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UNIVERSITY OF SOUTHAMPTON

FACULTY OF LAW, ARTS & SOCIAL SCIENCES

School of Management

**Risk Management Processes for Managing
Disruptions in Supply Chains**

by

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ABSTRACT

FACULTY OF LAW, ARTS & SOCIAL SCIENCES
SCHOOL OF MANAGEMENT

Doctor of Philosophy

RISK MANAGEMENT PROCESSES FOR MANAGING DISRUPTIONS IN
SUPPLY CHAINS

by Maria Tsiakkouri

The research focuses on formal supply chain disruption management (SCDM) processes and the usefulness of such procedures. Based on the risk management (RM) process, a generic SCDM process consists of the following interconnected phases: define context, identification, assessment, implementation and management and monitoring. Each phase is described, and possible activities and strategies a company may adopt are proposed.

Following a literature research in respect of SCDM strategies and RM processes, the application of SCDM processes in two case study company contexts, auto-manufacturing and water utilities, is examined. The auto-manufacturing company, which operates in a global supply chain and follows lean practices, does not adopt formal processes for managing supply chain disruptions. Disruptions are usually managed on a reactive basis by ‘fighting fires’ and proactive measures are based on the company’s experience in handling past disruption events. The water utilities company uses a formal RM process for managing disruptions along its water supply chain, apparently motivated by a requirement to follow regulations set by the regulators and because of its involvement in offering a product which meets basic needs of its customers.

The application of RM to supply chains is not a widely practiced concept as is evident from both the literature and the case study findings. Companies usually avoid spending resources on preparing for disruptions that may never materialize, and companies that do apply RM do so either because of regulations or disruptions in the past that had an adverse impact on the companies’ operations. When applied, though, it helps guide decision makers through the SCDM process, with which more informed decisions can be taken and important risks handled, increasing the resilience and robustness of the company to supply chain disruptions.

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DECLARATION OF AUTHORSHIP

I, Maria Tsiakkouri

declare that the thesis entitled

Risk Management Processes for Managing Disruptions in Supply Chains

and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

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1 Introduction

1.1 Global Market Challenges

Globalization is the most widely used term that characterizes today's business operations. Nowadays, a lot of companies have expanded their operations outside the geographical boundaries of countries, and even continents, and are now involved in one market, the global market, which can be divided into many submarkets that share the same characteristics and have the same requirements. By operating globally, companies try to reduce cost through economies of scale in purchasing, production, sourcing and through focused manufacturing and assembly operations (Christopher, 1998). Although this trend helps companies improve their competitive position and reduce costs, additionally they may engage their companies in longer supply chains, thus having to cooperate and coordinate with more parties. As a result, the number of companies responsible for delivering the product to the final customer has significantly increased (Kleindorfer et al., 2004). This makes supply chain relationships and operations more complex.

Companies operate in a global environment which is constantly changing, affecting the companies' strategies and operations. Supply chains exceed national boundaries, imposing challenges of globalization on managers who are responsible for the design of supply chains for existing and new product lines (Meixell and Gargeya, 2005). The global context (political, economic, socio-cultural, technological and environmental) is transforming and the company must adapt to these changes or even anticipate them in order to become profitable. Moreover, in the wake of globalization, customers are becoming smarter, desiring better quality products and services at lower prices. Thus, companies are not competing only for lower costs, but also for the quality and additional features of a product that differentiates it from other similar products. Global competition makes this even harder because each region or country requires different specifications for each product, thus increasing the variety of the products manufactured. As a result, companies are dealing with a number of challenges in order to respond to these global changes and competition.

In order to provide better quality products at lower prices and have the products available when customers request them, organizations had to change ‘the way they do business’. Outsourcing, lean manufacturing, reduced cycle times and lead times are some of the practices that are implemented by organizations which increase the cooperation and integration between companies. A company cannot depend solely on its own operations because it is part of a wider network, many times referred to as the extended enterprise. This network must seek the collaboration, coordination and integration of supply chain activities in order to achieve the satisfaction of the end customer. Parties of the supply chain contribute to the final customer experience in terms of costs, quality, speed, variety and innovation (Kleindorfer et al., 2004).

Supply chains by becoming more complex and geographically dispersed, increase the range of risks and disruptions they can face (Kleindorfer et al., 2004). Although globalization provides many advantages (e.g. higher revenues) for the firms that operate globally, it increases competition and uncertainty. Global and increased performance based competition, combined with rapidly changing technology and economic conditions, all contribute to marketplace uncertainty (Mentzer et al., 2001). Other factors that increase uncertainty are outsourcing and lean practices. Lean practices, outsourcing and generally a tendency to reduce the number of suppliers a company deals with, have changed the supply risk profile of companies (Christopher et al., 2004). The reasons are: limited buffer and safety stocks, dependence on one supplier for a critical material and short lead times, which result in having little time with no safety net to react when a risk materializes and affects the supply chain. Outsourced activities can include, for example, transportation, manufacturing and information systems. Outsourcing major components and/or activities to suppliers increases the dependency on these suppliers. This creates higher risk for the organization and the supply chain (Smeltzer and Siferd, 1998). It also leads to more complex supply chains that are more vulnerable to disruptions because more parties are involved and dependent.

In tough competition, firms need to operate more efficiently because when a firm fails, other firms are waiting to take its place (Sheffi, 2007). This underlines the

need to protect the market share because competitors are always in a standby position to acquire this share. Market uncertainty demands greater flexibility from companies and supply chains, which in turn requires greater flexibility in supply chain relationships (Mentzer et al., 2001). Uncertainty may be handled by developing a proactive risk management (RM) process that will protect supply chain parties from risk threats.

1.2 Supply Chain Disruptions

During the last few years, disruptions (Table 1.1) are becoming an increasing risk in global supply chains because globalization, in combination with longer paths and shorter cycle times, creates more opportunities for disruption and a smaller margin for error when a disruption takes place (Kleindorfer and Wassenhove, 2004; Kleindorfer and Saad, 2005). These result in making the companies more vulnerable to disruptions along the supply chain links. Vulnerability is an exposure to serious disturbance, arising from risks within the supply chain as well as risks external to it, that lead to deviations in the supply chain of components and materials from normal, expected or planned schedules or activities, all of which cause negative effects or consequences for the involved manufacturer and its sub-contractors (Svensson, 2000; Christopher and Peck, 2004). The more vulnerable the supply chain, the more likely that it will be affected by a disruption in the supply chain.

Table 1.1 : Disruption Examples

Events	Impact
<i>September 11th terrorist attacks on the World Trade Centre</i>	Thousands of lives lost, and an estimated damage of nearly \$80 billion (Grossi and Kunreuther, 2005).
<i>Fire destroyed Toyota's brake supplier plant in 1997</i>	Stopped Toyota's production lines and was estimated to cost Toyota approximately \$40 million per day (Nelson et al., 1998).
<i>Hurricane Mitch in 1998 that blew through Central America damaging banana plantations</i>	Damaged banana plantations resulted in Dole losing \$100 million for the fourth quarter and suffering a 4-percent revenue decline (Martha and Subbakrishna, 2002).

An organization's activities, strategies and goals determine the types of risks the organization is prone to. The types of risks also depend on which supply chain network the organization is part of and what type of relationships it has with its upstream and downstream suppliers. Supply risks can be specific to a firm due to its unique organization characteristics, industry nuances and the supply chains to which it belongs (Zsidisin et al., 2000). Thus, supply chain risks are not the same for each organization in the supply chain, but there are some risks (e.g. natural hazards, economic crisis, and terrorism) that can affect an organization, a portion or even a whole supply chain from raw material suppliers to the end customer.

In 2005 a postal questionnaire undertaken by the Chartered Management Institute addressed incidents (Table 1.2) that caused disruption to companies in the previous year (Gosling, 2006).

Table 1.2 : Company Disruptions by Incidents

<ul style="list-style-type: none"> • Loss of IT: 41 percent • Loss of people: 28 percent • Loss of telecoms: 25 percent • Loss of skills: 20 percent • Flood/High winds: 18 percent • Employee health and safety incident: 19 percent • Negative publicity/coverage: 17 percent • Loss of access to site: 11 percent 	<ul style="list-style-type: none"> • Damage to image, reputation, brand: 11 percent • Supply chain disruption: 10 percent • Environmental liability incident: 7 percent • Customer health/product safety issue/incident: 6 percent • Pressure group protest: 6 percent • Fire: 5 percent • Military action: 4 percent • Terrorist damage: 2 percent.
--	--

In Table 1.2 loss of IT is first on the list. This could be due to the high dependence on IT for business functions, the failure of which may cause disruption in the organization. Loss of people and telecoms are next on the list, highlighting that companies are dependent not only on technology but also on their employees and their skills. So, if a few employees leave a company, taking the know-how with them, then it will be very difficult to replace them. Telecoms also are very important because they maintain the contact of the organization internally and externally with its supply chain partners. Supply chain disruption is also on the

list, demonstrating the dependence the company has on the supply chain's operations.

Supply chain disruptions can have a number of negative effects on the performance of the organization from a simple system failure to a company closure. The negative effects can also extend to the firm's stock prices. Hendricks and Singhal (2005) looked into the long-term stock price effects and equity risk effects of disruptions based on a sample of 827 disruption announcements made over a 10-year period. They found that companies suffering from supply chain disruptions experienced 33–40% lower stock returns relative to their industry benchmarks over a 3-year time period that starts 1 year before and ends 2 years after the disruption announcement date. This demonstrates that disruption effects can extend to more than a year's time, affecting the firm's long-term financial performance. Thus, stock prices reflect the market's response to supply chain disruptions; the level of trust in companies that encounter disruptions decreases, investments in those companies decline and a disruption may have long-term effects on the company's credibility, reliability and revenues. The possible negative and long-term effects of a disruption on an organization may be mitigated by implementing RM processes.

1.2.1 Underlying Causes of Supply Chain Disruptions

Wilson (2007) defines a disruption as an event that interrupts the material flows in the supply chain, resulting in an abrupt cessation of the movement of goods. It can be caused by a natural disaster, labour dispute, dependence on a single supplier, supplier bankruptcy, terrorism, war and political instability. Thus, there are numerous causes that can affect the continuity of a supply chain ranging from natural disasters to political instability. Tang (2006a) differentiates between operational risks and disruptions, and states that in most cases, the business impact associated with disruptions is much greater than those with operational risks. Operational risks are the inherent uncertainties in a business environment such as uncertain customer demand, uncertain supply and uncertain cost. Tang (2006a) argues that disruptions can be triggered by both natural and man-made disasters, but the results are high severity impact on both the company and its

supply chain. Thus, Tang (2006a) distinguishes risks in two broad categories based on level of impact; daily business uncertainties from more unpredictable and rare events which have a greater impact on supply operations. Certain operational risks, though, can also cause disruptions because they may affect the continuity of the supply chain; therefore, a disruption can be caused from a routine operation such as equipment breakdown up to a mega event such as a strike with high impact consequences.

Xiao and Yu (2006) refer to disruptions in a typical supply chain caused by internal or external factors such as demand fluctuations (new orders, order cancellations), raw material and inventory shortages, delivery delays due to transportation problems or severe weather (storms, tornadoes), resource unavailability and natural disasters. Accordingly, they refer to sources of risk that can affect the supply of a material or product internally or externally to the supply chain as a cause of disruption to it. In order to be able to develop supply chain disruption management (SCDM) plans, the sources of supply chain disruption need to be identified so they can be dealt with. Following is a list of the most common sources of disruptions:

- **Supplier issues:** In 1978 a major expressway was closed, blocking off a single-source supplier of Toyota, affecting in this way Toyota's production (Tang, 1999).
- **Demand and Supply Variations:** Inaccurate supply planning resulted in an inventory shortage of 'hot' footwear models for Nike, which affected the sales for Q3 2001. The amount was \$100 million off target (Norrman and Jansson, 2004). Cisco, which is one of the world's leading producers of electronic network equipment, announced in 2001, a US\$2 billion write-off of inventory due to a dramatic fall-off in demand for its products (Cranfield University, 2002).
- **Accidents:** In February 1997, after a fire destroyed the plant of Toyota's brake manufacturer in Japan (Aisin Seiki), Toyota had to stop the production lines. Toyota was forced to shut down 18 plants for almost two weeks due to lack of

parts. The cost to Toyota was \$195 million and the estimated sales loss was 70,000 vehicles (\$325 million) (Mortimer, 2001). Toyota's reliance on just-in-time inventory systems left Toyota with no spare parts on hand to enable continued production, thus the only option was to stop producing cars until parts could be procured from other suppliers (Tang, 1999).

- ***Strikes and Labour disputes:*** In September 2002, acrimonious contract negotiations between the International Longshore and Warehouse Union (ILWU) and the Pacific Maritime Association (PMA) resulted in the union applying a work slowdown at all West Coast ports in the U.S. As a result, PMA responded by locking the ports for 10 days, ending the lockout on October 8, when President George Bush by invoking the Taft-Hartley Act of 1947, forced open the ports and pushed the parties back to the negotiating table. The closure of the 29 West Coast ports resulted in the massive ocean-going freight vessels serving the West Coast having to wait off-shore, with a growing inventory that needed to be handled after the strike. These huge container ships could not go to the Canadian or Mexican ports because they could not handle the ships and additionally they were too large to pass through the Panama Canal to the East Coast (Sheffi, 2007).
- ***Transportation Limitations:*** New United Motor Manufacturing Inc. (NUMMI), a joint venture between Toyota and GM, uses just-in-time (JIT) inventory, thus it is vulnerable to lengthy disruptions with a large risk of production stopping very quickly. NUMMI, just before the 2002 lockout on all U.S. West Coast ports, although it had pulled more parts than usual, was forced to shut down its Fremont, California plant after four days. Seven days into the lockout and uncertain what was going to happen, NUMMI chartered several Boeings 747s to bring parts from Japan, increasing the cost of every car produced with air-freight parts by \$300 to \$600. Thus, the costs increased significantly during that period because of the expensive airfreight, added storage and handling costs, and substantial worker overtime (Sheffi, 2007).

