firms exhibited high concern on human life and attempted to save the staff member from the incident. The firms measured the amount of damages on facilities destruction (e.g. buildings, equipment, machines, etc.), and expenses occurring from extra costs on non-routine operations, ND response and recovery activities. In general these losses occurred in the short-term.

There were significant differences in the damage experienced by FoodCo and PolyCo. Some minor losses occurred for FoodCo of these. The major expenses arose from the wastes of raw materials due to emergency shutdown of productions. The others occurred from purchasing protection equipment and from activities that attempted to continue business and operations. Thus, operating in the emergency period generated higher costs than the normal days due to long distances logistics routes and shortages of raw materials. However, PolyCo suffered massive losses as they could not protect the plant from the flood. PolyCo lost 70-80% of their total facilities. All the facilities which were left on the first floor were severely damaged. However, all these damages were paid back by the insurance company.

- Discontinued operations and business damage

Discontinued operations and business damage was used to illustrate losses occurring in terms of inability to deliver services or products. This dimension referred to the firms' inability to produce the product for sale, safeguard their reputation, and serve customers. To extend further, this showed that the impacts of the flood could be widespread in terms of long-term losses. This dimension could be measured in terms of time or financial value. Sometimes it was difficult to calculate or define as some indicators were intangible in value (e.g. reputation, customer satisfaction).

The severity of disruption is associated with the time that the firm was unable to continue operation and business. Therefore, the longer the period, the higher severity they received. PolyCo's plants were shut down for 4 months with another 6 months of low capacity operations. This caused them miss the opportunities to produce and sell the products. The vice president of manufacturing expressed a view that discontinued production caused a lost opportunity to sell:

"We missed around 3-4 months of it.... If the 3 months or 4 months of production had lost, that months all the sale had lost. In a month we made about 15,000 tons products, so 4 months is around the 50,000-60,000 tons, of sale we lost."

At the same time FoodCo halted the production from October 15th – November 14th, 2011 and took another 2-3 weeks to recover back to full operations. In 2011, FoodCo was in a stage of business expansion, the impacts of the flood caused them to miss opportunity to achieve the 2011 sales target which was accounted around 5-6%.

-Speed of recovery

Speed of recovery referred to the pace operational facilities and systems were restored at until they were in a satisfactory condition. This dimension is measured in terms of time from the ND occurrence, until recovery to an acceptable level, this means, not every firm could recover to the prior operation level. The two cases demonstrated different speeds of recovery. Due to high disruption at PolyCo's facilities, the staff was satisfied that they could resume back to full operations in 9 months. However, in this case PolyCo is perceived to have a low speed of recovery when compared with FoodCo, who had a fast speed of recovery to normal business within two month.

ND Response

The firms used ND response as the ability to address to the flood incident aims to minimize the amount of losses. The activities begin when firms detected a warning sign of the ND onset or before the flood entered the facilities. There were three main approaches that were applied by the firms; facilities protection, damage minimization, business and operational continuity (BOC). Facilities protection and BOC activities were the first two which were introduced and exercised in parallel. Minimizing damage would be implemented if the firm thought that the flooding would rise higher than their capabilities. It was also found that the firms used different ND responses to manage different problems. For example, Facilities protection and minimizing damage were used when the flooding was going to be disrupted own facilities and operations. Whereas, BOC was used when the infrastructure and own facilities were already disrupted or the suppliers were already disrupted. Therefore, each ND response was applied at different times to implement and also needed to be executed at an appropriate time.

ND Response and ND Disruption Performance

There were different outcomes between ND response and ND disruption performance because each firm used different ND response in different ways. Comparing FoodCo that had lower ND disruption to PolyCo, it can be seen that the ND response distinguished between low and high ND disruptions. Therefore, the two case comparisons reflect on how the different ND response affected different level of ND disruption performance.

- Facilities protection

From the data analysis, there appears to be a negative relationship between facilities protection and disruption damage. Facilities protection was used to limit the scope and magnitude of ND impact on facilities, assets and operations. A common activity was to build temporary physical defences. FoodCo, who had high facilities protection, was able to protect their facilities and had low disruption damage. This was in contrast with PolyCo who had low facilities protection, so the staff could not protect their facilities which resulted in high disruption damage.

Both firms had competent employees to obtain information on how to build flood-proof walls and they had good collaboration among staff, but why FoodCo had a better performance than PolyCo? Prioritising critical factors explains why FoodCo was successful and PolyCo failed in facilities protection. FoodCo only focused on the critical areas and equipment, while PolyCo staff decided to protect the whole area and took more time to make flood protection, while having a limited number of staff. The assistant general manager from FoodCo explained the importance of critical assets prioritisation and the speed of recovery: *“We left this area to be flooded, we just protected the main area which were the production zone at that time...As we did not have any flood plan earlier, so we only protect the electrical system room... if we could not protect and it was flooded, it took at least 4 months.”*

The data also indicates that having knowledge to build the flood defences is a significant factor. As it was the first time that FoodCo experienced flooding, the staff did not have knowledge how to build the flood defences. The staff overcame this constraint by proactively seeking knowledge and collaborating with their networks for their advice on flood protection. The staff was also enthusiastic to develop and seek new ways of building flood defences to speed up the process and shorten the time of the traditional flood defences. The assistant manager explained that they built the flood defences quickly, by adapting and using available and new materials to build and reinforce its structure when the flood started raising *“It was fast because we used Isowall (to make to flood defenses).”* PolyCo acquired flooding protection knowledge through network collaboration as well. The director informed that the company was nearly flooded in 2010, they actively learnt from their network how to make flood protection. However, the traditional knowledge could not effectively be used in a new flooding context: *“We discuss with the insurance, but most of the time we think that putting sand bags we can escape this. It is not a big thing and that’s with toward in the 2010, but this time the water level is too much.”*

The protection facilities demonstrated high concern on close monitoring. FoodCo used close monitoring to maintain the flood defences. Not all of staff left the plants when the flood came in. Instead they stayed on high frequency and ongoing monitored the flood levels and the barriers, then enforced or repaired them accordingly. The high frequency of monitoring allowed the staff to react promptly to repair and reinforce even when the water rose higher than expected. The assistant general manager described *“We had teams to continuously monitor even though the*

flood water was around our factories. The team walked around the flood defences and check to see if there were any breaches. What we had to reinforce." PolyCo provided a contrasting view, they were not able to maintain the protection because they did not exhibit to have close monitoring, at the same time, they received the flood information quite late. Within the paucity of time and unavailable protection resources, they could not reinforce the flood defences properly with the flood magnitude and height.

Overall, the cross-case data analyses suggest a negative relationship between facilities protection and severity of disruption. So, firms with high facilities protection and the ability to make and maintain flood protection will result in reduced damages to their facilities. Both firms agree on the importance of protect facilities from the severity of damage: A FoodCo production manager noted: *"We could protect from flooding... consequently, it had less amount of damage"*, and a PolyCo HRM (human resource management) official who the consequence of failing to make protection: *"If that year we had achieved to make flood protection, there would not have been such a huge damage to our plants."*

Proposition 1: Firms with high facilities protection capabilities, are more likely to have a low severity of ND disruption.