- ***Terrorist Attacks:*** The September 11 terrorist attacks caused the closure of U.S. airports and enhanced security at U.S ports and at the Canadian and Mexican borders, significantly slowing down the transportation of parts and products. One company affected by these measures was Ford, which was unable to switch the transport mode of delivery due to an increased demand for ground transportation. As a result of part delivery problems, Ford closed five of the U.S plants for weeks and reduced its production volume by 13% in the fourth quarter of 2001 (Hicks, 2002).
- ***Natural Hazards:*** Hurricane Katrina in August 2005, the Kobe earthquake in Japan in 1995 and hurricane Andrew in 1992 disabled transportation networks, stopped business operations and caused great infrastructure problems.
- ***Computer Virus Attacks:*** The well known ‘Love Bug’ computer virus, a fast-spreading infection, which in 2002 caused billions of dollars in estimated damages, shut down e-mails among others at the Pentagon, NASA and Ford (Chopra and Sodhi, 2004).
- ***Economic Crises:*** The currency crisis of the Indonesian Rupiah in 1997 had a great effect on Indonesia. As an example, Indonesia’s national car manufacturer, Astra, postponed production because they were unable to pay for imported parts. Additionally, 60% of Jakarta’s public transport system was suspended because of the soaring price of the spare parts needed to repair the city’s buses (Tang, 2006b).
- ***Political and Legal Instability:*** One of Edrich’s clients obtains valves for car airbags from Indonesia. Although the Indonesian source is cheaper than sources in Eastern Europe, it suffers more risk of political unrest. This became evident during the 1998 riots in Indonesia, when vandals set fire to the plant. (Gilbert and Gips, 2000).
- ***Diseases:*** In 2001, the foot and mouth disease (FMD) cost the agricultural sector £2.4 billion and impacted on the U.K national economy approximately

£4 billion. British leather production decreased by 50 percent because millions of potentially infected cattle were slaughtered. This affected the flow of raw material to leather suppliers who in their turn provided material to manufacturers such as Nike (shoes), Louis Vuitton (handbags), and Jaguar (car seats). These manufacturers were forced to look for alternative sources of leather supply. Thus, the U.K. leather producers lost many of their customers and were unable to recover to pre-FMD sales levels (Sheffi, 2007).

We can see from the examples the interconnectivity between different causes of disruptions. For example, the closure of all U.S west ports was caused by strikes, but the strikes caused transportation limitations for the large vessels that could only use specified ports. Transportation limitations meant goods tied up in transit, leaving manufacturing companies unable to produce their goods because they had a shortage of the necessary materials. Possible effects from different sources of risk can be mitigated or prevented if the companies in the supply chain use proactive SCDM so they can deal with uncertain and unknown situations.

In addition to the different sources of risks, sometimes over-reaction, unnecessary interventions, second guessing, mistrust and distorted information throughout a supply chain increase the risks within the supply chain (Childerhouse et al., 2003). Misunderstanding of the sources of risk and unnecessary actions to handle them can lead to unintended effects, creating further risks rather than mitigating them because the 'real' sources of risks are not identified. Supply chain members need to be familiar with the sources of disruptions they may encounter; close relationships and collaborations between supply chain members assist in identifying the right sources of disruptions.

1.3 Research Aim

The company and consequently the supply chain face many global challenges that increase their vulnerability to disruptions. There is a variety of sources of risk that can lead to supply chain disruptions which, if not handled effectively, may have a negative and even a large impact on the company and its supply chain.

The purpose of this study is to explore the current practices companies employ for implementing SCDM, and based on these practices, to present formal SCDM processes, and also to identify the benefits achieved by adopting a formalized approach. The empirical research, which is based on case studies, involves identifying how two different types of companies handle disruptions along their supply chain, determining if they adopt any formal RM processes and examining how their SCDM process might be improved by adopting a formalized approach.

Two research questions will guide the research process:

1. *How do companies proactively reduce the potential impacts of sources of disruptions in supply chains affecting them?*
2. *How might a formal risk management process improve supply chain disruption management?*

The research objectives are linked with the research questions and describe in more detail the areas the research will focus on.

Research Objectives

- 1) To describe what methods companies use in order to manage proactively supply chain disruptions.
 1. Provide literature review on methods companies use to handle supply chain disruptions.
 2. Investigate through interviews the proactive methods different types of companies use.
 3. Identify any formal risk management processes used by companies interviewed for dealing with sources of risk in the supply chain.
- 2) To determine and describe the processes for managing proactively supply chain disruptions.

1. Describe the steps of the processes from identifying risks to developing proactive supply chain disruption management strategies.
- 3) To undertake case studies in order to obtain a deeper understanding of the complexity of the issues involved in achieving proactive supply chain disruption management.
1. Identify how managers perceive disruptions and identify the kinds of disruptions they are mostly concerned with.
 2. Identify sources of risks in the companies' supply chains and determine if they make use of formal processes to handle them.
 3. Identify the benefits from adopting a formal supply chain disruption management process.

This research aims to contribute to the development of proactive SCDM processes that may help companies deal with disruptions along their supply chain so they can become more resilient and flexible in the presence of disruptions.

What follows is an overview of the chapters presented.

Chapter 2: Addresses Supply Chain Management (SCM) and typically applied practices that help manage supply chains, such as Vendor Managed Inventory and Information Technology.

Chapter 3: Reveals SCDM strategies companies use in order to build more resilient and flexible supply chains. These strategies not only help in reducing supply chain vulnerability but can also protect the company and the supply chain from disruptive events. Some of the strategies presented include flexible sourcing strategies, flexible transportation and supply network visibility.

Chapter 4: Presents the SCDM process and analysis of the five phases (define context, identification, assessment, implement and manage, and monitor and control) a company may follow. Further, the importance of the SCDM process is highlighted.

Chapter 5: Explains the research methodology adopted for the empirical research along with the research philosophy and approach of the researcher. The case study methodology is described and the data collection methods are supplied as well.

Chapter 6: Displays the data related to the auto-manufacturing company's supply chain with an analysis of issues such as managers' risk perception, sources of disruptions and current SCDM processes.

Chapter 7: Contains the water utilities case study with an explanation of the water and product supply chains, where the constraints along the network are identified. Also presented are the sources of disruptions, how employees conceptualize risk and the RM process applied.

Chapter 8: Discusses the case study findings related to supply chains, sources of disruptions, employees' risk perception and the RM process.

Chapter 9: Provides an overview of the research findings, the research limitations and suggestions for future work.

2 Supply Chain Management Issues

Risk sources are evident in every supply chain link and are possible threats for the continuity of supply chain activities. In order for the company to be able to deal with sources of supply chain risks and cooperate with supply chain entities to handle them, it is important there are planning and coordination processes in place between supply chain entities. Managing a company internally is challenging due to all the activities, processes, planning and coordination that need to be achieved. Regarding supply chains, coordination and communication are even harder to be achieved amongst supply chain entities due to the different company strategies, policies and practices. Therefore the necessity arises for supply chain management (SCM); this helps in administering the activities and processes so that effectiveness and efficiency are achieved among supply chain members' supply chain activities.

For a supply chain to be managed effectively and efficiently, risk sources need to be identified and handled, thus reducing the vulnerability of the company in the presence of supply chain disruptions, and also enhancing cooperation and coordination amongst supply chain parties. SCM practices help in reducing the supply chain risk levels due to the coordination and cooperation activities (e.g. EDI, VMI, IT) that can be developed concurrently between supply chain members which may reduce possible threats related to supply chain continuity.

The term SCM was first used in the early 1980s to refer to the management of materials across departments within a company but was soon developed from the focal firm to include upstream production chains and downstream distribution channels (Lamming et al., 2000). In the 1980s the focal company usually owned its upstream suppliers and downstream customers; for example, production companies were engaged in many steps of production starting from raw materials, to manufacturing, distribution and finally to retailing. In the late 1980s and early 1990s, logistics as an activity (i.e., bringing products from point A to point B) developed into SCM as an essential function in order to integrate complex global networks of procurement, manufacturing, distribution and sales (Kleindorfer and

Wassenhove, 2004). Additionally, Christopher (1998) argues that SCM builds upon the framework of logistics (creating a single plan for the flow of product and information through a business) and seeks to achieve linkage and coordination between the processes of the network entities such as suppliers, customers and the focal company. Thus, they argue that SCM is an extension of logistics, and is a multi-disciplinary approach which takes into consideration not only logistics but the management of activities such as procurement, sales and production among the supply chain members.

Christopher and Peck (2004) agree with this argument by stating that in the 1990s, SCM extended the integration of elements of logistics, operations management and marketing into cross-functional inter-organizational processes in order to coordinate and make more efficient the flow of goods and services to the final customer. They argue that this was enabled with the exponential growth in information technology, which capacitated further improvements in efficiency and greater awareness of a changing marketplace and emerging customer requirements. SCM heavily depends on information technology for successful implementation in areas such as Vendor Managed Inventory (Appendix I), Collaborative Planning and Forecasting (Appendix II) and Information Technology (Appendix III) for providing real time market information, better forecasts and better activities planning. Furthermore, supply chain partners need to not only coordinate their activities but also develop mutual trust and strategies, in order for the collaboration along the supply chain to be mutually beneficial.

SCM can be concerned with improving not only the efficiency of product flows but also the quality of the products and customer satisfaction. As businesses become global and companies are linked more closely through the sharing of information, knowledge and expertise, SCM will evolve to encompass changing supply chain functions and relationships. Mentzer et al. (2001) stress the strategic and holistic nature of SCM that first has to be accomplished and understood by supply chain entities, companies and departments. Then they need to decide on the tactics to be implemented in order to fulfil the supply chain strategies. Supply

chain partners need to coordinate their operations and set their supply chain strategies for the effective management of their supply chain.

2.1 Supply Chain Management Definitions

SCM is a general term that different people conceptualize differently. Therefore, listing the SCM definitions (Table 2.1) given by different researchers of the field is a helpful method to understand the nature of SCM and what activities it includes.

Table 2.1 : Supply Chain Management Definitions

Researchers	Supply Chain Management Definitions
Thomas and Griffin (1996)	The management of material and information flows both in and between facilities, such as vendors, assembly plants and distribution centres.
Christopher (1998)	The management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at lower cost to the supply chain as a whole.
Mentzer et al. (2001)	The systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole.
Stock and Lambert (2001)	The integration of key business processes from end user through original suppliers that provides products, services and information that add value for customers and other stakeholders.
Stevenson (2005)	The goal is to link all components of the supply chain so that the market demand is met as efficiently and as effectively as possible across the entire chain. This requires matching supply and demand at each stage of the chain. Organizations in a supply chain are both customers and suppliers.

Tang (2006a)	The management of material, information and financial flows through a network of organizations (i.e., suppliers, manufacturers, logistics providers, wholesalers/ distributors, retailers) that aims to produce and deliver products or services for the consumers. It includes the coordination and collaboration of processes and activities across different functions such as marketing, sales, production, product design, procurement, logistics, finance and information technology within the network of organizations.
Council for SCM Professionals (CSCMP) - (Peck, 2006)	Encompasses the planning and management of all activities involved in sourcing and procurement, conversion and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers and customers. SCM integrates supply and demand management within and across companies.
Sheffi (2007)	Focuses on the flow of products through the global web of suppliers, manufacturers, distributors, transportation carriers and retailers, from raw materials to finished goods in consumers' hands and the recycling and disposal of these products.

These definitions suggest that SCM manages the integration of companies' activities and processes upstream and downstream in the supply chain, such as procurement, production, marketing, finance and distribution, in order to achieve final customer satisfaction. SCM encompasses a range of activities, from raw materials extraction up to the end customer delivery and satisfaction; it governs the upstream and downstream flows of materials and information between the supply chain companies (Thomas and Griffin, 1996; Stock and Lambert, 2001). Sheffi (2007) adds that SCM can also be applied at the recycle and disposal activities of materials and products, which are part of the reverse supply chain.

Tang (2006a) notes that not only materials and information pass through the supply chain but also financial flows. Furthermore, Stock and Lambert (2001) add that services which relate to consultancy and after sales customer service are also part of the supply chain. Thus, SCM does not manage only the flow of materials, products and information, but also those concerned with financial transactions and services. Additionally, SCM aims to offer improved customer value and

satisfaction at the best possible cost, competitive advantage and long term performance (Christopher, 1998; Mentzer et al., 2001).

Based on the above definitions, SCM can be described as the management of bidirectional flows of information, materials, services and finance among the upstream and downstream supply network entities such are vendors, manufacturers, assembly plants, distributors and retailers, from raw materials to end consumer. The supply chain members' goal is to provide stakeholder value and satisfaction at the lowest possible cost, facilitate competitive advantage, reduce risk and foster long term performance of the supply chain. Giunipero and Eltantawy (2004) suggest that SCM also seeks to reduce risk and enhance competitive performance by integrating internal functions within an organization and effectively linking them with the external operations of supply members and final customers.

Performance metrics are important indicators for assessing the performance of each of the key processes in the supply chain on selected risk dimensions which are defined by the supply chain participants (Kleindorfer and Wassenhove, 2004). These metrics can measure how effective the supply chain processes are, for example, under normal operations, during a natural hazard or during major supply chain reorganizations. The metrics, used by operating personnel who discern abnormal conditions in order to report 'near misses', serve to identify potential vulnerabilities in particular sites and throughout the overall supply chain. The metrics in conjunction with the employees' judgment can reveal how effectively a system operates under risk threats and where they need to build-in risk mitigation strategies. Employees using the proper tools to monitor and track key processes can see the results of their actions implemented in risk-reduction activities over time. This not only motivates them to contribute to this process, but also makes them cognizant of which RM processes are more effective than others.

Typically, one member of a supply chain is not fully informed about what is happening in other parts of the chain such as finished goods inventory, material inventory and work-in-process (Christopher and Lee, 2001). For that reason, SCM tries to achieve an integration and coordination of the various business activities,

in order for the companies to have access to information that directly affects their operations. The type and quality of information heavily depends on the types of relationships that are formed between the companies along the supply chain.