- Damage Minimization

The data analyses suggest a negative relationship between damage minimization and disruption damage. Damage minimization was used to reduce and eliminate further damages to: lives, assets, and operations. The most common damage minimization practices involved evacuation of staff, assets relocation, and plant shutdown. This capability was used in a similar purpose with facilities protection, but it was seen as an alternative strategy when firms have seen that they could not protect themselves from the magnitude of the flood. Both PolyCo and FoodCo showed to be successful from applying fire drilling training to the flooding emergency incident. Everyone was asked to evacuate the facilities safely.

The data suggest that disruption damage could be reduced in different ways. One of the significant practices which was found in both cases was being proactive. FoodCo showed to have proactive actions by engaging in advance preparations. Relocating some of the finished goods to safe warehouse locations before the flood arrived. The assistant general manager described about their strategies and a preparation: *"In a case of an electricity blackout, we might have been to generate own power. If we ran out of the fuels, we had to move (the goods) out. We already contact refrigerator warehouse in advance...We have a contact lists. We can leaf them anywhere."* Both firms reduced their productivity a few days before the flood water arrived, so when the flood arrived and they had emergency shutdown the production, so they could reduce an amount of damages. FoodCo only had minimal damage from emergency shut down which led to the loss of some production material. The firm did not exercise their relocation plans because they were able to protect their facilities.

In contrast, in PolyCo's case, when the flood was going to enter the plant, the staff exercised all possible tasks that could reduce the disruption damages. Because they did not prepare for being flooded, several damage minimization activities were used and immediately developed in order to respond to the emerging situation. The power manager explained *"On September 22nd, it was the first day that water entered into the plants. We change our ideas from flood protection to damage minimization and it had around 8 hours to work on this."* The activities were immediately created and organized reactively to deal with the emerging problems. However, the data also revealed

that being attentive with the situation helped PolyCo to save their critical items, e.g. computer servers and documentation, for which they came back afterwards. These critical items helped them later during the recovery.

Executing an appropriate strategy was also considered to be significant. PolyCo did not assess the possible outcomes and their constraints. Consequently, they did not take appropriate actions to reduce disruption damage. They wasted time to reduce the amount of the finished goods in the warehouse by asking the customers without receiving good feedback few weeks prior the flood entered. A production manager noted: *"We talked to our marketing people. We asked them to deliver more to customers whatever were possible... We could not do much because there is limitation of the trucks, limitation of people. There is a limitation of customers which they could not take too much. They were also going to get affected through all these things. Nobody was ready to take it...all of a sudden in 10 days we cannot do much export orders- That was also not possible."*

A vice president manufacturing identified one of the core of the problems of having high disruption damage. They did not use appropriate practices in an appropriate time. The staff kept going to work on flood protection until they could do so no longer. As a result, the goods were left to soak in the water which caused high amounts of damage. He noted *"By the time we decided to react, water was all over. Truck could not move on the roads. We did not ship the inventories...our product is like big bulky, bag has 1 tons, 1.2 tons of materials. To ship all and like that we had 5,000 or 6,000 tons inventories. To ship that you need a lot of times and breaker and a lot of resources that we people could not manage in time. A production manager also shared a similar opinion "a lot of stocks were left, finished goods left. That remained here and ...that got affected with Flood."*

Another example showed that systematic shutdown help to reduce disruption damage, but unsystematic shutdown cause to have a longer process of recovery. As mentioned earlier PolyCo had lower the production capacity a few days in advance, but due to the nature of the heavy machines, so it required more time to shut down appropriately. A power and production manager described the importance of appropriate shutdown the production system and severity of damage consecutively: *"With this volume of water and the paucity of time... I switched off the electronic equipment because when the water came in it would lead to higher damage. If we shut the system down, it would not cause more damage. When we wanted to restart, the damage would be less and it would not take a long time"*. Therefore, if they had not stopped everything abruptly, probably their recovery time would have been quicker.

The analyses illustrated that high minimization damage capabilities are associated with activity activation. One reason that PolyCo had a high disruption damage because of they did not ask their logistics network to relocate the goods earlier. FoodCo also did not prepare to move any assets higher up which it would be risky to lead high level of losses if they could not protect the assets from the flood.

Overall, damages minimization capabilities were used to reduce the amount of damage, if the firm executed them with appropriate activities and at appropriate time according to the flood level. Nevertheless, there were limitations in the use of damage minimization. As both firms did not have experience in dealing with flooding prior to the incident, it was hard for them to choose appropriate activities and use them appropriately. For example, relocation or shutting down the factory was an important but a difficult decision to take. Both cases hesitated to shut down their

productions. They considered it as the last option to go for as this could affect their major incomes. This was because it could induce to time consuming, unknown losses from expenses and incomes and inability to operate.

Proposition 2a: If firms foresee the ND situation that they could not protect themselves from the high magnitude of the flood, they can execute damage minimization at the appropriate time.

Proposition 2b: Firms that implement damage minimization in appropriate ways during the disruption, are likely to reduce a disruption damage.

- Business and operational continuity (BOC)

BOC appears to have a positive relationship with disruption damage and negative relationship with discontinued operations and business damage. This is because BOC was used when the firms wanted to maintain operations, and deliver services and products to fulfil existing customer orders due to external disruptions e.g. suppliers and infrastructure disruption or own operations disruptions from ND. The activities involved reconfiguring and realigning the supply chain flow and activities among the supply network to operate under irregular conditions in order to produce and deliver the products or delivering the products from different locations or service to customers or engaging in operate in a safe place. The case studies showed that BOC help to reduce disruption damage and discontinued operations and business damage.

Both cases demonstrated to have a high BOC and could reduce the flooding impacts. The BOC was organized with diverse patterns of activities. FoodCo showed BOC and shut down the plant only around one and half months during the flooding because they had a high BOC. As FoodCo had a centralized operations system, the firm showed a strong focus on continuously serving the customers in the flooding emergency situation as long as possible. The productions and logistics were also restructured to be flexible and operate under the emergency conditions. For example, production operated on the basis of prioritization according to available raw materials, and critical products and customers. Flexibility strategy was employed to refine the logistics system such as, delivery zone, logistics routes, and alternative vehicles, introducing new loading systems, and new supplier contracts so that the delivery would be continued in any emerging situation. These activities were flexible to operate under different conditions of flood risk areas, traffic restrictions and a limited number of vehicles. These, the staff could not plan far ahead and it needed real-time updates according to the emerging situations. They also prioritized the production capability based on the available raw materials and customers.