2.2 Supply Chain Relationships

Supply chain members heavily depend on each other for the reliability of information and coordination between them so they can plan their activities and processes effectively. In general, a supply chain network can be divided into three main subsystems: Supplier Relationship Management (SRM), Internal Supply Chain Management (ISCM) and Customer Relationship Management (CRM) (Kleindorfer and Saad, 2005). ISCM is the core of any chain because upstream, it links both the producer and supplier's network (SRM), and downstream, the producer and its customer/distribution network (CRM). For supply chain companies to be able to interact and coordinate their activities along the supply chain, first each individual company must have the ability to coordinate and integrate its internal departments and functions.

SCM includes the development of relationships between the supplier and the company in such a way that suppliers support the firms' business strategies and suppliers are constantly motivated to improve their performance in respect to the client (Weele, 2005). This is achieved by integrating suppliers into the company's overall business processes to improve productivity by developing the physical and information infrastructure to facilitate the interaction (Weele, 2005). Weele (2005) believes that in order for the suppliers and the firm to cooperate and exchange information, they need to be motivated. Thus, there must be a win-win situation that will induce both parties to participate in a collaborative and trusting relationship.

Some of the supply chain relationship processes that support the implementation of SCM are listed in Table 2.2.

Table 2.2 : Supply Chain Relationship Processes (Mentzer et al., 2001)

Supply Chain Relationship Processes	
<i>Integrated behaviour</i>	Coordinated effort between supply chain partners to dynamically respond to the needs of the end customer.
<i>Mutually sharing information</i>	The willingness of the supply chain entities to make available to other members of the supply chain strategic and tactical data. Information sharing can be related to inventory levels, forecasts, sales promotions strategies and marketing strategies. This cooperation helps reduce the uncertainty and results in improved performance between supply partners.
<i>Mutually sharing risks and rewards</i>	Supply chain members should cooperate on the risks and rewards which offer a competitive advantage. Risk and reward sharing is important for long term focus and cooperation among the supply chain members.
<i>Cooperation</i>	Cross-functional coordination between supply chain members, in which cooperation starts with joint planning and ends with joint control activities to evaluate performance of the supply chain members, as well as the supply chain as a whole.
<i>The same goal and the same focus on servicing customers</i>	Successful relationships aim to integrate supply chain policy to avoid redundancy and overlap, while trying to achieve a level of cooperation that permits participants to be more effective at lower cost levels. Policy integration is possible if there are similar cultures and management techniques among the supply chain companies.
<i>Integration of processes</i>	Processes along the supply chain from sourcing, to manufacturing, to distribution should be integrated so the supply chain activities are coordinated to offer better value products at lower costs. Integration can be achieved through cross-functional teams, in-plant supplier personnel and third party providers.
<i>Partners to build and maintain long term relationships</i>	The length of the relationship should not only be limited to the duration of the contract but extend the relationship after the contract end. Additionally, it is better to have a small number of partners in order to facilitate increased cooperation; having a large number of partners does not allow the company either the time or the resources to maintain long-term close relationships with all its partners.

These processes include requirements that supply chain members can agree on among them in order to implement SCM effectively. Basically, supply chain parties can operate closely in long-term relationships, with coordination based on sharing information, risks and rewards. This is a challenging task because each supply chain partner sets its own strategies and targets and may be reluctant to

share company information related to sales and performance levels. Companies have to realize that sharing information, technology and risks is beneficial for the parties involved because it helps increase the level of visibility along the supply chain.

Modern views of SCM highlight the requirement for close integration between suppliers and customers, moving away from the adversarial relationship of the past (New and Westbrook, 2004). Trust helps resolve issues in an uncertain and changing environment, thus creating competitive capabilities between the supply chain partners which help increase the performance level of the supply chain. Additionally, the cooperation of suppliers and customers may result in lower inventory levels and holding costs, smaller demand and supply variations and better value products at lower costs. Thus, supply chain partners should collaborate in managing the supply chain because the overall outcome that the customer receives (e.g. lower prices, better quality products, on time delivery) is much better than if each company acted and planned alone.

Supplier's Reliability

The supplier's reliability needs to be verified before the company collaborates with them. Due to the volatile and unpredictable environment most suppliers are involved in, business capabilities change, strengths can become weaknesses and financial losses may be greater than earnings. The company must have these changes in mind and must constantly monitor the performance of their suppliers. Gilbert and Gips (2000) propose examining the supplier's resources, procedures and management processes. These can be verified by quality control programs, visits to the supplier and customer locations and by using scorecards to assess the supplier's reliability. The company can prepare a card that identifies each contributing vendor, along with its critical suppliers and the specific departments of these vendors if necessary (Gilbert and Gips, 2000). Moreover, the company must decide up to which tier of supplier it must examine; this heavily depends on if it is a sole supplier and on the criticality of the component. How extensively a business should look into the suppliers of a supplier depends on how critical the product is to the company's business (Gilbert and Gips, 2000). Gilbert and Gips

(2000) suggest avoiding suppliers that are prone to natural hazards, political instability and furthermore advocate choosing suppliers with management stability and infrastructure integrity. Suppliers must be carefully chosen and continuously monitored and in cases where collaborating with them increases vulnerability substantially, it may be advisable to try and find new suppliers or advise them to improve their processes.

2.3 The trend towards Outsourcing

SCM becomes even more complex when companies outsource activities such as logistics, marketing, production and sales, or parts of certain activities to other companies, for example, transportation and information technology. With outsourcing the number of company links in the supply chain increases, thus the coordination of different companies becomes a challenging task for SCM increasing the risk sources a company may face. Outsourcing is the tendency to contract out activities that were previously conducted within the organization (Cranfield, 2002). Organizations outsource because they believe that they are more likely to succeed if they focus on the activities in which they have a differential advantage over competitors.

The main reason that companies are turning towards outsourcing is the need to focus on their core competences and outsource the activities to organizations that provide better performance on certain activities than the company. Specifically, outsourcing is the function with which organizations are increasingly focusing on their 'core business' (functions they perform well and where they have a differential advantage) and the other non-core businesses are outsourced (procured outside the firm) (Christopher, 1998). For example, certain auto-manufacturing companies used to make their own parts yet now only assemble the finished products. The company with outsourcing has more time, expertise and knowledge to specialize on the in-house activities that offer a competitive advantage.

Similarly Quinn (1992) believes it is best for a company to focus on its core activities where it can achieve competitive advantage and outsource the non-core activities where it can achieve cost reduction, quality improvement, lead time

reduction and innovation. Additionally, Stevenson (2005) argues that a company decides to outsource due to a variety of reasons such as the cost of new technology so they can continue manufacturing the part in-house, asset utilization, reduce the company's leverage in the supply chain and whether it would delay or help time-to-market for new products. By concentrating on the core competence activities you can achieve cost reduction and quality improvement of the products because it is outsourced to a company that has the technology, facilities and know-how to perform that activity much better and cheaper than if it was produced in house.

A company with outsourcing heavily depends on another company to provide the goods or services for the continuity of its business. Thus, companies are something more than just business partners. Most of them engage in long term relationships where common practices and goals become heavily important between the two partners, and especially for the company that outsources the activity. The company before outsourcing needs to think about the associated costs and risks: the unknown and unpredictable costs that may derive from the outsourced activity the company didn't anticipate, plus the risks if the supplier is not performing to the specific pre-arranged company requirements. Outsourcing is best achieved when best-in-class suppliers are available (Weele, 2005). The company based on a market analysis needs to identify the most suitable companies to outsource the activities to.

There is a tendency to outsource activities to low labour cost regions (Stevenson, 2005). Although companies can benefit from lower labour costs, their risk profile increases significantly due to political and economic instability in some of these regions. Stevenson (2005) advises that further to the usual risk performance metrics, constant monitoring of political and economic conditions must be achieved. This is judicious for companies that are part of supply chains operating in politically, economically and geographically vulnerable countries; they need to be alert to such changes which pose a high threat for the continuity of supply chain operations.

The company needs to assess if it is in a position to outsource, and if so, then the company must revise very carefully the advantages versus the disadvantages for outsourcing a function. In Table 2.3 the advantages and disadvantages of outsourcing are listed (Weele, 2005):

Table 2.3 : Advantages and Disadvantages of Outsourcing (Weele, 2005)

Advantages	Disadvantages
<ul style="list-style-type: none"> • Freeing up of cash: investments can be concentrated on core activities. • Optimal usage of knowledge, equipment and experience of third party. • Increased flexibility: fluctuations in the workload can more easily be absorbed. • Easier and more focused primary processes in the organization. • Input through an independent party's point of view, reducing the risks of introverted short-sightedness in the organization. 	<ul style="list-style-type: none"> • Increased dependence on suppliers. • Continuous follow-up and monitoring of the supplier relationship is necessary. • Risks of communication and organizational problems during the transfer of activities to a third party. • Risk of leakage of confidential information. • Depending on balance of power between parties: inability to execute contractual performance incentives and penalties. • Risk of losing essential strategic knowledge.

Outsourcing is very helpful if used when available outsourced parties are capable of performing the activity better than if it was produced in-house and when it adds value to the company's business performance. Outsourcing may be a disadvantage if the company does not have in place plans and actions to protect, for example, sensitive information or are unable to penalize the supplier for not providing the agreed-upon services or goods. A company needs to look into the supplier it is cooperating with (e.g. financial status, credibility, project outcomes, customer satisfaction) and also determine if the two companies can collaborate and communicate successfully. There is a risk for the supply chain if the contractor turns out to be deficient in his obligations, which can as a result impact on the company's and supply chain's operations. After deciding if it is beneficial to outsource, the type of outsourcing (Appendix IV) needs to be determined, by comparing the advantages with the disadvantages of each type.

2.4 Conclusions

SCM provides good planning, coordination and cooperation between supply chain parties which are essential factors for not only adding value to the products and services provided, but also for developing more efficient and effective practices between supply chain members. SCM activities also encompass RM; sources of risks are present in the everyday supply chains' operational activities for which companies encounter and develop methods and processes in dealing with them, usually based on experience and repeatability of negative outcome events.

In the presence of potential negative outcomes which may affect profitability and supply chain continuity, supply chain partners develop, maybe not in a formalized RM process, procedures (e.g. supplier technical assistance, CPFR) in dealing with risk and uncertainty which may not be the most efficient and effective options for enhancing supply chain resilience. SCM though doesn't underline the use of formal processes and especially proactive RM processes, which are important for dealing with uncertainty and handling possible disruption events in an agreed and formalized approach at a company level or between supply chain entities. Thus, companies may have sources of supply chain risk they are not aware of due to the lack of formalized procedures in place in identifying sources of risk and developing suitable action plans.

SCM practices successful implementation heavily depends on trust between supply chain entities, which guides the validity of information exchanged and the effectiveness of the supply chain network. Without trust strong supply chain relationships are difficult to be achieved which may affect the cost and quality of the final product and/or services offered. Thus, trust enhances relationships between supply chain entities and better cooperation and coordination may be achieved which benefits the involved parties. Trust, also helps companies identify the possible supply chain risk threats that may affect their operations and enhances cooperation between supply chain entities to handle them, in order to build more resilient and flexible supply chain processes. As a result, SCM

promotes the development of supply chain relationships, but trust helps build tighter and longer term relationships between supply chain entities.

SCM processes are helpful in managing the activities between supply chain partners, by using practices such as information technology and inventory management. These practices although have been developed to offer better coordination and cost reduction between supply chain partners, they may also help reduce the supply chain partners' vulnerability levels in the presence of uncertainty. Also, when companies choose SCM strategies, although they may be reducing a risk in one area, they may be exacerbating the materialization of a risk in another related area. For example, with inventory management although the company may achieve less safety stocks and increase capital availability, it may increase the company's vulnerability to unavailable stocks due to a surge in demand. Formal SCDM processes though, may help identify the interrelation between risks and develop the appropriate SCM strategies and activities.

3 Supply Chain Disruption Management Strategies

By implementing SCM strategies the company may proactively reduce the company's vulnerability levels in the presence of possible supply chain disruptions. Due to certain SCM strategies in place, certain sources of risk can be prevented from developing, but due to the numerous sources of risks a supply chain may face, it's very difficult to control all of them, especially when some are unmanageable (e.g. weather conditions, terrorist attacks). When disruptions materialize, the continuity of supply chain operations is affected which may cause negative effects such as bad reputation, complete damage of facilities or production stoppage. Establishing formal processes in its systems instead of ad hoc SCM strategies developed from experience, will not only help foresee the possible effects of a disruption materializing, but should also facilitate the development of measures that will mitigate possible impacts and also help focus on the important risk sources depending on the company's risk appetite.

As a starting point of the research related to SCDM, the research focused on the current methods companies use to handle supply chain disruptions. Based on the literature, strategies and activities were identified which companies apply to increase their robustness and resilience so as to deal with the inherent uncertainty they face in their supply chain environment. These strategies are presented in Table 3.1, where the categories are based on the most widely applied strategies companies adopt which help increase the supply chain's proactive responsiveness to disruptions.