Another reason why FoodCo continued their business far better than other firms in the surrounding areas was because of their proactive behaviour. As the purchasing manager said: *"We could still continue our productions because we already prepared our raw materials. We knew that we would certainly be flooded when the water arrived nearby our areas. We knew our production plans and quantity we needed to produce as we already coordinate with planning department...We could continue our production for sometimes until the flood water increased. Then, we stopped our product for a period of time... We had to say that when the water arrived our factory, some suppliers already stopped their production, but our factory was still run the productions. We could produce more than the others...because we already worked in advance."*

The data also suggest that FoodCo pay attention to support functions by activating effective operations continuity activities. Several departments, e.g. sales and logistics, were relocated to work in a better working conditions, facilities and locations that supported their operations and is

convenient to transport. At the same time, there was high collaboration and information sharing between SC networks. It was stressed that in order to continue the activities it was necessary to work closely with the networks. Therefore, if they received the information fast, they were able to decide the next actions. FoodCo used information to eliminate risk by accessing real-time information from multiple sources before making the delivery plans. The logistics manager described the importance of accessing and sharing the information: *“First of all when we had the problem, we knew that in a case of flooding we had to study on transportation routes. For logistics, we had to search for information; and from the government website, we could see the flooding maps. For our group, we had an information centre for sharing the information, such as this road was flooded, and this one was not. Then, we would communicate with our transport providers, you should go this way, you would not be flooded.”*

PolyCo used similar practices to relocate to a new location for being new operation centre from the assistance of networks, but this was done after they were flooded. PolyCo demonstrated to have a high BOC because they were successful to maintain their existing customers due to the corporate risk diversification policies. The products were delivered to the existing customer orders from multiple production locations. Their products were delivered by affiliated plants both domestically and overseas, instead of by the flooded plants. The multiple production locations assisted PolyCo to return their customers, so the customer did not to move to their competitors. The vice president manufacturing stated of being less affected from using multiple production locations: *“It was just stop plant, but all customers, they were being supplied by our other sites in Asia, Thailand, in Indonesia, in China. So they were being taking care, customer almost did not affected, that planning we had.”*

FoodCo embedded themselves in a lot of BOC practices could potentially lead to a higher cost, as a result this led to higher disruption damage. The cost of BOC increase due to logistics suppliers were motivated to continue their works by increasing the fee, while the staffed were facilitated by renting an accommodation or providing transportation. A Logistics manager described: *“During that time we had to admit that we gave extra fee on the transportation, so the logistics expenses in that year increased slightly than the normal. During the crisis period we paid extra in order to motivate them.”*

Based on the evidence, even though using BOC could reduce the discontinued operations and business damage, at the same it demonstrates to lead to a higher disruption damage. BOC is associated with shutting down period and maintaining their customers. The activities helped the firms to continue their operations rather than reducing the impacts in terms facilities and assets as facilities protection and damage minimization. However, it also leads to a higher cost of BOC activities from its operations.

Proposition 3: Firms that implement business and operational continuity (BOC) during the disruption, are likely to increase disruption damage as well as reduce discontinued operations and business damage. However, the disruption damage would be lower than the discontinued operations and business damage.

Overall, the cross-case analyses demonstrate that all three ND response: facilities protection, damage minimization as well as BOC are essential for firms to limit their losses and address the flooding by exercising ND response with appropriate actions and an in a timely manner. These ND responses clearly associate with severity of ND disruption and speed of recovery. Both cases suggest that firms should increase the three capabilities to enable abilities to respond, address

the problems, and minimize the severity of ND disruptions. Therefore, if a firm has a higher level of such ND response, it helps reduce severity of ND disruption and requires less time to recover.

Proposition4. Firms with high ND response (employ appropriate ND response; facilities protection, damage minimization, and BOC in the appropriate time and depending on the emerging situation), are more likely to have a low severity of damage.

ND recovery

The firms used ND recovery as the ability to restore and reconstruct the damaged facilities, systems and equipment to return to at an acceptable condition (pre-ND incident, worst or better conditions). The recovery activities were exercised within a context of limited resources.

FoodCo and PolyCo who were successful and unsuccessful in responding to the flood, respectively, showed differences in how their recovery tasks were managed and their spent time on those tasks. The findings suggest that the firms used two major approaches to ND recovery activities to resume normal operations: 1) ND restoring facilities e.g. cleaning, investigating the damages, repairing and restoring equipment, machines, systems, and utilities, and 2) BOC to fulfil back orders. FoodCo had very low damages, because their physical assets were not disrupted, the staff spent around one week working on the restoration of operation activities and spent most of their recovery time on BOC for fulfilling the orders to their customers. PolyCo had a higher severity of damage than FoodCo, they spent most of the time around nine months to work on restoring the facilities which the activities were similar and were carried on from BOC that they did before shutting down the plants. However, they worked in better conditions of infrastructures and less time constraints.

ND recovery and disruption performance

ND recovery appears to have positive relationship with the speed of recovery. Both of them demonstrated to have a high ND recovery that could enhance the speed of recovery. They expressed strong commitment on the recovery tasks, even though they faced several challenges.

The two cases converged that without network collaboration, they could not overcome the challenges and had achieved a fast speed of recovery. Both PolyCo and FoodCo worked closely with their networks, both internal and external organizations to have open communication, information sharing and help each other to resolve the recovery problems. For example, PolyCo had joint meetings with the suppliers, including experts and let them engage and design recovery tasks for better solutions and outcomes. One of the biggest challenges of PolyCo was the state of their machines and equipment which were the previous models and obsolete. This made it was difficult to find new replacement parts and technicians to work on it. Due to corporate policy to design the production and operating systems in different plants similarly, so the technicians from the other plants helped them to work this. Finally, the team had to upgrade to new systems. Currently, the team enjoys their new systems because they generate production efficiency and produces a greater production capacity than the previous one.

Flexibility was found with strong evidences in both firms to accomplish their tasks with a fast speed of recovery. Both PolyCo and FoodCo initiated new ways to overcome the constraints. FoodCo staff still maintained flexible processes to deliver the products, reintroducing several strategies which were used before closing the plants such as prioritizing product items, flexible policy, new distribution centres, flexible logistics operations, accessing and sharing information.

These emergency processes were used to fulfil the orders for another 2 weeks until the situation resumed to normal. The logistics manager recalled how they managed logistics tasks during the disruption: *“In our normal operations in the past, we did use large vehicles to distribute the goods... However, during the incident we had to use big cars because the small one was not work. We chose the car that could access to the customers’ shops.”*

PolyCo’s power manager described in great detail the flexibility process: *“(In the case of a mismatch specification of equipment) after having the discussion, we had to continuously update our plans during that time. For example, if this equipment had not arrived, we had to shift to work on another scheme and waited until the equipment of this scheme arrived... We had to adjust and change our work plan everyday.”*

Even though, both PolyCo and FoodCo suffered at different levels and worked in different recovery activities, there were similar practices between them in terms of how they could have such a fast recovery. Therefore, they focused on facilitating an acceleration of recovery speed. The data indicates that both firms showed enthusiasm to make the advance recovery preparations even though the flood had not completely dried out. The activities, e.g. recovery planning, purchasing recovery items, and in the case of FoodCo maintaining the machines and equipment because the equipment was not disrupted, created a fast start of recovery activities. This allowed FoodCo to start the production promptly when the roads were available, and PolyCo to do restoration activities. FoodCo’s production manager of described the reason of ‘how’ they recovered quickly: *“During the shutting down period we did not left the machines, we had teams to the check the machines. We thought that if we would start the production, the machines must be able to use... So we were ready to start the production when we could travel around.”* *The results also show that PolyCo used more strategies in order to have a fast pace the recovery time. For example, PolyCo teams embedded themselves in multiple restoration operation activities in parallel in order to save time, such as replacing the damaged facilities and equipment and testing the systems at the same time. The vice president of manufacturing noted “we started working parallelly during those 3 months.”*