Table 3.1 : Supply Chain Disruption Management Strategies

SCDM Strategies	Benefits
<i>Demand Management</i> (Lee, 2002; Martha and Subbkrishna, 2002; Tang, 2006b) Good understanding of consumer preferences, ways of response to price changes and different product offerings.	<ul style="list-style-type: none"> ● Promote a product in stock ● Induce suppliers to buy a product ● Respond quickly to disruptions ● Satisfied customers
<i>Standardization</i> (Rice and Caniato, 2003a; Sheffi, 2007)	<ul style="list-style-type: none"> ● Shift production and personnel between

Standard factories, platforms, equipment, components and processes.	<p>facilities</p> <ul style="list-style-type: none"> • Interchange-ability • Same part for different products
<i>Employees Flexibility</i> (Mishina, 1992; Rice and Caniato, 2003a) Cross-trained workers that work on different workstations, team leaders, employees familiar to emergency situations.	<ul style="list-style-type: none"> • Workstation rotation • Production rate flexibility • Employees expertise
<i>Stockpiling Inventory</i> (Gilbert and Gips, 2000; Chopra and Sodhi, 2004) Maintain extra inventory of component or critical parts.	<ul style="list-style-type: none"> • Quick Response • Protect from foreseeable disruptions
<i>Spare Capacity</i> (New and Westbrook, 2004; Chopra and Sodhi, 2004; Sheffi, 2007) Retain redundant production capacity instead of building up stock.	<ul style="list-style-type: none"> • Deal with uncertainty • Hold less inventory • Flexible production rates
<i>Inventory Centralization</i> (Lee and Wolfe, 2003; Tang, 2006b, Sheffi, 2007) Surpluses of parts, subassemblies and products in one area can be moved to support demand deriving from a different area.	<ul style="list-style-type: none"> • Flexibility in product requirements • Lower inventory costs and requirements • Satisfy broader area of customers
<i>Postponement Strategy</i> (Christopher, 1998; Lee and Wolfe, 2003; Tang 2006b; Sheffi, 2007) Production of a generic product based on total aggregate demand of all products; generic product is customized later, with better estimation of customer requirements.	<ul style="list-style-type: none"> • Meet demand • Cost-effective and time-efficient • Reconfigure the product quickly • Fewer stock keeping variants
<i>Economic Supply Incentives</i> (Tang, 2006b) Create additional suppliers when they are unavailable.	<ul style="list-style-type: none"> • Suppliers develop needed competency • Back-up and quantity flexibility contracts with suppliers
<i>Flexible Transportation</i> (Rice and Caniato, 2003a; Tang 2006b) Multi modal, multi carrier and multiple routes transportation.	<ul style="list-style-type: none"> • Prevent supply chain operations stoppages • Flexible logistics strategy • Switch carriers quickly
<i>Flexible Sourcing Strategies</i> (Gilbert and Gips, 2000; Rice and Caniato, 2003a; Lee and Wolfe, 2003; Chopra and Sodhi, 2004; Tang, 2006a) Multiple Sources, Create a local supply source, Flexible Contracts.	<ul style="list-style-type: none"> • Necessary back-up • Continuous supply of materials • Spread risk across two companies and locations • Quantity flexibility
<i>Supply Network Visibility</i> (Hicks, 2002; Lee and Wolfe, 2003) Accessing and sharing information upon close collaboration in the supply network from upstream to	<ul style="list-style-type: none"> • Real time information • Reduce inventories • Increase customer service

downstream suppliers, with no barriers to vision.	<ul style="list-style-type: none"> • Reroute goods, revise production plans, redeploy production resources and adjust capacities
<i>Insurance</i> (Deloach, 2007; Sheffi, 2007) Paying a premium to an insurer who will compensate up to an agreed amount to the company if the event occurs.	<ul style="list-style-type: none"> • Pay for financial losses • Lower premium costs if company has RM processes in place

Robustness

Tang (2006a) proposed for SCDM the development of robust strategies so they can motivate organizations to secure their supply chains. Robust strategies serve dual purposes. Firstly, these strategies can help a company reduce cost and/or improve customer satisfaction under normal circumstances. Secondly, these strategies should assist a company in maintaining its operations during and after a major disruption. Developing robust strategies requires the implementation of new procedures for which the company may incur extra costs. Examples of such strategies include reserve capacity at a supplier's plant and flexible contracts. Although these plans may involve an additional monetary outlay for their development in terms of staff training, new software systems and equipment, to cite a few, in the long term the benefits will be much greater than the original costs.

Resilience

In materials sciences resilience is the ability of a material to return to its original state or position after a deformation that does not exceed its elastic limit (Rice and Caniato, 2003a; Sheffi, 2007). The elastic limit is the characteristic that enables the material to recover, thus the bigger the limits the better the elasticity. In business terms, resilience characterizes the company's ability to respond to an unpredicted disruption and re-establish normal operations or move to a new, more desirable state, after being disturbed (Rice and Caniato, 2003a; Christopher and Peck, 2004; Peck, 2006; Tang, 2006b). Robustness and resilience are very similar concepts; robustness highlights the ability of a company to maintain the continuity of its operations and resilience, the ability of the company in recovering from a disruption to a state not worse than the previous one. Thus, with resilience the

company can achieve a better operational state than before the disruption. Resilience does not only measure the company's ability but also the speed at which it can return to the usual performance level after a high impact disruption (Sheffi, 2007). How quickly and effectively a company will return to its normal or desirable operations depend not only on the processes and the infrastructure it has in place, but also on the company's speed to react to a disruption.

If certain features are engineered into a supply chain, they can improve its resilience (Christopher and Peck, 2004). Sheffi and Rice (2005) believe resilience can be achieved by creating redundancy or increasing flexibility. Sheffi and Rice (2005) state that flexibility may create company capabilities that can detect threats and respond to them quickly. They propose resilient companies build flexibility into each of the five essential supply chain elements: suppliers, conversion processes, distribution channels, control systems and underlying corporate culture. Flexibility in these elements will assist the company reconfigure current operating systems in order to proactively respond to possible threats. These processes, though, must be in place so the supply chain can easily and quickly switch between procedures, for instance, special supply contracts and multiple transportation methods. If these processes are not in place, both time and money will be wasted before the company develops response plans and locates the alternative resources required. By then, competition may have taken a portion of its business; it will have unsatisfied customers due to unavailability of the product and extra operating costs may be enormous (e.g. extra shifts, airfreight, new suppliers).

Redundancy is used by keeping some resources in case of a disruption, safety stocks and multiple suppliers, even when the secondary suppliers have higher costs and low capacity operation rates (Sheffi and Rice, 2005). These extra resources act as safety nets in the event of a disruption. However, Sheffi and Rice (2005) argue that redundancy represents pure cost with no return unless a disruption materializes and flexibility offers more leverage and operational advantages. These are points that SC managers need to decide when enhancing the resilience of the company as well as the cost they are willing to incur to increase

resilience. A company usually considers the trade-off between the cost of risk mitigation investments and the expected disruption costs (Kleindorfer and Saad, 2005). Flexibility and redundancy both incur extra costs, and flexibility requires some degree of redundancy if the company wants to change between operating levels. Flexibility, however, stresses the importance of developing capabilities in the company that will help react in the event of a disruption, thus developing manoeuvring capabilities in the system.

Resilience helps companies achieve competitive advantage over companies that do not have resilience capabilities when a disruption materializes (Rice and Caniato, 2003a). Following is an example of two companies which depended on the same supplier affected by a disruption, consequently impacting their operations. These two companies due to varying resilience levels responded differently. This example from early 2000 concerns a fire in the main Philips radio-frequency chip plant; at this time, Nokia and Ericsson depended solely on Philips Electronics for RFCs. Although both companies were equally affected, their responses were different. Nokia realized the seriousness of the fire and responded by assigning 30 employees to work with Philips and other suppliers to maintain a steady RFC supply. Ericsson didn't realize the seriousness of the situations and ultimately mounted only a modest effort to restore supply. As a result, Nokia achieved its sales plans, while Ericsson was unable to introduce a critical new product causing an estimated \$400-million-revenue loss. This impacted on Ericsson, which ultimately exited from the business of producing cellular phones (Rice and Caniato, 2003a). This example demonstrates the importance resilience procedures play towards the profitability and viability of a company.

Sheffi (2007) advises that a company can reduce its vulnerability to disruption by increasing both security (reducing probability of a disruption) and resilience (building in capabilities for bouncing back quickly). In order to increase security the company requires layered defences, tracking and responding to 'near misses', increasing the participation of all employees in security efforts and collaborating with government agencies, trading partners and even competitors. These

safeguards highlight the importance of collaboration and coordination of all the responsible parties and reflect a continuous improvement of the processes in place so that potential security breaches will be reduced. Attention here is to building in processes and capabilities that will enhance the resilience of the company so in the case of a disruption materializing, the company will be capable of rebounding effectively. Sheffi (2007) also states that by reducing the company's vulnerability to disruptions, it also reduces its vulnerability to daily demand fluctuations; therefore it improves its general performance. Because the company invests in building proactive capabilities to handle potential demand disruptions, it can also handle demand risks because the required processes and procedures are already in place and easily executed.

While trying to reduce risk threats and supply chain loss from supply chain disruptions, the trade-off amongst robustness and resilience in the presence of disruptions and the overall effectiveness of the supply chain under normal operations need to be carefully considered. This is why cost benefit analysis needs to be carefully performed. Relying also on capable decision makers to determine if it's worth investing in risk mitigation strategies, and if so, which are the most appropriate. These strategies should avoid sacrificing the supply chain effectiveness in the need to build more robust and resilient supply chains. Strategies and effectiveness need to coexist and be mutually dependent; they need to increase the effectiveness of the company and its supply chain.

Rice and Caniato (2003a) argue that in order for a company to be able to manage disruptions effectively, it must achieve fundamental security and preparedness activities such as:

Physical security measures: Access control, badges, guards, camera systems.

Personnel security: Criminal, credit and background checks on potential employees.

Standard risk assessment: Consideration of risks such as fire, flood, vandalism and disruptions to utilities.

Basic cyber security: Anti-virus software, firewalls, passwords.

Continuity plan: Responses for small-scale incidents to recover internal operations.

Freight protection: Employee background checks, cargo seals, tracking technologies, sensors.

If a company is able to establish these procedures and the employees are familiar with executing them, they will transition more easily to SCDM strategies; employees will be more capable of applying them with knowledge of basic threat management activities. Following are the descriptions of the SCDM strategies a company may adopt if it has already implemented the fundamental security activities.

3.1 Demand Management

Demand management needs a good understanding of consumer preferences and how they would respond to price changes and different product offerings (Lee, 2002). The company, by knowing the customers' preferences and their reactions to offerings of different kinds of products at different prices, may promote a product or product configuration in stock rather than a product, for example, in short-supply due to a disrupted supplier who was unable to provide the desired product quantities. In this way, companies are trying to meet demand by providing the right products at the right prices, so in the case of a disruption, companies will induce customers to buy what is available and avoid products that are in short-supply (Lee and Wolfe, 2003). It's crucial that the alternative products a company proposes to its customers can satisfy the customer at both the desired quality and price levels; if customers are offered inferior products at the same or higher price, then the customer will be disappointed with the company's product offering.

Demand management is effectively supported by component designs that use both common and substitutable parts, postponements and standardized interfaces (Lee and Wolfe, 2003). With such designs, the company can reconfigure a product quickly with component parts that are widely available. A company needs to be

certain that the substitutable component parts will not dissatisfy the customers and they will offer the same or a better quality product than the original one. It is advisable when a firm designs a product and its production process to consider the availability of a part from different suppliers, the design and parts commonality between a variety of products and production processes and the ability to modify a product at the latest possible production step. Thus, in the event of a disruption, the company may be able to find an alternative supplier, or redesign the product so they can fit a similar component part with the one which is short in supply. As a result, when the product is highly modular it's easier to influence customer choice (Martha and Subbakrishna, 2002).

An organization may also use pricing mechanisms to influence customers to choose items that are more widely available (Tang, 2006b). This is also an alternative strategy organizations may follow, where they can induce customers to purchase an item instead of the intended one by offering price discounts and better deals so the customers will be inclined to choose the upgraded or discounted offer. As an example, due to an earthquake in Taiwan in September 1999, Dell incurred supply disruptions from their Taiwanese suppliers (Tang, 2006b). Dell responded by offering special 'low-cost upgrade' options to customers if they selected similar computers with parts from alternative suppliers. This strategy helped Dell satisfy its customers during a supply crisis and also Dell's third quarter 1999 earnings increased 41 percent over the previous year (Martha and Subbakrishna, 2002). Responding to a crisis by offering better for value money products helped Dell shift the demand from products in short supply to available ones as well as increase its earnings in a disruption situation.

Retailers implement assortment planning (reconfigure product location, number and set of products on display) to influence the product choice and demand of the customer to purchase products that are widely available when there is supply disruption of certain products (Chong et al., 2001). This marketing strategy tries to place products so they reach the customers' awareness more easily, allowing them to consider purchasing the product on display if they cannot find the product they originally wanted. The product placed by the retailers must meet the

specifications, and the price needs to be approximately the same as the unavailable product. Having unsatisfied customers is something a retailer should try to avoid because dissatisfaction adversely affects sales.

With silent product rollover strategy, new products are entered into the market with no formal announcements. In this way, consumers are not familiar with the specific product characteristics and are more likely to choose the products that are offered instead of the products that are out of stock or being phased out (Tang, 2006b). The new products have an advantage over the older ones because they may have better and updated specifications plus the customer may notice that the previous versions are being gradually removed from the market, so they would like to obtain the 'improved' version. In the case of disruptions, the company needs to have already developed and have available the alternative product.

Online retailers may develop a personalized pricing and promotion strategy in order to entice each customer's product choice by having records, for example, of the customer's past click sequence and past purchasing history (Tang, 2006b). They can develop a list of the customer's preferences, and in a disruption event, will try to offer similar products so the company can meet the customer's requirements in order to avoid lost sales and promote products that are available. The proposed product is best when similar to the desired product and in compliance with the consumer's expectations, estimated by previous purchases.

By implementing demand management in various ways, a company can influence customers' preferences and entice them to purchase an item that the company has available.

3.2 Standardization

Companies use standard factories (Intel, GM), equipment (Southwest, Ryan Air), components (Lucent, Dell) and processes (Helix, UPS), which offer interchangeability and build in flexibility so companies can respond to disruptions (Sheffi, 2007). Using standard processes, components and equipment enables a company to switch production from one disrupted facility to another, or to find an

alternative supplier for component parts that are not highly modular or to borrow component parts from another plant with available inventory. Instead of using customer-made and engineered-to-order parts, companies try to maximize the use of standard parts so that they can be procured from many sources, thus increasing the use of standard parts over special parts (Sheffi, 2007). In this way, if a supplier is disrupted or a transportation route is idled, then the part may be provided by another supplier and easily be fitted to the product.

Volkswagen's 'B Platform' is used for a number of car models which share around 70% of their content, from the budget-priced Skoda Octavia and the mid-priced VW Golf, Beetle, and GTI to the luxurious Audi A3 and TT (Sheffi, 2007). This provides flexibility because the company can change production and exchange component parts between car models in the case of a disruption.

Similarly, General Motors runs near-identical plants in Argentina, Poland, China, Thailand and Brazil, built to a common template that uses the same design, processes and technology (Sheffi, 2007). Sheffi (2007) notes that none of GM's five flexible plants has fixed conveyor lines that carry car bodies in a pre-designed assembly pattern, so they can adjust plants to changing requirements and each plant can be reconfigured in a weekend. The GM plants not only offer flexibility among plants but are also able to change production within the same plants. This offers resilience within plants in a disruption event due to the ability to respond to changing demand requirements.

By modifying a product so standard parts are used, although it reduces part inventory cost and complexity, it is costly to modify existing material standards (Rice and Caniato, 2003a). With standard parts, the company uses fewer parts for the same products and the cost to order, handle and maintain that inventory is also reduced, providing not only flexibility in the case of disruption but also cost effectiveness. On the other hand, having to change the design of the products and the production processes requires investments and time to ensure that the re-engineered product reaches the desirable quality standards. Until the company achieves the desired quality for standardization, the investment, personnel training and reconfiguration of the supply network will require significant costs, especially

at the beginning of the implementation phase; however, later on the company may benefit from the cost effectiveness and efficiency standardization provides. Thus, although the cost benefit analysis will have a negative output in the short term, in the long term, the benefits for having standard parts and processes may compensate for the initial investment.

Standardization of the technical capabilities of several plants (e.g. equipment, personnel, and processes) is not enough if one plant is disrupted (Sheffi, 2007). Additional planning is required of the alternative routes for the flow of inbound material to shift into the alternative facility and the ability of the alternative plant to service the customers from that facility (Sheffi, 2007). The alternative plant will be utilized more than during its normal operations, perhaps meeting its maximum capacity, and the staff may be required to work overtime, or alternatively staff from the destroyed plant may be transferred to the new facility. Responding to a disruption is achieved by having in place not only standardization but also contingency plans such as alternative suppliers and supply contracts to provide extra stock if needed, flexible logistics and transportation providers so components parts are rerouted to the alternative location with no delays and then sent to the responding customer locations.

If a company considers applying standardization, the design of the product, the component parts and the processes need to be modified. Component and platform commonality and modular product designs need to be designed so that the same component can be applied to several products (Sheffi, 2007). An advantage is that it leverages common processing capabilities for lower cost and also the backup is more readily available (Rice and Caniato, 2003a). Therefore, cost effectiveness, flexibility and resilience can be established due to the commonality of processes and components, employees can rotate between processes and standard parts are more easily obtained by a number of suppliers.

3.3 Employees Flexibility

Employee flexibility is an important asset for the company that can use its employees in times of crisis by rotating them to different workstations. By

developing cross-trained workers that can work on different workstations, a company can redeploy employees and production as required (Rice and Caniato, 2003a). In case a workstation requires more workforce, the company can hire temporary employees or use existing employees to work overtime. One of the ways Microsoft reduces operating leverage to increase its flexibility to respond to unexpected shocks in demand, technology or regulation is by using more temporary employees than expected (Pickford, 2001). These translate into extra costs and quality issues because employees working extra shifts will be tired and may be more prone to making mistakes and also, the newly hired temp employees may not be familiar with the nature of the work, causing quality issues. Moreover, by having cross – trained employees, the work system needs to be modified in order to utilize multi-skilled employees (Rice and Caniato, 2003a). In order for employees to be flexible and rotate between workstations but at the same time avoid disabling other production processes, the work system needs to be modified and rescheduled so it can calculate these changes and possible ways of dealing with them. There is some considerable investment in the training of workers and changing of even the production process so this flexibility is embedded in production. The long term benefits are flexibility and resilience to changing demand needs.

Another possible way to respond to a crisis is by assigning team leaders that are familiar with performing all the jobs on their team. Toyota employs team leaders who can work on any assembly line station, thus reducing the need for more station-specific workers to cover absences and to ensure daily production targets are satisfied (Mishina, 1992). This is a cost efficient way that helps a company rotate personnel to jobs requiring extra workers, or avoid in the absence of employees the need of employees working overtime if there are available team leaders to satisfy the required production capacity. Other companies may choose to utilize not just team leaders but also additional employees for workstation rotation. This highly depends on the demand patterns of a customer. If demand is uncertain and is constantly changing, then more flexible employees are required to satisfy demand.

Flexible employees need also be familiar with how to react in emergency situations. Thus, training needs to be established so when there is a crisis, the employees will be capable of responding quickly and effectively. People that have dealt with crisis situations can be hired so they can help develop response plans and train the employees. A company can hire people with military, law enforcement or intelligence agency experience and also establish an executive level position such as director or chief of security (Rice and Caniato, 2003a). Certain U.S. global companies have recruited security experts from non-U.S. law enforcement agencies such as the Israeli Mossad, Irish Garda, British Intelligence and the Hong Kong Police, in order to incorporate security expertise into their supply chains (Rice and Caniato, 2003a). Such experience will help a company deal with a number of risks and utilize people with knowledge and practical experience for dealing with crisis situations.

Companies operate in a volatile environment where global market dynamics change consistently. Teams trained to change according to the situation respond more effectively not only to demand fluctuations but also to unpredictable disruptions (Sheffi, 2007). Multi-skilled workers cross trained in various functions and experienced in dealing with uncertainties and changes to the supply chain will be helpful for the company's security. Likewise, company culture that embraces change, initiative and motivates employees to respond proactively to situations is important.

3.4 Stockpiling Inventory

A company may choose to increase its resilience to disruptions by stockpiling inventory. Although this strategy may protect a company from supply chain disruptions for a number of days, if the disruption continues for more time than anticipated, then the stock levels may not be adequate for production or satisfying demand. Chopra and Sodhi (2004) argue it is more reasonable to build inventory if the size of disruptions can be estimated with reasonable confidence and for products with low holding costs, low risk of obsolescence and deterioration such as the large petroleum reserve kept by the U.S.A. This strategy is preferred for

protecting a company from relative foreseeable disruptions, like recurring natural hazards or equipment breakdown. Further, it is best applied for items that do not deteriorate quickly and do not require large amounts of investments to stock and maintain them. Although a company by keeping extra inventory of parts and products can respond to small changes in demand and supply, extra inventory is expensive because it ties up capital. Additionally, extra inventory requires management, warehousing, maintenance and prevention of damage or pilferage and some of the products may become obsolete while they are stored, as new, better and less expensive products are introduced into the market (Sheffi, 2007). Companies keep an inventory of critical parts and equipment (Gilbert and Gips, 2000). Increasing the critical parts' inventory may help maintain the continuity of the production line, but the extra amount of inventory needs to be carefully calculated and the benefits justified.

Holding extra inventory can lead to relaxed manufacturing, procurement and logistics disciplines at the expense of quality products, service and delivery (Sheffi, 2007). Sheffi (2007) argues that holding extra inventory can contribute to hidden manufacturing problems because production managers use the extra inventory to replace a defective part or complete a customer order from the finished goods inventory rather than examine the source of the problem. Although stockpiling inventory provides a safety net to demand and supply fluctuations, it also relaxes the management discipline regarding the quality of the products. A way to overcome this is by stockpiling inventory which managers will be able to use only in an event of a disruption. Of course, if the parts have a high obsolescence rate then this emergency stock needs to be renewed regularly, so that the parts are up to date and suitable for production.

Sheffi (2007) provides an example from Johnson and Johnson, a principal provider of medical suppliers to hospitals and pharmacies. J & J keeps safety stock in warehouses in case demand for any of its products exceeds forecasts. The Pentagon, one of its clients, buys in predictable patterns medical supplies which J & J provides from its manufacturing facilities and warehouses. However, in case of a war or a major disaster, the Pentagon will need large amounts of medical

supplies very quickly; thus J & J has an agreement with the U.S government to stockpile certain quantities of medical supplies where J & J's inventory is not placed in a dedicated warehouse but is placed with the rest of the J & J's stock. In this way, J & J determines a 'red line' for each product; when the inventory for a specific product reaches the red line, J & J computers signal the ordering hospital or pharmacy that it is out of stock. Going below the red line requires the Pentagon's approval as this inventory cannot be used to deal with day-to-day variations. As a result, J & J's needs to operate as if such inventory is not available. Companies may stock extra inventory in the possibility of a disruption, but if there is a request to use this inventory due to a problem which does not qualify as a disruption, then the approval of management needs to be obtained in order to use more than the allowed level (e.g. red line).

Moreover, it is advisable to stock extra inventory when the company cooperates with suppliers whose deliveries are not always predictable (due to distance, location, or process peculiarities); in this way, the company can modify its strategy to increase inventory by implementing a higher 'reorder point' (Sheffi, 2007). Although a company might be advised to change to a more reliable supplier, there may be some advantages for using a certain supplier such as quality products at very competitive prices and the suppliers are the long term preferred suppliers of the company. In order to deal with uncertainties linked with a supplier whose deliveries are unpredictable, stockpiling more inventory than usual is a way of dealing with delivery uncertainties. Furthermore, companies depending on suppliers that offer patented processes can also use stockpiling, since there won't be an available source if the supplier has a problem (Gilbert and Gips, 2000). While stockpiling incurs greater inventory costs, it reduces the possibility of the company having no inventory when required, especially regarding critical component inventory or a component that alternative suppliers may not provide.

Chopra and Sodhi (2004) propose using different transport modes depending on the type of inventory. They use the example of Dell that keeps very small amounts of inventory of high value components in the United States and uses air-transport

to deliver components from the Far East as necessary. Dell also keeps some inventory for the less costly components, which is shipped frequently at low cost to the United States. Dell, by trying to reduce inventory costs combines quick delivery with expensive inventory items. It may have chosen this strategy because it is more cost effective to transport by air than to maintain inventory of high value items. With this combination Dell is able to respond to disruptions because it uses air transport on a regular basis, and thus they may use this mode of transport if certain inventory parts are needed urgently. A possible problem of this strategy could involve air strikes; Dell would not be able to transport the components to the U.S., leaving the production line without the necessary component parts.

3.5 Spare Capacity

Spare capacity is an alternative strategy that helps companies deal with disruption situations. Instead of stockpiling inventory, companies may choose to reserve spare production capacity at their plants and with their suppliers, or even establish a balance between spare capacity and stockpiling.

Certain companies retain redundant capacity so that they can respond to uncertainty instead of building up stock (New and Westbrook, 2004; Sheffi, 2007). In this way companies may deal with uncertainty in demand and disruptions, but simultaneously they need to be certain that they have the required inventory and employees to operate the extra capacity. Sheffi (2007) suggests that companies may build redundant production lines for their most important products. As a strategy it helps the company increase its resilience and flexibility in a disruption situation or even deal with operational problems, but is costly by tying up capital on production lines that may never be fully utilized. In addition, managers and employees learn to depend on this extra capacity rather than trying to implement best practices on the available capacity. With spare capacity production, resources are not used for some or most of the time, and this is often considered wasteful (New and Westbrook, 2004). Depending on the criticality of the product, the necessity of having the production line running and the lost

capital of not having spare capacity can determine the amount of spare capacity. For example, Toyota operates plants at 80% utilization, and consequently, can handle demand variation without needing to keep inventory (Chopra and Sodhi, 2004).

Another possible way of dealing with disruptions, depending on the cost of the products, is to balance capacity and inventory (Chopra and Sodhi, 2004). Depending on the cost of having reserved capacity against the cost of reserving extra inventory, a company may decide for which production processes to reserve extra capacity and for which products or processes to stock more inventory. Cisco Systems has capacity to assemble higher-value products in the U.S. so they can respond speedily to orders from up-market domestic customers (Chopra and Sodhi, 2004). On the other hand, Cisco keeps inventory of lower-value, high-demand products, produced in low-cost overseas locations.

Excess capacity, unlike inventory, can only be increased or decreased over a period of time, and therefore building it usually becomes a strategic choice (Chopra and Sodhi, 2004). In order for a company to determine the inventory amount, supply contracts need to be developed and the quality of the products need to be approved so they can be used in the production process. This procedure usually requires less time for a company than building in or decreasing a production line capacity. This is because production process levels need to be changed and employees trained, which takes more time than changing the inventory levels ordered from a current or a new supplier. Thus, there are a number of variables the company needs to calculate before determining a production line's capacity utilization and a product's inventory levels.

3.6 Inventory Centralization

With the centralization of inventory, surpluses of parts, subassemblies and products in one area can be moved to support demands deriving from different areas (Lee and Wolfe, 2003; Sheffi, 2007). Inventory centralization offers the required flexibility in an event of disruption because inventory in one location can cover the deficits and requirements of another. Some companies prefer

centralizing inventory because the inventory holding and obsolescence costs for extra safety stock inventories in each company location can be very expensive especially when the product life cycle shortens and the product variety increases (Tang, 2006b). Strategically located warehouses and distribution centres can help diminish inventory costs and also serve a broader area of customers. Instead of having each company location reserving extra safety stock, inventory can be pooled into fewer locations so holding and obsolescence costs are decreased because multiple plants of the same company can share the inventory costs.

Companies by closing local warehouses and integrating them into regional distribution centres (RDCs), serving a wider geographical area, can reduce considerably total inventory requirements (Christopher, 1998). With fewer warehouses a company can satisfy a larger and more spread out customer base, simultaneously decreasing the amount of total inventory and tied up capital. For example, Philips has decreased its consumer electronics products warehouses in Western Europe from twenty-two to four, and Apple Computers replaced their thirteen national warehouses with two European RDCs (Christopher, 1998). Two companies, Toyota and Sears, keep inventories of cars and appliances respectively at specific locations so that nearby retailers can share these inventories (Tang, 2006b). Another example is from online bookseller Amazon, which serves all its customers in the U.S.A., with inventory kept in a number of warehouses; in each warehouse Amazon pools demand from a wide geographical area, leading to more stable forecasts and lower total inventory (Chopra and Sodhi, 2004). This helps Amazon satisfy customers by avoiding high inventory costs when dealing with usual demand fluctuations and in the event of a disruption, allocates the strategic stocks quickly to the affected areas. Centralizing inventories offers resilience to uncertainty and decreases total inventory costs.