The case also illustrated that the speed of the reconstruction of facilities depended on the collaboration. The team utilized the relationship with the networks for giving them priority attention. A production manager explained the importance of networks: *“We have a good relationship with the suppliers help us to get many of the things faster. We got thing faster inside and we got it installed we started the plant in April. This is quite a fast operation to get back into normal thing.”*

Recovery target and insurance companies play a significant part in PolyCo case. To explain this, the pressure from relevant stakeholders encouraged the staff work fast because the team was afraid that the insurance company would not pay their claims. In parallel, the management used the recovery target to put pressure to the staff members to make their commitment to meet the recovery targets. The vice president of manufacturing noted the importance of the recovery target as an enforcement: *“The thing mobilized very fast because we had our target set by our management.... So within that time we had to finish everything, cleaning everything and then start the plants. The target was very tight.”*

Both cases showed high ND recovery, but they had different speed of recovery. PolyCo suffered from inabilities to protect and minimize damage, so they spent around nine months. Whereas FoodCo spent one month and a half months only to get back to full operations because they were able to protect their facilities from the flooding. The production manager of FoodCo also described

a reason about the association between facilities disruption damage and speed of recovery: *“We recovered quickly because the inside of our factory was not affected.”* With high ND recovery and a low disruption damage, FoodCo had a high speed of recovery. Thus, they shut down the operation just for a short period of time, they subsequently were able to preserve their customer orders. A manager shared an idea about the consequence if they were unable to re-open their operations quickly: *“They (customers) might have bought from the other people if we would disappear for a long-time. This would make a huge impact on them, and then they might leave us.”*

PolyCo had high disruption damage, so they spent longer time on the recovery tasks than FoodCo. A PolyCo HRD official stated: *“speed of recovery depends on the level of damage.”* However, the firm showed fast recovery when compared with the other firms who had similar flood severity.

The data suggest that high ND recovery had a positive relationship with speed of recovery and disruption damage is a moderator. Both cases demonstrated high ND recovery which they actively engaged in the recovery tasks and found ways to accelerate the recovery tasks, which resulted in enhancing them to achieve fast recovery in a case of having low disruption damage. Table 4 summarizes the comparison between FoodCo and PolyCo and suggests the following proposition:

Proposition 5a: Firms with a high ND recovery is more likely to have a high speed of recovery, when the disruption damage is low.

ND response and ND recovery and ND disruption performance

ND response appears to have negative relationship with recovery. To be able to accelerate ND recovery activities and achieve a fast recovery or not, depended on the ND response. PolyCo exhibited that inappropriate ND response activities, especially damage minimization could lead to slow pace of ND recovery because of working on more number of tasks at the same time and result in slow recovery. The production manager indicated that they spent a long time restoring facilities due to inappropriate shut down of the production systems. He admitted that if they had taken a corrective action of the ND response, to shut down the production systematically, the ND recovery would have been easier: *“We learned to shut down.... Since it was the unplanned shut down, we had to go through all the operations like again heat up the plant take it to higher temperature, melt out everything whatever inside the reactors.... Had we not stopped everything abruptly, probably our recovery time to be very faster.”*

Proposition 5b: Firms with appropriate ND response, are more likely to facilitate and employ less ND recovery and achieve a high speed of recovery.

From the above explanation, it is reasonable to see that the firm that had a high severity of ND disruption would take a longer time to recover than the one had low disruption. At the same time, it appeared that the speed of recovery was found to be used for reducing the severity of disruption as well, such as high speed of recovery could minimize discontinued operations and business and disruption damages. When FoodCo reopened their operations, there was a surge in demand for the products due to the competitors were suffered and inability. They fulfilled the customers' orders at the peak time. FoodCo's assistant general manager expressed the importance of high speed of recovery and its relationship with discontinued operations and business damage and severity of disruptions: *“Even though we lost one month sale, but we came back to re-operate*

faster than anyone else. At that time, there was shortage of products in the markets and we were the fastest person who was able to fill in the products. It appeared the sale after the flood reached the highest record, the sale reaches the peak, so it was nearly offset the sale that disappeared for the whole month... That year, there was a sale growth, but it just did not achieve the target."

The case studies showed the positive relationship between ND recovery and speed of recovery, and they led to have negative relationship with discontinued operations damage. Therefore, this can be concluded that the discontinued operations and business damage is limited by the speed of recovery. Thus, the severity of damage (which consists of disruption damage and discontinued operations and business damage) appear to be lower than it should be by achieving the high speed of recovery. To illustrate, both FoodCo and PolyCo expressed the need to return to the previous condition, before the disruption, as soon as possible because the delay of recovery could cause more suffering for them. the firms could have lost income, customers, reputation, or incur any expenses from having a delay of recovery. The proposition is explained as follows:

Proposition 5c: Firms with high ND recovery which achieves a high speed of recovery, can have a lower discontinued operations damage, affecting relatively less ND disruption.

Enabling ND capabilities

The response and recover show a positive relationship with enabling ND capabilities. The data suggest that enabling ND capabilities are fundamental abilities that firms require to facilitate ND response and ND recovery. The activities involved foreseeing ND, ND incident management, and resources access. The firms needed to use these three capabilities in the first place to help facilitate ND response and ND recovery. The three enabling ND activities were found to interact and enhance each other holistically. Foreseeing ND appeared to be the first point that was required to support the other capabilities. The analysis found that the present of enabling ND capabilities could influence different levels of ND response and ND recovery.

Enabling ND capabilities, ND response and ND recovery

- Foreseeing ND

The firms used foreseeing ND to understand nature of ND and help decide appropriate further actions. These capabilities involved detecting and monitoring, obtaining, forecasting, updating and interpreting ND and supply chain information. Foreseeing ND seem to be the crucial factors that differentiate FoodCo from PolyCo who had high and low ND response. FoodCo who had high foreseeing was able to understand the current and future ND situation closely and knew what to do. This was in contrast with PolyCo, because staff did not understand the situation, they were not able to build appropriate flood defences with the water level. As a result, they were unsuccessful of making protection facilities and had high disruption damage. The data demonstrated opposite behaviour between FoodCo and PolyCo in various aspects.

Interpreting information was first highlighted to explain what caused FoodCo and PolyCo to behave differently after quickly identifying the threats and have prompt reactions. Particularly, FoodCo interpreted and forecasted by using their local knowledge after having the field work assessment. The staff saw there would be high potential for flooding in their own area, so they had prior preparations for flood response e.g. setting up flood teams, having meetings, and storing protective materials. The assistant manager shared the view 'why' they decided to prepare for the flood in advance: *"It was not that clear when we listened to the news. We had field work*

monitoring and I went out with the other colleagues. In the real situation, the water was really enormous. It was beyond my imagination. From what I heard on the news, it was totally different.... and after seeing I think the levee would certainly breach. Looking from an engineering perspective on the infrastructure conditions, I think it was really risky. Then I came back to report that we had a high potential to get flooded...Then we started buying the protective materials."

Knowledge to interpret the data closely was one of the key factors. In PolyCo the staff did not realize that their data was incomplete, and they should have accessed to information surrounding land elevations. While, FoodCo seek advice from their networks who were experts, so they were able to make various proactive respond activities in advance.