Centralized inventory though, usually leads to higher transport costs because products need to travel greater distances, and frequently high air expenses will be essential to ensure short lead time for delivery to customer (Christopher, 1998). The distances and lead times increase but inventory costs diminish. The company's logistics and transportation services need to calculate the best

available routes and transportation methods in order to decrease transportation costs and increase responsiveness when parts are needed. For certain companies, centralizing inventories is more profitable than decentralization because total inventory costs diminish and flexibility of the company's network is enhanced in respect to the transportation costs required.

Rather than keeping more safety stocks, companies may consider stockpiling at certain 'strategic' locations (e.g. warehouse, logistics hubs, distribution centres) with some of their supply chain partners (e.g. retailers, repair centres) (Tang, 2006b). A company can cooperate with other supply chain parties to share between them central inventory locations, which will not only diminish considerably the cost of building and maintaining an inventory location but also build better relationships among supply chain partners.

3.7 Postponement

The term 'postponement' applies to situations in which a generic product is produced based on the total aggregate demand of all products, and the generic product is customized later on when there is better estimation of customer requirements (Christopher, 1998; Tang, 2006b; Sheffi, 2007). When demand can be estimated with better accuracy, the generic product can be modified in order to produce a number of different products. Postponement is a cost-effective mass customization tool that can deal with regular demand fluctuations from normal circumstances in organizations such as Xilinx, Hewlett Packard and Benetton (Tang, 2006b). Time, capital and inventory are saved because products are not produced based on just forecasting, which may result in unsold products or unsatisfied customers if a product is unavailable, but on customer orders. For example, in order for Hewlett Packard to be able to produce 500,000 different configurations of workstations in an effective manner, it first mass-produced a generic version of the workstation in a make-to-stock manner and then in order to respond to customer orders quickly, it inserted certain product-specific components into these generic workstations (Feitzinger and Lee, 1997; Tang 2006b). In this way forecasting is better estimated at a generic level than at the

finished product level (Christopher, 1998). By producing a product at a generic level, the forecasting error for each individual product decreases because the company does not need to calculate the demand for each individual product but only estimate the aggregate demand for the generic product and, when demand is better estimated, finalize the products.

Postponement can be achieved by utilizing standardization of components and subassemblies, modular design, postponement of operations and re-sequencing of operations to delay the point of product differentiation (Tang, 2006a; Tang, 2006b). Postponement strategy highly depends on standardization of processes and component parts up to a level which forms the basis of the product, and then the product is differentiated into a variety of products. General Motors implements a joint platform strategy which enables the company to manufacture components (e.g. engines and transmissions) before committing to the production of specific models, thus postponing this commitment until demand can be forecasted with better certainty (Sheffi, 2007). Another example can be seen by revisiting Philip's semiconductor plant fire from 2000, which disrupted Nokia's supply of radio frequency chips (Tang, 2006a; Tang, 2006b). Nokia's cell phones being modularly designed enabled Nokia to postpone the insertion of radio frequency chips until the end of the assembly process. Thus, Nokia was able to reconfigure the design of its basic phones so that the modified ones could accept slightly different chips from other suppliers.

Standardization and postponement can provide cost-effectiveness and time-efficiency to the company not only in handling demand uncertainty but also in the event of a disruption because processes are in place that can accommodate daily demand variations as well as deal with larger impact events outside the normal business activities. A company, by being able to readjust component and module parts without affecting the quality of the product and simultaneously respond to a disruption situation, has a greater advantage over competitors that do not apply postponement strategy. If one component is in short supply, a company can meet demand by using alternative configurations as in the case of Nokia (Lee and

Wolfe, 2003). The company though, needs to be aware of the alternative suppliers and ensure that the quality standards of components are met.

Under a postponement approach, inventory can be kept at a generic level, thus having fewer stock-keeping variants and even less inventory in total (Christopher, 1998). Inventory variability decreases because the base part for the product variants requires the same components, thereby reducing the total inventory in contrast to the larger inventory requirements when the company does not implement postponement strategy. To offer an example, inventory of paint is kept as a common base and after the customer orders, it is mixed to the precise colour specifications; this has helped significantly lower paint inventory at retail stores (Chopra and Sodhi, 2004). Similarly, Benetton stockpiles inventory in one location of un-dyed sweaters and after specific orders have been received, the sweaters are coloured, which helps Benetton greatly reduce inventory risk and meet customer demand (Chopra and Sodhi, 2004). However, having fewer stock variants is also a disadvantage because the company highly depends on certain components; if these become unavailable and if companies do not have alternative sources of suppliers or suppliers can't meet production requirements with such short notice, it will cause a large negative impact on the company.

Usually, the redesign of products for postponement will increase the total manufacturing costs due to the two-stage manufacturing processes (Sheffi, 2007). Postponement strategy incurs extra investments due to the re-design of the manufacturing processes and component parts and the new contracts with suppliers and customers that need to be arranged. This cost, though, can be offset by lower inventory carrying costs, lower discounting, improved availability and better customer satisfaction (Sheffi, 2007). With postponement the availability of the product and customer satisfaction increase by simultaneously keeping lower inventory levels which offset the increased manufacturing costs. For example, Benetton's postponement dying operation increased the manufacturing costs per garment approximately by 10 percent (Sheffi, 2007). On the other hand, sales increase by reducing stock-outs of popular colours and the cost of overstocking and the associated costs of discounts and merchandise liquidations decreased. As

a result, products are available when customers request them, increasing customer responsiveness and at the same time reducing stock-levels, where large stock-levels and unsold items lead to discounts and profit margin loss.

3.8 Economic Supply Incentives

When the available suppliers are limited and the company may only be able to cooperate with one supplier, then a possible solution is to create additional suppliers. In such circumstances, Tang (2006b) proposes that a company may provide certain economic incentives to develop additional suppliers. Thus, a company may induce suppliers to engage in a business for which they will already have a customer for their products. Due to its key supplier attitude, Intercon Japan offered to a new supplier, Nagoya Steel, economic incentives to develop a new steel process technology for producing different kinds of cable connectors (Mishina, 1991; Tang, 1999; Tang, 2006b). In order to make Nagoya Steel more competitive, the incentives Intercon Japan provided, consisted of a minimum order quantity, technical advice about the new steel process technology and information about the market demand for the new process technology. Based on this example, a company needs to assist its supplier with know-how, technical capabilities and estimated demand levels. Intercon Japan, by using suppliers that use different process technologies, was able to keep pressure on both suppliers to maintain the cost low (Tang, 2006b). Economic supply incentives are beneficial for both parties engaging in a contract; a supplier diversifies in a new business with a minimum order quantity, and a customer maintains the competition for quality and price levels between two suppliers.

3.9 Flexible Transportation

Transportation is an important link in the network because it connects suppliers by transporting goods from one supplier to another. There are multiple modes, carriers and routes a company may choose from in order to optimize its network. By adopting a flexible transportation strategy, the company enhances its resilience in case of a transport disruption or a need to reroute goods because it can switch

from one mode of transport to another, switch carriers or follow an alternative route.

Multi-modal transportation enables a company to choose the optimum transportation methods such as rail, truck, ship or airplane to satisfy the company's transportation requirements. In this way, a company may change from a traditional mode of transport from a certain supplier into a temporary one because the former may be unavailable or due to changing circumstances, it does not continue to be the best option. For example, Chrysler applies this strategy with a third-party logistics provider with which Chrysler can change the mode of transport from air to ground at short notice (Tang, 2006b). Following the events of 9/11, Chrysler's logistics team analyzed their production flow by September 12th and realized that they were in danger of running out of an updated steering-gear part (Martha and Subbakrishna, 2002). This part was usually sent by air from the plant in Virginia to the assembly plant in Mexico and due to the air travel restrictions after 9/11, Chrysler quickly used an expedited truck service to deliver the parts as quickly as possible. By using logistics providers to source transportation, the advantage is that they may have greater leverage and access (Rice and Caniato, 2003a). Especially when they have contracts and long term relationships with transportation providers, it's easier for these providers to respond in an event of crisis than for a company to seek such services in a time of crisis when maybe providers will choose to service existing long term clients. On the other hand, contracts and good relations require commitment (volume, cost) to the logistics provider (Rice and Caniato, 2003a). In order for a logistics provider to respond in a time of crisis and try to find the best possible solution, a company would have to develop good relations and prefer the provider for the logistics requirements of the company, so the provider knows the needs of the company and how to best respond in a company crisis situation. The ability of a company to switch transportation methods instantly provides flexibility to the company, allowing it to avoid disabled trade lanes and also to switch to a transportation method which, although in high demand, the company will be able to use it.

To ensure continuous flow of parts in a disruption event and to achieve low-cost global deliveries, various air cargo companies such as Aeroméxico Cargo, KLM Cargo, Delta Air Logistics and Air France Cargo have formed an alliance called SkyTeam Cargo (Tang, 2006b). With multi-carrier transportation a company depends on a number of different carrier companies to provide the flexibility to switch from one carrier to another. The company, by changing carriers, also needs to confirm that the alternative carrier has the required capacity and that it can respond to a disruption situation.

Alternatively, a company can also rely on the spot market for extra capacity because it may offer an efficient transaction with no upfront or lasting commitment (Rice and Caniato, 2003a). If a company has extra transportation requirements which carriers cannot satisfy, then it can turn to the spot market, which does not require any in-advance contracts although the availability of spot market transportation companies is not guaranteed. The disadvantage is the use of an unknown carrier which translates into added risk and potential for exceptional high pricing (Rice and Caniato, 2003a).

A company may choose to adopt a multiple routes strategy so it can use air, sea, rail and road and change from one route to another if there is a disruption on a transportation route such as road closure or strike at a port. Companies may consider alternative routes to ensure the smooth flow of material through the supply chain (Tang, 2006b). For example, because of the lengthy delays at U.S. west coast ports and heavy traffic jams along different west coast freeways, various U.S. east coast companies are encouraging shippers to develop new routes in addition to the traditional ones (i.e. ocean freight from Asia to the west coast and then rail transportation from the west coast to the east coast). In order to be able to adopt multiple routes, though, the necessary carriers and modes of transportations are required. So, if there is a strike in a country and the rail network is disabled, then the company may alter its route and use the road instead. The company needs to design the optimal transportation network that will not only optimize carrier responsiveness at the lowest possible cost but also have the flexibility to avoid disabled trade lanes and provide the component on schedule.

3.10 Flexible Sourcing Strategies

Sole Source

Sole sourcing is when only one supplier in the world has the technology or the process to provide the component (Walker, 2005). High dependence of a procuring company on a sole source supplier increases the company's vulnerability to disruptions and it may even be exposed to higher prices by its sole supplier. For example, the Osaka plant of Sumitomo Metal Industries was the sole supplier for most of the brake shoes used by Toyota in all of its domestic cars. Although the Osaka plant wasn't damaged by the Kobe quake in 1995, it lost gas and water supplies, resulting in halted production at most of Toyota's car manufacturing plants all over Japan as these plants quickly exhausted their supplies of brake shoes. The disruption lost Toyota production an estimated 20,000 cars and around \$200 million in lost revenue (Sheffi, 2007). Clearly when a procuring company decides to sole source, it should consider disruption scenarios and determine how resilient the company would be in such scenarios. If the company's effectiveness and efficiency is vulnerable under disruption scenarios, then the company may consider adopting other strategies such as multiple sourcing, component standardization and economic supply incentives.

Single Source

With single sourcing two or more suppliers have the technology and the process to supply the part, but the organization due to business reasons decides to purchase from only one source (Walker, 2005). With single sourcing the company has the flexibility to choose a component from available suppliers whereas with sole sourcing, the company has only one option. With single sourcing the supplier provides better quality at lower cost to the customer (Larson and Kulchitsky, 1998). Good supply – customer relationships, quality products and even lower cost are some of the reasons that customers prefer to single source. Also, the supplier becomes familiar with the company's requirements and offers better quality products because the supplier and customer cooperate to develop the desired component. Regarding the cost of the component, most companies using

single sourcing are knowledgeable of the other component suppliers they could cooperate with, so if the chosen supplier decides to increase the cost, then the company has the option to source from another supplier.

With single sourcing, the vulnerability of the company is not as high as in sole sourcing because there are other suppliers for the component that they could contract in an emergency situation. If the need should arise, finding an available alternative supplier can be time consuming. Even if the company manages to find an alternative supplier, the alternative component specifications may be slightly different from the component produced by the previous supplier, thus forcing the need to test the quality and maybe even change the specifications of the part, causing extra time and money. The company's workers may be required to work overtime in order to make up for lost production, the new component part may have an initial large failure rate and the customers may be dissatisfied from not receiving the part on time especially in a lean system.

Single sourcing increases the vulnerability of the organization to disruption unless a supplier has, for example, multiple flexible sites and backup plans (Rice and Caniato, 2003a). If there is a disruption in a supplier's facility and the supplier can switch production to an alternative facility without affecting supply, then the company may not be affected. Supplier's contingency plans in case of a disruption also diminish the company's vulnerability, but there is always the chance that the plans may not work out, affecting negatively the continuity of the company's production line.

Multiple Sources

Multiple sourcing is when the component is offered by a number of substitutable suppliers (Walker, 2005). Instead of relying on one supplier, a manufacturer purchases the component from two or more suppliers, so in a supplier emergency situation the manufacturer can rely on the other supplier. For example, in November 1998 Hurricane Mitch blew throughout Central America destroying 10% of the worldwide banana plantations crop, with Dole losing 25% of its global banana supply and Chiquita, 15% (\$200 million in damages) (Martha and

Subbakrishna, 2002; Sheffi, 2007). Dole lost approximately one-quarter of its worldwide production and without alternative suppliers in the region, it suffered an interruption in supply from Central America for more than a year. Chiquita had secondary sources for Central American bananas in Mexico, Panama and Columbia, which were less affected by the hurricane, as well as the Ivory Coast, Martinique, and even Australia. Thus, Chiquita leveraged its alternative sources, generating a 4 percent increase in revenues in the fourth quarter of 1998.