There was strong evidence that PolyCo did not know how to respond appropriately when the water entered because they did not stay attentive, rather they misjudged and underestimated the situation. The PolyCo's purchasing manager admitted that they activated the wrong strategy at an inappropriate time because they misjudged the situation resulting in high severity of disruptions: *"We might have the wrong plans. We had never thought the flood would be such this height. The plant was flooded almost 2 meters. Therefore, we never experienced this since the plat had been built or prior than that."*, and PolyCo's production manager: *"As I said we did not expected such a huge flood at all... Flash flood could be there a few centimetres...Nobody expected it was going to be there for 45 days."*

It was necessary to access quality information in a real time for effective interpretation. Both of them try to obtain the information from reliable sources especially government and had triangulation data collecting the flooding information from various sources such as public news, self-monitoring at the sources, government collaboration. However, this is not enough, in order to be able to interpret accurately also associated with how much data they obtained for analysing. It appeared to see that FoodCo tracked the data in a national scale, whereas PolyCo more locally focused. This could be another reason why PolyCo misjudged and interpret the situation wrongly. A PolyCo HRD who monitored the information expressed his view how they have improved information scope after failure to understand the situation: *"After 2011 we looked in a bigger picture. We monitored weather forecast, dam flow rate and discharge rate of water, we search more than the local."*

Accessing information was very challenging during disaster emergency situation. Unavailable and incorrect and late information was a common problem to have an accurate interpretation. PolyCo could not overcome this problem partly due to relying heavily on government information and adhered with the previous year experience. They had low information sharing with the networks and were reactive to wait for the government to inform. They received the information was late and this delay decision makings and gradually lost sight to make close forecast on the flood arrival, duration and height. In contrast, high collaboration for information sharing between FoodCo and the networks helped them to understand the situation and make closely forecasting. They did not only obtain the information from the media and government, but also used their comprehensive networks around the country, to continuously update real-time flooding information. This approach enabled FoodCo to understand the real situation and supported their ability to interpret the situation precisely.

After flooding occurred, both cases demonstrated that foreseeing ND had a significant role at the beginning of the recovery stage, as it was used to forecast when to start recovery activities. Both firms continuously monitored and recorded the flood information. Before the flood receded,

PolyCo staff travelled to the site for the flood investigation. Similarly, FoodCo measured the water around the factory. With such monitoring activities, they planned and prepared for recovery tasks in advance. Consequently, they were prompt in starting those tasks when the flood receded.

- ND incident management

ND incident management appears to have a positive relationship with ND response and ND recovery. It is the ability to operate, control and monitor emergency response and recovery tasks to emerging and uncertain situations. It consists of a combination of activities, such as: setting up cross-functional teams, planning, meetings, disseminating information and decision making. Its application is concerned with the effectiveness of process management. ND incident management was perceived as a place to make centralized decision making for guiding direction to staff. Therefore, it influenced how well the firm's response and recovery was carried out. Overall, FoodCo (high) and PolyCo (low) had different ND incident management, they addressed the incident in a similar way, such as: forming cross-sectional teams, intensively increasing the number of meetings and sharing information. Required information would be obtained for analysis for making decisions and communicate these to staff. Decision-making, including plans, strategies, and activities were decided in the meeting, and then the tasks and responsibilities were assigned to the appropriate staff.

However, there were some minor differences among the two firms. FoodCo assigned a staff member who was good at crisis management to be the team leader in this situation. At the same time, the team members would also exchange and generate new ideas, and brainstorm for problem solving. The team worked closely together and the individual tasks were monitored. Therefore, the teams would assign a task to their staff, at the same time, the staff would report and continuously update their progress of their responsible tasks (e.g. making flood protection, fieldwork monitoring, etc.) at the meeting and if they had any problems the teams would help to overcome the problems. This process of activities was cyclical in nature. On the other hand, the decision making at PolyCo was centralized on the management team and did not exhibit if they followed the same process.

Flooding response and recovery plans and procedures were emphasized for being used as a guideline for the teams and staff to follow. Emergency plans had long been introduced in FoodCo and PolyCo, but they focused on fire and other disruptions rather than flooding. As it was FoodCo's first exposure to extreme flooding, it was difficult for the teams to initiate flood plans and procedures. The teams actively looked for advice from specialists in their networks and this method of obtaining knowledge facilitated the team to be able to make their own plans. The continuous updated plans, procedure and activities based on the real situation, were essential to have proper activities in dealing with emerging problems, particularly in emergency response. FoodCo teams exhibited high attentiveness to the uncertain situations by continuously reviewing and updating their plans, as a result the teams could respond quickly to the changing situation. In comparison PolyCo's staff recognized that the magnitude of the flood in that year (2011) was bigger than the previous year. At the beginning of the flood the teams updated the plans. However, as they did not make continual efforts to update information in real time, the use of plans in a reactive manner led to PolyCo failing to respond to the rapid changes.

Communication and information sharing was highlighted the need to manage efficiency. PolyCo had low incident management in the recovery phase because they did not communicate to the staff clearly and comprehensively. The information of how height they should have lifted the

equipment to was missing; therefore, the staff had inappropriate damage minimization and resulted in high damage because they left them on the desks which were lower than the flood level. FoodCo's production manager, on the other hand, they used communication in dynamic way to keep up with the emerging situation: *"We continuously (communicated)... We knew when the water would arrive... We did not expect it would be that high, but as I told you, we applied 'plan, do, check, act' strategy on this case."*

Conducting ND incident management activities in the ND recovery had similarities to conducting them in the response. The only difference is about prior flooding; the decision-making processes were made based on immediate attention and an urgent matter with high pressure. There was a common agreement that recovery plans should be designed upon the actual flood disruptions, the staff prepared for the recovery tasks in advance before the flood had fully receded. PolyCo's vice President noted the importance of having early plans. *"As I told you we were planning for our plant start-up already while we were sitting in another place, so we saved time. So, you can imagine if we would have started that work after coming here after the water receded. We would have lost another few months, so we did not lose. We used that time to order things and keep things ready. As soon as the site was ready for people to come in, the activities also started fast, the recovery."* Since FoodCo did not suffer from the flood, they did not put much time in developing the plan. This was the opposite with PolyCo, as the recovery plans were a big task. The staff were monitoring and investigating damages when the facilities were sinking under the flood. Fortunately, the staff used the information from the computer sever and plant drawing that they saved from the flood to estimate the damage and make recovery plans.

In the recovery phase, there was major progress made by PolyCo to use ND incident management in a constructive way. They had high ND recovery and speed of recovery for several reasons. After being flooded, PolyCo relocated to a new place, the management and the key staff members could continue recovery planning, meeting, and doing temporary transactions (e.g. contact suppliers, and making recovery purchasing orders). The firms set up a communication and information facility. Not only had the recovery plans, procedures, and targets had been established in advance, the management knew how to use the recovery targets to make agreements among the staff. Therefore, at PolyCo the recovery goal motivated the staff to make their commitment to achieve the target. The staff also often revisited and adjusted the recovery plans according to unpredictable issues. Lastly, the recovery plans were reviewed and updated according to the emerging situation. A PolyCo utility manager describe the important of incident management play a role to help them to recover *"(We could recover faster than it should have been) I think this is because we had well planning and procedure."*

- ND resource access

There seems to be a positive relationship between mitigation resource access and ND response and ND recovery. Accessing mitigation resources involves searching, selecting, and obtaining raw materials and equipment for ND responses and recovery. ND resource access was important throughout the ND disruption as it helped the firms address the emerging situation as well as recovery to normal operations. The ND resources which were used in response could be categorized into two main groups: (1) equipment for protection, damage minimization and restoring facilities and (2) raw materials for making products, which were used in BOC activities. The first was commonly used by both companies, and the latter was found in FoodCo.

PolyCo had medium capabilities in response and high in recovery which will be explained later on.

FoodCo had high ND resource access, a purchasing manager described how ND resource access could play a part to facilitate them to have a low ND severity: *“We could notice that we shut down our plant less than the others and reopened faster than the other as well due to if they were fresh vegetables we would use any transport 10 wheels, 6 wheels cars, even the military trucks for picking up (the materials).”*

In flooding situation, the market did not function normally, the firms operated under conditions of chaos and supply constraints (Christopher and Peck, 2004) due to limited resources, traffic and suppliers' disruptions. Overcoming these barriers was challenging for both firms. Due to the intensity of time constraints it became difficult to access resources. It was found that ability to access resources associated with speed especially before the flooding entered. Both cases exhibited to quickly access to ND resources when they saw there could be a problem. This helped them to solve the supply shortage and did not find any difficulty to acquire the resources. FoodCo purchasing manager told they stocked up resources in advance for avoiding supply disruptions. *“Actually, when the flood arrived our factory, many suppliers already stopped the productions, but our factory was operating. We could run our production longer than them because we had available materials to support and we worked in advance.”*

Even in the recovery phase, it also addressed the necessary of advanced acquisition when both FoodCo and PolyCo attempted to have a fast start of recovery. The purchasing of recovery orders was made in advance in order to reduce the purchasing lead time. This effort helped both firms to reduce the purchasing lead time and immediately restart the recovery tasks when the plant was reopened. In-depth analysis allowed us to understand that this preparation was not an easy for PolyCo to come up with recovery purchasing lists when the plants were being flooded. They utilized own knowledge and skills with some maps and drawing charts that were saved from the flood to help facilitate them to order the restoring items appropriately and quickly.

Importantly, to be able to make flood defences appropriately, it needed to access resources in an appropriate amount and right specification. PolyCo's general administration noted that they obtained higher specification of equipment *“In 2011, we saw that there would be a huge flood, so we needed appropriate pumps that big enough to pump out the water.”* However, both cases did not acquire enough flood protection resources with the magnitude of the flood.

By engaging themselves in network collaboration, this increased chance to access to resources and overcome supply shortage throughout the crisis period. FoodCo generated open-discussion and sharing information with their suppliers and staff for updating the situation and problem solving. FoodCo actively engaged with their networks for resource access throughout the crisis period. For example, FoodCo acquired additional flood equipment through the help of their raw material suppliers and made collaboration with the suppliers to quickly access critical material before being flooded. In contrast, PolyCo used network collaboration in a limited manner. PolyCo limited themselves on government network to access to response equipment. However, in the recovery there were able to utilize more number of their networks e.g. affiliated companies and suppliers. To extend this, during the flood response, the PolyCo staff accessed protective equipment from local governments, such as: big pumps for draining the water to help on the flood protection, but they did not activate their logistics suppliers for relocating the assets and this caused massive damage to the facilities. However, they became proficient in utilizing their network in the recovery. The staff members increased their priority level with the suppliers and increased the chances to receive fast recovery orders through requesting their suppliers to have joint meetings and make recovery plans together.

To be able to avoid materials shortage, FoodCo tapped into supplier risk assessments to make sense of and separate the suppliers who were vulnerable to the flood with the group who were not: *“Our strategy is when the flooding was coming, we would make a list which areas were prone to the flood?, Which factories had potential to be flooded?, and, How many percent?”* Critical items would be stocked as the priority. They decided to manage critical raw materials from managing the inventory level on highly vulnerable suppliers, and these high preparations enabled their capabilities to continue business and operations until deciding to shut down the factory.

Another reason why FoodCo had high resource access capabilities and could access any resources during the emergency period, was due to staff had proactive behaviour. They could initiate new ways of practice to deal with unforeseen situations and were also able to adapt the existing resources for new uses. This innovation helped save time and allowed for a quick reaction. FoodCo’s aim was to access raw materials for continuing production, whereas PolyCo’s aim was to get access to new machines and equipment to reconstruct their plants. Due to the tight recovery targets, numerous tasks, and having limited human resources available, PolyCo allocated some of these tasks to experts who had knowledge in dealing with this situation and therefore provided them with fast solutions.

At the same time, the purchasing activities, system and process were restructured to work in any emerging situation. This included payment terms, inbound logistics, inventory level, and having alternative or new suppliers and products. For example, purchasing activities of protection materials and equipment were decentralized and made at each individual department according to their responsibilities rather than at the purchasing department as they normally practice. The payment methods did not have to follow the routine operation process and it could be preceded without waiting for document approval. Some purchasing tasks were reassigned to the teams that worked in a safe location and a better condition in travelling. The purchasing delivery methods were modified to self-picking rather than suppliers delivery.

Flexibility processes were implemented in FoodCo activities. This is very important and it could be done in various ways e.g. flexible inventory management, alternative suppliers, and alternative routes. The purchasing at FoodCo teams had to restructure and modify inbound delivery systems and purchasing systems to emergency modes. PolyCo teams immediately readjusted the work process and created alternative gateways of having several suppliers to join in the projects because the delay of delivery of some import component parts might cause indefinite suspension of operations. The utilities manager noted: *“We did not wait...if this supplier could not do it, we could ask another to do. Alternatively, we allocated the tasks from the same project to different suppliers”*

Enabling ND capabilities are the essential abilities that enhance ND response and ND recovery. Each enabling capabilities continuously interact with each other holistically, rather than in a linear function. The data from the table 5 suggests that having a higher level of enabling ND capabilities enables firms to respond and recover effectively.

Proposition 6a: Firms with high enabling ND capabilities (with (a) foreseeing ND, (b) incident management, and (c) ND resources), are more likely to have a high ND response.

Proposition 6b: Firms with high enabling ND capabilities (with (a) foreseeing ND, (b) incident management, and (c) ND resources), are more likely to have a high ND recovery.

DISCUSSIONS

ND response has been long noted as an important capability for minimizing severity of disruption in humanitarian field. This paper explains ND response and demonstrates how firms used it to minimize the impacts from flooding. We find that ND response is a hallmark leading to high or low disruptions and also promotes recovery in the later phase. The paper identifies three ND response: facilities protection, damage minimization, and operations and business continuity which firms should use to respond to a ND situation. It also explains how to activate, when these capabilities should be exercised appropriately in a timely manner and for which purposes. The ability to facilities protection and minimize damage and protect facilities aims for ensuring safety and alleviating the impacts. Operations and business continuity in this paper is different from the literature that focuses on planning in advance. The data shows that without an advanced preparation firms can still exercise those response activities (e.g. relocations, flexible logistics function) if they have good networks. It seemed to be these three approaches were used as a combination according to each firm's preference; there was no one clear rule to go for or appropriate proportion of using them. Exercising these capabilities is not difficult, the challenge is that firms need to use them at the appropriate time, and keep cost at minimum. Thus, firms should be able to shift their strategy from facilities protection to minimize damages at an appropriate time as well.