Chopra and Sodhi (2004) suggest using redundant suppliers only if organizations can maintain economies of scale. Motorola implements a strategy which uses multiple suppliers for high volume products and single sourcing for low volume products, so it can lower the risk of disruption while maintaining economies of scale with its suppliers (Chopra and Sodhi, 2004). This strategy helps Motorola achieve economies of scale with its high volume items and also protects the company from a supplier emergency situation. With low volume items, it's difficult to achieve economies of scale by having multiple suppliers, but there is also the risk of a single supplier disruption which may affect the company's production. To such situations the company may respond by having a list of alternative suppliers it cooperates with, ones which can satisfy the extra capacity although it's a low volume product, or else the company can rely on spot markets to provide the product. Although Toyota tries to achieve economies of scale by single sourcing at the plant level, it also enlists redundant suppliers globally (Chopra and Sodhi, 2004). Thus, even though a company single supplies a Toyota plant, it needs to keep prices down so it can remain competitive for business across the entire Toyota network. In implementing this strategy, Toyota tries to motivate suppliers to offer the best deals so they can maintain and even increase the level of business with Toyota.

Redundant suppliers offer the company a certain degree of security in an emergency situation, but this may not be a cost effective solution. Thus, the company needs to develop contracts that will offer the company economies of scale at the best possible deal. Additionally, it is better to use redundant suppliers with products that have high holding costs and/or a high rate of obsolescence

(Chopra and Sodhi, 2004). In this way, the company does not need to build great amounts of high value stock which has the risk of obsolescence because, when one supplier can't provide the necessary volume, the other may be able to. Gilbert and Gips (2000) propose that organizations should arrange for back-up suppliers of key components and services to prevent emergencies, and to promote competitive bidding between possible suppliers.

Gilbert and Gips (2000) also suggest choosing suppliers from different geographical locations because natural hazards or labour strike are unlikely to affect both simultaneously. Suppliers in different geographical areas, although may incur more transportation costs and longer lead times, minimize the possibility of a disruption affecting them simultaneously. This is because a number of disruptions are caused by natural hazards, port and road closures; thus if a supplier is affected, the other supplier in a different geographical location may produce the disrupted supplier's volume.

A company, by having several suppliers, may receive lower prices but longer time in negotiations and communications may delay or disturb production schedules (Render and Heizer, 1997; Berger and Zeng, 2006). Depending on several suppliers for a certain part involves more contract negotiations, quality checks and communications (e.g. payments, coordination).

Create a local supply source

Companies using offshore suppliers for the bulk of the required volume may give a part of their business to smaller-scale local manufacturers who, although may be more expensive, can respond to changing demand more quickly than the main offshore supply base (Sheffi, 2001; Lee and Wolfe, 2003). This responsiveness the local supply source offers the company enhances the company's resilience both in regular uncertainties and crisis. The extra cost the local supply source incurs is balanced with the company's responsiveness to uncertain customer demand and the company's protection from disruptions. For example, if a disruption blocks transport between, for instance, the U.S. and overseas, the local source will be used to provide the required back-up. HP uses this strategy to

produce the majority of DeskJet printers in Singapore (lower cost) but also maintains a supplemental supplier in Vancouver for quick response to the North American market where the facility is more flexible, faster and closer to the market (Lee and Wolfe, 2003; Sheffi, 2007). To add another example, retailer Zara manufactures its products at its in-house plants and outsources other basic items to their suppliers in China (Ghemawat and Nuemo, 2003). This strategy not only increases the resilience and flexibility of the company but also reduces transportation costs and disruptions related to transportation.

The disadvantages of a local supply source are higher cost, lower volume leverage and no assurance that the additional supplier is more resilient (Rice and Caniato, 2003a). Although the local supply source may deal with irregular demand, if the main supplier is disrupted, the local supplier may not have the additional capacity to meet the disrupted facility's requirements. Additionally, the extra cost to maintain and contract a local supplier may not provide economies of scale that benefit the company. The extra cost of using the local supplier is in effect a premium paid for reducing the supply chain risk in the case of disruption (Sheffi, 2001).

Flexible Contracts

A flexible supply base may also be achieved by entering into different supply contracts, such as back-up supply contracts and quantity flexibility contracts (Tang, 2006b). In these types of contracts, there is some element of flexibility on the quantities contracted for and the delivery of these. Under such contracts, the cost per unit is potentially higher and may also entail fixed costs for committed volume (Rice and Caniato, 2003a). The supplier pre-engages to provide a specified volume of parts when needed in a timely manner, thus providing the flexibility to the company to order the parts when demand is better known. On the other hand, the cost for such flexible volumes is fixed so the procuring company cannot achieve better deals when the market prices are lower. For this reason, the procuring company needs to forecast market prices and fluctuations in order to close the best deal.

In a back-up contract, the customer is contracted to a contingent specific order quantity with the supplier. The supplier delivers a pre-specified fraction of a contracted quantity before the beginning of the contractual period and reserves capacity for producing and delivering the remaining units (i.e. the back-up units). Following early demand monitoring, the customer may order up to the back-up quantity by paying the original purchase cost and also receive quick delivery. Nonetheless, the customer will pay a penalty cost for any of the back-up units that are not purchased (Eppen and Iyer 1997; Tang 2006b). With a back-up contract, the company can order the required units later than usual when demand is better estimated, therefore achieving quick delivery but can also reduce inventory because they are using the items closer to customer real demand. A disadvantage is that the procuring company has to purchase the whole agreed-upon order quantity or else there is a penalty cost. This penalty cost is outweighed by the reduction of the inventory cost due to the holding and obsolescence costs decrease. Depending on the penalty cost and the expenses the company pays by having unwanted items, it can decide if it's worth not ordering the agreed quantity. With the back-up contract, if there is a disruption, for example, at a supplier's warehouse, the remaining units can be ordered and delivered in a timely manner.

In a quantity flexibility contract, the customer is committed to order a certain quantity in advance, but the customer has the flexibility to change this quantity upward or downward up to a certain limit within a specified time frame (Tsay and Lovejoy, 1999; Tang, 2006b). This contract allows a company to order the amount that suits better its requirements in predetermined levels. Accordingly, in the event of disruption or when there is increased demand, the company can order upwards. When demand decreases the company can order a reduced volume, avoiding in this way stocking unnecessary inventory and spending needless transportation costs. The difference with back-up contracts is that the company does not order a base volume and then the rest or there is a penalty cost, but has the flexibility to order in predetermined upper and lower limits in a certain time frame. This time frame may not be as close to real demand as with a back-up

contract but at least the company has limits that can increase or decrease its orders.

HP establishes fixed supply contracts with suppliers that specialize in cost efficiency to provide guaranteed quantities (Shah, 2002; Lee and Wolfe, 2003). Then, flexible contracts with upper and lower volume limits are provided to a supplier that specializes in flexibility, which, although costing more per unit, the added value of flexibility is worth it. Should demand exceed both types of contracts, then HP relies on spot markets to make up the difference. This flexible procurement strategy allows HP to respond to changing demand but also to respond in the case of a disruption because it relies on different markets and maintains the continuity of the supply chain.

3.11 Total Supply Network Visibility

Visibility is the ability of supply chain members to see from one end of the pipeline to the other with no barriers to vision such as inventory. This allows supply chain partners to schedule their production more efficiently than just relying on forecasts. Achieving supply network visibility is difficult because companies may have direct contact up to their first tier suppliers, have no access with their second tier suppliers and no information of the component flow in the remaining supply chain.

Total supply network visibility does not only reduce the ‘bullwhip’ effect, but also helps the supply chain partners respond more quickly to a disruption. If there is a disruption in one part of the supply chain, other supply chain members can respond more effectively by immediately rerouting goods, revising production plans, redeploying production resources and adjusting capacities (Lee and Wolfe, 2003). This can be achieved by having information on the locations and form (raw material, subassemblies, work in process, in transit, or finished goods) of inventories in the supply chain and information about the capacity of the suppliers, manufacturers, transportation providers and distribution networks. Information visibility requires at least two processes: (1) event-driven data of supply chain operations and (2) a tight integration of information systems across

suppliers, manufacturers, logistics providers and customers (Lee and Wolfe, 2003). For example, Cisco's e-Hub connects multiple tiers of suppliers and instantly provides all interested parties with a complete picture of potential supply shortfalls. The e-Hub consists of problem resolution paths so that problems, once identified, can be resolved quickly (Lee and Wolfe, 2003). Such systems help network companies find quick solutions to potential shortfalls, allowing continuity of the supply chain. The data that companies share with other suppliers need to be accurate, or the system and the potential solutions it may propose might not reflect the real situation.

Comprehensive tracking and monitoring provides real-time visibility and monitoring capabilities which recognize a potential shortfall in the normal flow of inventory. When problems occur, the operations and procurement managers need to come together, where the visibility and monitoring system needs to provide concrete and exact information on the specific areas affected, as well as the degree of the problem caused (Lee and Wolfe, 2003). In 1995, UPS LG implemented a supply chain tracking and visibility system (Hicks, 2002). This system monitors the movement of goods from when they leave manufacturing plants, during transit until they arrive at one of UPS LG's 450 distribution centres and until delivered to customers. When a shipment misses a milestone, such as arriving at a dock late, the system can alert UPS LG officials and key customer contacts by sending e-mail and wireless alerts. The system provides real-time information where it alerts the interested parties so that quick alternative plans can be scheduled. Thus, if a truck is late, the logistics team is aware of this and can seek a solution immediately. For example, after September 11, the UPS logistics group was without a key distribution centre where it kept critical repair parts flowing to customers (Hicks, 2002). Following September 11 the system helped speed company's efforts to source parts from alternative facilities in Long Island and in New Jersey. Although customers experienced delays for several weeks, UPS LG continued delivering goods, even to customers that had sourced service parts from the destroyed distribution centre. Visibility of transit goods and inventories in warehouses helped officials find alternative ways to supply customers' goods. Knowing goods locations and availability, the logistics team can decide in an

emergency situation how to reroute goods and use the available capacity of other distribution centres to satisfy its client base. Network visibility helps react timely in emergency situations and does not waste resources of the parties by trying to communicate and coordinate so they can develop a response plan which is timely and cost consuming.

3.12 Insurance

The most traditional and widely used way of dealing with uncertainty and emergency situations is insurance. A company may insure for an event by paying a premium to the insurer, who will compensate the company up to an agreed amount in the face of a disruption event. What happens, though, to all the unsatisfied customers, the extra transportations costs, the rerouting of goods and the contracts with new suppliers if needed? These factors are not necessarily addressed by insurance, but if present, they are covered up to a certain point. A definite assertion is that insurance does not finance the company until it starts operating at normal levels after a disruption, and the company may never achieve this state due to the actions taken in the presence and after a disruption.

After September 11, which was one of the most costly events of insurance history (40% was insured of the approximately \$80 billion damages), reinsurers were mostly reluctant to renew coverage and the few who did charged extremely high rates for very limited protection (Lehman, 2004; Grossi and Kunreuther, 2005). In this instance, insurers were not able to get reinsurance, or raise adequate capital either internally or from the capital markets, and began to offer policies that clearly excluded terrorism coverage. A disruption from a terrorist attack or other major event such as natural disasters can result in billions of dollars lost, an extremely expensive compensation which insurers may not afford or are not willing to pay. In the instance the insurers are willing to cover a possible disruption, the insurance premiums they charge are enormous. For example, Delta Airlines terrorism insurance premiums increased from US\$2 million in 2001 to US\$152 million in 2002 (Tang, 2006b). Although a terrorist attack may cause

instant damages, a company's reputation may also be damaged due to the company's inability to react to the situation, resulting in unsatisfied customers.

Few companies depend on insurance to secure their supply chains from disruptions for two basic reasons (Rice and Caniato, 2003b; Tang, 2006b). Firstly, insurance premiums for major disruptions are extremely expensive. Secondly, although insurance can provide financial help to a company after a major disruption, it cannot protect it from losing its customers. Sheffi (2007) proposes that investments for the security of a company against disruptions comprise true insurance. The securities investment aim is primarily to prevent damage rather than compensate for it. Further, although insurance may pay for financial losses, it rarely covers the loss of customer confidence and damaged reputations, which may only be covered in the event security investments are in place.

Where a company can demonstrate to insurance providers that it is trying to improve its processes in a comprehensive, disciplined manner, resulting in a lower incidence rate, the company then may pay lower premium costs (Deloach, 2000). Proactive RM processes have a dual benefit; not only do they enhance a company's resilience to disruptions but RM processes also reduce the premiums paid to the insurers for a number of risks. These processes more importantly help a company recover from a disruption and enable it to return to normal production levels sooner and more efficiently than if there weren't any RM strategies in place.

3.13 Conclusions

Risk sources are present in supply chain operations such as: stock levels, deliveries and production. Companies having to deal with uncertainty related to supply chain operations, have developed SCM processes that not only help achieve better coordination and cooperation between a supplier and its customer but also help increase resilience and robustness of the company in the presence of risks. Thus, SCM activities also help reduce uncertainty and vulnerability related to supply chain operations. For example, component standardization helps to increase component commonality for a variety of products and store less stock

variants. It also helps reduce risk in the event a supplier is disrupted because another supplier may supply the company if it is a common part.

SCM strategies and activities can provide a degree of resilience and robustness to a company, but may not provide risk efficient options (Chapman and Ward, 2003). Without following a formalized process it is more challenging to identify the best cost effective solutions for risk sources because not all possible important risks may be identified and assessed. SCM helps deal with risk sources, but a formal SCDM process will help identify and assess the best possible SCDM strategies. Thus, company and supply chain capabilities are needed, not only to handle daily operational risks but also to have processes to deal with possible sources of disruptions. A very important factor to achieve this is to invest in employees training and development for dealing with risk sources and responding to disruption situations because they are the executors of these activities who also have the required know-how.