This study explores recovery capabilities in the context of after being disrupted which differs from the previous study (Craighead et al., 2007) which focuses on strategies that can be prepared before disruptions occur. It also extends a view of current literature on how firms recover and minimize ND disruption through increasing the speed of recovery from having proactive preparation. Since we applied a process perspective, some of these capabilities are new to the operations and supply chain literature, such as restoring facilities. As we might expect, it also finds that ND recovery affects severity of disruption through a speed of recovery (Macdonald and Corsi, 2013). The study extends a view of current literature how a firm can increase a speed of recovery. Thus, firms need to have a fast start of recovery and this can be done by preparing several recovery activities in advance, such as recovery purchasing orders and recovery planning. Furthermore, the case study also illustrates through a clear view of the literature how firms can return to a better position after being disrupted (Christopher & Peck, 2004; Pettit et al., 2010).

This study unpacks and explains a process for understanding how and when a company decides and executes appropriate response and recovery to ND. The ability to manage a ND incident on an ad-hoc basis, foresee ND, and access resources are the backbone of ND responses and recovery. This enhances our understanding that firms should not only focus on ND response and ND recovery, but should develop these three enabling ND capabilities their effectiveness. As the enabling ND capabilities and ND response and ND recovery are not related to each other in a linear manner, but they emerge holistically from the individual activities. The propositions show and suggest firms needed to consider the used of these capabilities in the holistic way, rather than in isolation. The speed of recovery does not only depend on the ND recovery (Macdonald and Corsi, 2013), it also associates with ND response. The proposed framework has significant implications not only to academics, but also practitioners. With the framework, companies can identify, develop and adapt relevant capabilities and processes for real-life implementation,

including what conditions the firms would be able to respond and recover to ND. This finding differs from the mainstream literature in crisis management, business continuity, disaster management, risk management that suggest businesses need to prepare and invest resources for disruptive low-probability events such as ND that lead to an unknown level of damages.

The study agrees with the supply chain resilience literature that firms need to engage in flexibility and being proactive. Thus, the findings suggest that without flexibility, firms are less responsive (Sheffi & Rice, 2005), and lack the ability to adapt to situations of disruption (Carvalho et al., 2012). Thus, the level of flexibility requirement will increase during unstable situations (Christopher and Holweg, 2011). However, firms should be able to initiate new solutions to minimize the impacts of ND. At the same time 'being proactive' in this context emphasizes more on the short-term implementation, such as preparing for purchasing recovery equipment before a flood recedes; rather than long-term preparations including but not limited to creating risk management culture, knowledge management (Christopher and Peck, 2004; Sheffi and Rice, 2005), and building logistics capabilities (Ponomarov and Holcomb (2009). This study adds that firms should be able to adjust their resources in a new context and having short-term proactive, not long-term proactive (preparing resources in routine operations without knowing when ND occurs) as we normally understand. Lastly 'Continuous update' is introduced for firms to stay attentive and gradually develop their capabilities at the same pace as the unpredictable and volatile situation.

The study uncovers what ND disruption performance and its measures for practitioners and academics could understand that different capabilities could influence a different level of performance. This is noteworthy for firms to learn ND disruption performance as a guidance that can be used for evaluating their decisions (e.g. relocating the finishing goods or leaving it), how well they respond to or recovery from the flood. The indicators have been developed and explicate its application. Thus, a level of tangible and intangible damage is presented as a result of assessing their ND response and ND recovery which firms can adapt for use in practice. The model highlights the importance of a fast speed of recovery for minimizing the ND severity of impacts, this is similar to the finding of Craighead et al. 2007. However, this study advances the knowledge of how firms achieve a fast speed of recovery.

ND are known to cause to supply shortage and this study encourages firms to utilize and activate their previous existing resources, such as supply chain and information systems, knowledge, skills and networks collaboration for responding and recovering. Even though these previous capabilities are known to the literature as supply chain resilience strategies (Tukamuhabwa et al., 2015), this paper extends current views of operations and supply chain literature how firms can use those strategies during emergency situations and where the resources come from. Thus, those resources can be activated from previous resources or acquiring new one for empowering enabling ND capabilities, ND response, and ND recovery. This perhaps can be explained by improvisation from Weick (1998, p. 544) who compared an organization could "*deal with the unforeseen, it works without a prior stipulation, it works with the unexpected*" as jazz musicians. This could be interpret that an organization could modify and use their previous abilities or experiences to a new context and compound with abilities to create or extend to a new one without preparation.

To explain further, this challenges the current belief in the supply chain resilience literature on the ways that resilience strategies are developed. The study suggests that some resources could be acquired temporarily for ad-hoc use during the ND, if firms have good ND foreseeing abilities and

the knowledge about how such resources might be accessed. For example, the literature claims the need for a redundancy strategy such that it is necessary to own or occupy such resources (e.g. alternative warehouses and inventories) in advance. Instead, this study shows that it is possible to just tap into alternative resources when needed, by activating a network relationship or knowledge, because severe ND is infrequent. If firms change their inventory systems and keep more amounts of them for buffering against ND threats, this will increase cost in long run. The prior study of Ravasi & Turati (2005) in entrepreneurial learning help explains that when firms lack of competencies they can adopt the previous knowledge or increase their ability by obtaining from the external sources.

CONCLUSIONS

Reflecting on the comparative case studies, the paper contributes and outlines several recommendations to academics and practitioners in the area of operations and supply chain risk and resilience management on how firms respond in emergency and recover from ND, and how they influence to different level of performance. The study highlights the limitations of current understanding and extends the concept of ND response and ND recovery based on a focus on flooding. It highlights not only what they are, but also how, why and when ND response and ND recovery capabilities are effectively developed and work when there is a ND. The proposed framework and propositions arising from the two comparative retrospective business practices shows an integration of academically fragmented areas of knowledge as well as helping advance knowledge of operations and supply chain literature. It unveils capabilities, firms need to withstand ND; different capabilities need to be tailored along with different phases, including enabling ND capabilities, ND response and ND recovery. The study uncovers what ND disruption performance and its measures for practitioners and academics could understand that different capabilities could influence a different level of performance. The indicators have been developed and explicate its application.

Although, the case studies demonstrate that some businesses can respond and recover to ND without having prior ND preparation or experience, there is no suggestion to follow this course of no preparation as it can be very risky as well. During ND disruptions, firms needed to operate in chaos and unpredictable situations and they always face constraints in supplies, logistics or communication. To be competent in future ND response and ND recovery, there is no resting point for firms to prepare and invest in basic requirements e.g. ND planning, knowledge, skills, and supply chain and information system, that can be activated and utilized when it is necessary.

Lastly, since this study aims progress theory building and proposition development on the basis of inductive analysis and exploratory research, the main contribution is to add and enrich our understanding in a rich context of ND response and ND recovery rather than generalization. It hopes that this study sparks new practices in an appropriate way. Even though the study is conducted in the 2011 Thailand flooding, it hopes to be applied in the other risk contexts. One limitation of this study is that it is based on a purposive sample from two firms collected from the Thailand 2011 flooding; further research should include more case studies in other types of ND and different countries.

REFERENCES

Altay, N., & Green, W. G. (2006). OR/MS research in disaster operations management. *European*

Journal of Operational Research, 175(1), 475-493.

Ambulkar, S., Blackhurst, J., & Grawe, S. (2015). Firm's resilience to supply chain disruptions: Scale development and empirical examination. *Journal of Operations Management*, 33, 111-122.

BBC, (2017) Hard disk and camera makers hit by Thai floods. Retrieved from bbc.co.uk, May 9

Becken, S., & Hughey, K. F. (2013). Linking tourism into emergency management structures to enhance disaster risk reduction. *Tourism Management*, 36, 77-85.

Business Continuity Institute (2014). *Business continuity institute supply chain resilience trends 2009-2013 surveys*. Business Continuity Institute.

Carvalho, H., Azevedo, S. G., & Cruz-Machado, V. (2012). Agile and resilient approaches to supply chain management: influence on performance and competitiveness. *Logistics Research*, 4(1-2), 49-62.

Chopra, S., & Sodhi, M. S. (2004). Managing risk to avoid supply-chain breakdown. *MIT Sloan Management Review*, 46(1), 53-61.

Craighead, C. W., Blackhurst, J., Rungtusanatham, M. J., & Handfield, R. B. (2007). The severity of supply chain disruptions: design characteristics and mitigation capabilities. *Decision Sciences*, 38(1), 131-156.

Christopher, M., & Peck, H. (2004). Building the resilient supply chain. *The International Journal of Logistics Management*, 15(2), 1-14.

Christopher, M., Peck, H., & Towill, D. (2006). A taxonomy for selecting global supply chain strategies. *The International Journal of Logistics Management*, 17(2), 277-287.

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

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review*, 14(4), 532-550.

Elahi, E. (2013). Risk management: the next source of competitive advantage. *Foresight*, 15(2), 117-131.

Faulkner, B. (2001). Towards a framework for tourism disaster management. *Tourism Management*, 22(2), 135-147.

FEMA (2017). Animals in disasters: the four phases of emergency management. Retrieved from training.fema.gov/emi.aspx , April 23.

Financial Times. (2017). Thai floods hit global hard drive production. Retrieved from ft.com, May 13.

Guha-Sapir, D., Hoyois, P. & Below, R. (2013). *Annual Disaster Statistical Review 2013-The Numbers and Trends*, Centre for Research on the Epidemiology of Disasters (CRED), Institute of Health and Society (IRSS), Université catholique de Louvain – Brussels, Belgium

Hendricks, K. B., & 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 and Operations management*, 14(1), 35-52.

IFRC (2014). Disaster and crisis management. Retrieved from ifrc.org, May 13.

Jüttner, U. (2005). Supply chain risk management: Understanding the business requirements from a practitioner perspective. *The International Journal of Logistics Management*, 16(1), 120-141.

Jüttner, U., & Maklan, S. (2011). Supply chain resilience in the global financial crisis: an empirical study. *Supply Chain Management: An International Journal*, 16(4), 246-259.

Ketokivi, M., & Choi, T. (2014). Renaissance of case research as a scientific method. *Journal of Operations Management*, 32(5), 232-240.

Kleindorfer, P. R., & Saad, G. H. (2005). Managing disruption risks in supply chains. *Production and Operations Management*, 14(1), 53-68.

Knemeyer, A. M., Zinn, W., & Eroglu, C. (2009). Proactive planning for catastrophic events in supply chains. *Journal of Operations Management*, 27(2), 141-153.

Kovács, G., & Spens, K. M. (2007). Humanitarian logistics in disaster relief operations. *International Journal of Physical Distribution & Logistics Management*, 37(2), 99-114.

Lettieri, E., Masella, C., & Radaelli, G. (2009). Disaster management: findings from a systematic review. *Disaster Prevention and Management: An International Journal*, 18(2), 117-136.

Manuj, I., & Mentzer, J. T. (2008). Global supply chain risk management strategies. *International Journal of Physical Distribution & Logistics Management*, 38(3), 192-223.

Moe, T. L., & Pathranarakul, P. (2006). An integrated approach to natural disaster management: public project management and its critical success factors. *Disaster Prevention and Management: An International Journal*, 15(3), 396-413.

Norrman, A., & Jansson, U. (2004). Ericsson's proactive supply chain risk management approach after a serious sub-supplier accident. *International Journal of Physical Distribution & Logistics Management*, 34(5), 434-456.

Oke, A., & Gopalakrishnan, M. (2009). Managing disruptions in supply chains: A case study of a retail supply chain. *International Journal of Production Economics*, 118(1), 168-174.

Park, Y., Hong, P., & Roh, J. J. (2013). Supply chain lessons from the catastrophic natural disaster in Japan. *Business Horizons*, 56(1), 75-85.

-
- Pettit, T. J., Fiksel, J., & Croxton, K. L. (2010). Ensuring supply chain resilience: development of a conceptual framework. *Journal of Business Logistics*, 31(1), 1-21.
- Pettit, T. J., Croxton, K. L., & Fiksel, J. (2013). Ensuring supply chain resilience: development and implementation of an assessment tool. *Journal of Business Logistics*, 34(1), 46-76.
- Ponomarov, S. Y., & Holcomb, M. C. (2009). Understanding the concept of supply chain resilience. *The International Journal of Logistics Management*, 20(1), 124-143.
- Rice, J. B., & Caniato, F. (2003). Building a secure and resilient supply network. *Supply Chain Management Review*, 7 (5), 22-30
- Runyan, R. C. (2006). Small business in the face of crisis: identifying barriers to recovery from a Natural Disaster. *Journal of Contingencies and Crisis Management*, 14(1), 12-26.
- Saldaña, J. (2015). *The coding manual for qualitative researchers*. Sage.
- Sheffi, Y., & Rice Jr, J. B. (2005). A supply chain view of the resilient enterprise. *MIT Sloan Management Review*, 47(1), 41.
- Tang, C. S. (2006). Perspectives in supply chain risk management. *International Journal of Production Economics*, 103(2), 451-488.
- Trkman, P., & McCormack, K. (2009). Supply chain risk in turbulent environments—A conceptual model for managing supply chain network risk. *International Journal of Production Economics*, 119(2), 247-258.
- Tukamuhabwa, B. R., Stevenson, M., Busby, J., & Zorzini, M. (2015). Supply chain resilience: definition, review and theoretical foundations for further study. *International Journal of Production Research*, 53(18), 5592-5623.
- Vugrin, E. D., Warren, D. E., Ehlen, M. A., & Camphouse, R. C. (2010). A framework for assessing the resilience of infrastructure and economic systems. *Sustainable and resilient critical infrastructure systems* (pp. 77-116). Springer Berlin Heidelberg.
- Wieland, A., & Marcus Wallenburg, C. (2012). Dealing with supply chain risks: Linking risk management practices and strategies to performance. *International Journal of Physical Distribution & Logistics Management*, 42(10), 887-905.
- World Bank (2017), Thai Flood 2011 overview rapid assessment for resilient recovery and reconstruction planning”, Retrieved from worldbank.org , April 23
- Wright, J. (2013). Taking a broader view of supply chain resilience. *Supply Chain Management Review*, 17(2), 26-31.