Organizations usually need to proactively manage risk in order to protect their assets and profits and stay in business (Finch, 2004). When a supply chain is operating in an environment where the possible range of sources of risks is unidentified and the exposure undetermined, it's unable to offer its companies protective measures in the wake of uncertainty. Thus, by applying formal SCDM, important sources of risks may be identified and suitable mitigation strategies developed.

4 Supply Chain Disruption Management Processes

The global structure of supply chains, the trend towards outsourcing, lean practices and shorter cycle times have increased the vulnerability between supply chain links. As already mentioned, RM is embedded in SCM activities, thus companies by developing SCM activities also reduce their vulnerability in the presence of risk threats. In order though, for both the company and the supply chain partners to be knowledgeable of the possible risk sources they may face and the severity of these, a more formalized procedure could be followed which would focus on handling proactively supply chain disruptions. This procedure would help identify the risk sources which would be then assessed before developing the appropriate SCDM actions.

As the vulnerability of supply chains increases, SCDM is becoming an area of growing importance; the focus of SCDM is to understand and try to avoid the devastating ripple effects that disruptions can have on a supply chain (Norrman and Jansson, 2004). SCDM also helps with the management of supply chain disruptions through coordination and collaboration among supply chain partners, to ensure profitability and continuity of the supply chain (Tang, 2006a). Moreover, a Cranfield study (2002) defines SCDM as the identification and management of risks within the supply chain and risks external to it through a coordinated approach amongst supply chain members to reduce supply chain vulnerability as a whole. Developing a common RM culture along the supply chain helps identify risks and develop common processes to mitigate them.

Bandyopadhyay et al. (1999) identified four basic steps in a RM process: risk identification, risk analysis, risk reduction – transfer and acceptance and risk monitoring. Similarly, Berger and Zeng (2006), propose a framework which starts with risk identification, continues with risk assessment and risk prioritization and finishes with risk management strategies. The framework does not refer to the RM actions the company can choose to adopt such as risk reduction, transfer and acceptance, and the risk monitoring phase which Bandyopadhyay et al. (1999) refer to. Additionally, risk assessment is used instead of the term risk analysis. So,

we can distinguish that although researchers are referring to the same process, the level of detail and the wording differ.

On the other hand, Kleindorfer and Saad (2005) state that traditional RM includes identifying vulnerabilities, triggers for these vulnerabilities, likelihood of occurrence, mitigation and risk transfer activities. First, they refer to vulnerabilities instead of risks, and also they do not refer to the risk assessment phase but to the likelihood of occurrence, which is a phase of the risk assessment process. Moreover, they merely refer to the RM actions of mitigation and transfer and do not refer to the monitoring phase. The term vulnerability is used to demonstrate the supply chain processes that are prone to disruption and if affected can have a negative impact on the company. Risk sources, if unmanaged, contribute to supply chain vulnerability; thus it is best to know the supply chain risk sources and then detect the areas a supply chain is vulnerable to disruptions.

Deloach (2000) argues that for an organization to establish a RM process, a system needs to be developed that will guide the decision makers in dealing with risk. From a company perspective, Deloach (2000) presents the Arthur Andersen business risk management process (BRMP), which is a systematic process for building and improving risk management capabilities. First, a BRMP must be established by setting the goals and objectives, a common language and the oversight structure. This is very important, because defining clearly the goals and aims of the company will determine the analogous actions and processes that are needed and a mutual understanding of RM processes will be achieved. The steps of the BRMP are:

- Assess business risks (identify, source and measure)
- Develop business risk management strategies (avoid, retain, reduce, exploit and transfer)
- Design / Implement RM capabilities
- Monitor RM performance and,

- Continuously improve RM capabilities

We can see that BRMP is similar to the previous RM processes, but it is more informative and complete. RM is a continuous process where changes are considered and procedures altered and improved. Deloach (2000) believes BRMP provides to designated processes and risk-owners a useful process for defining the important tasks for RM.

For a RM process to be both effective and efficient through all its stages where changes need to be considered, an iterative approach needs to be adopted (Figure 4.1). An iterative process involves revisiting or looping back to earlier phases to develop, refine or reconsider aspects of the analysis undertaken to date (Chapman and Ward, 2003). Thus, as analysis is undertaken and more information is gathered, new variables are considered through the different stages where all necessary information needs to be viewed and processed so the important issues are identified and managed. However, some previous assessment of the importance of identified sources is essential to guide the initial structuring, to avoid too many or too few source and response categories (Chapman and Ward, 2003). This helps in shaping an initial picture of the sources of risk a supply chain may face with the associated responses. As analysis is refined and sources are grouped more analytically, then more specialized and tailor made responses will be developed.

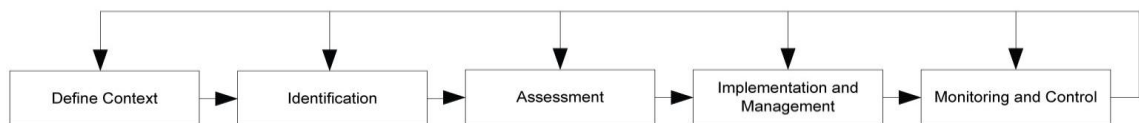


Figure 4.1 : Risk Management Iterative Process

In order for a RM process to be developed and implemented, first, company employees need to become familiar with the term risk and the RM process before they are actively involved in the process. Even if employees understand the value adding activities of RM, with no support from top management, a common RM understanding will be difficult to achieve throughout the company. Senior

management understanding and approval is needed in order to set up organizational responsibilities for managing the RM process (Kleindorfer and Saad, 2005).

The company also highly depends on the competencies of its employees in not only detecting risk threats but also developing RM plans and executing them. Therefore, the company needs to invest in its people and collaborate with risk 'aware' suppliers, so SCDM processes are effectively developed and implemented. In managing supply chain risks, leading companies (e.g. Ericsson, Dell) educate their employees and suppliers about security and resilience, in order to raise awareness and underline the importance of secure and resilient systems (Rice and Caniato, 2003a). Even if RM strategies are carefully analyzed and planned, if the employees and suppliers are unable to undertake the RM activities effectively, then the desirable outcomes won't be achieved.

Collaboration is important between supply chain entities for the identification and management of risk (Christopher and Peck, 2004). This is because companies nowadays are highly dependent on each other, and if one link in the supply chain breaks, depending on how strong the link is, it may have a domino effect on the rest of the supply chain. Having supply chain partners who also adopt SCDM will strengthen the network links and make the supply chain more robust and resilient to supply chain disruptions. If one company does not collaborate with its partners so they can identify the sources of risk and areas of concerns, then they won't be fully aware of the possible threats, having in this way an impact on the effectiveness of the RM process. Suppliers' awareness can be raised through a workshop approach in which they can gain the interest, confidence and support of suppliers (Deloach, 2000). A focal company which has an influencing power on the supply chain may be responsible to raise awareness between supply chain parties with seminars, training programs and even sending experts to the partner companies to help them to become familiarized with the RM process.

Companies usually train their employees on how to carry out an emergency response plan through in-house training and use simulations and exercises to examine and practise the emergency response plan (Rice and Caniato, 2003a;

Sheffi, 2007). Simulation, a widely used exercise tool by companies, assesses a variety of disruption scenario impacts on the company and on the whole supply chain, with company employees examining supply part availability at key suppliers, transportation providers or other 'disrupted' parts of the supply chain (Rice and Caniato, 2003a). This is a cost effective tool with which supply chain 'reality' can be moved onto a computer program and then a variety of disruption scenarios can be tested. Developing plans and then testing them as if there were a real situation provides a company with an estimation of the effectiveness of the development plans and a chance to see if its employees have the necessary skills or if more training is needed. In these emergency response exercises, suppliers and customers who have the expertise and know-how may add value and important information regarding ways to deal with possible threats. As an example, organizations such as FedEx are encouraging their employees to spot would-be terrorists and report them directly to the DHS through a special computer link (Sheffi, 2007).

Companies, in order to test their employees' skills, perform drills in a real context environment. Some companies periodically surprise local facilities and announce a 'supply network disruption drill' which includes interaction with local authorities, customers and suppliers (Rice and Caniato, 2003a). The involved parties need to be informed so they are available to perform the drill, and then coordinated, so every party contributes to the success of the drill. Then each party can assess its own effectiveness and the effectiveness of the whole drill and note any shortfalls that need to be reconsidered and re-planned.

Zsidisin et al. (2000) also suggest that if RM was taught at universities, in corporate training or elsewhere, managers would be more familiar with how to manage supply chain disruptions. Developing RM culture and awareness are both difficult and challenging tasks because managers are unfamiliar with these processes and may not even support them. Education and training must be high on the list if the companies want their managers to become familiar and enhance their capabilities on issues concerning RM.

For the SCDM activities to be developed, the input of employee experiences is required. During training, the employees need to comprehend the process and follow a systematic approach so the necessary information is obtained and the correct analysis is performed. Using formal procedures to systematically capture personal experience from a wide range of personnel can be very effective in identifying issues and potential responses (Chapman and Ward, 2003). Along with the department members that will take part in the process, senior managers and risk analysts are helpful in the implementation of it. Senior managers help empower the process by ensuring that risk analysis effort reflects the needs and concerns of senior managers and by confirming that it contains the relevant judgments and expertise of senior management (Chapman and Ward, 2003). Based on the company's strategy and the company results related to risk they would like to achieve, senior managers can monitor the process and input when their expertise and comments are needed.

To allow RM to develop in a way that suits the organization, the risk analysis team provides facilitation and modeling as well as their skills in method design, computational, teaching, and management. When the SCDM process is first developed and implemented, the input from a team of experts is required so the company can develop the appropriate methods and employees become familiar with the process. After the company is fairly confident with the procedure, the risk analysis team can monitor the process and ensure the effective implementation of it.

Based on the RM processes applied at a company level, SCDM processes can be developed that will facilitate the supply chain parties, take effective measures and make efficient decisions to manage risk while minimizing cost along the supply chain. SCDM processes have begun to be applied by multinational companies that have realized the value of knowing the sources of risks in their supply chains and developed mitigation strategies to deal with them. Dell, Toyota and Motorola are amongst companies that identify risks in their supply chains and create mitigation strategies that neutralize potentially negative effects (Chopra and Sodhi, 2004). Ericsson also has developed RM processes for minimizing risk exposure in the

supply chain. It follows the traditional RM process to consider risks along the supply chain, specifically supplier risks (Norrman and Jansson, 2004). Before implementing RM, a company needs to take into consideration variables such as the environment it operates in, its suppliers, supply chain relationships and available finances.

Following, based on the phases and activities of RM processes, the SCDM process is presented.

4.1 Define Context

As a first step of the SCDM process, the aims of SCDM analysis need to be established and understood. This phase is the foundation for the goals of RM, where all the setup of the process and integration of the management plans are established so all members are familiar with the proposed approach (Chapman and Ward, 2003). It is the stage where, based on the strategy of the process procedures, tactical plans are developed which can be implemented by the members of the SCDM process.

Tasks which may be considered during the define context stage include scoping the process (providing a strategic plan for SCDM) and planning SCDM (providing processes at an operational level) (Chapman and Ward, 2003). Thus, the tasks guide the plan for the SCDM process at both a strategic and operational level by setting the strategic plan and then in helping determine the design of the relative tactical plans. Scoping the process deals with issues such as: Who is doing the analysis for whom? Why is a formal SCDM process being undertaken (what benefits must be achieved)? It also ensures that management is aware of any limitations of the proposed analysis that may warrant further attention of immediate concern outside the SCDM process (Chapman and Ward, 2003). These questions help shape the overall direction of the SCDM process (e.g. develop RM plans for important sources of risk), identify the parties to be involved and develop the risk reporting process (e.g. engineering, business continuity, board of directors). The process tasks involve dealing with issues such as the appropriate structure and level of detail in the analysis, what type of models, methods and

software to be used and what other resources over what time frame are required so processes become operational (Chapman and Ward, 2003). The appropriate software and methods need to be adopted across the company so the analysis is performed similarly across departments and even between supply chain partners. Based on the scope of the process task, the plan the process task is developed, and as operational activities are tested and implemented, the analysis becomes more informative.

Linked to the previous scope and plan tasks, Chapman and Ward (2003) propose the issues that need to be considered before RM is implemented:

- Who wants risk analysis to support a formal RM, and who is to undertake the analysis? Identify the parties in the process
- Why is the analysis being undertaken? Clarify the process objectives
- What issues should the analysis consider? Structure the sources of uncertainty via a top-down issue appreciation
- Which way should the analysis be carried out? Select a process approach
- Wherewithal needed? Determine the resources required
- When should the analysis take place? Determine the process timing
- How might this analysis relate to later analysis in the life cycle of the RM? Assess the process strategy and plan.

The who, why and what questions help shape the scope of a process; at this stage, alterations are made until all involved parties agree so the plan for the process is developed. The which way, wherewithal and when questions help form the 'plan the process' step and develop the appropriate methods based on resources and timing. After these two processes pass through an iterative approach, they are assessed and if approved, the parties move to the 'identify phase'.

4.1.1 Product Supply Chain Design

After the scope and plan processes are developed, a map of the product's supply chain needs to be designed so that a better view and understanding of the supply chain is obtained. A holistic view of the supply chain that connects upstream with downstream suppliers can be provided, where, for example, supply processes, transportation networks and suppliers are listed. The more upstream and downstream supply chain partners the company cooperates with, the more detailed and informed is the supply chain map because it provides more information of the supply chain processes and controls. In this way, a company has a better view of the potential threats that can affect the continuity of its supply chain.

During the product supply chain design process, it is advisable for the map to include plant and inventory locations and sizing, key suppliers and customers, transportation methods, product allocation, distribution centers and sourcing arrangements (Kleindorfer and Saad, 2005; Kleindorfer and Wassenhove, 2004). This information is required so managers identify where the possible sources of risks can be located, i.e. country with political instability, inventory location that serves whole of Europe having no additional location, supplier prone to natural hazards and transportation route prone to strikes. Accordingly, they can highlight the countries, processes, locations and methods that they believe increase the vulnerability of the supply chain to disruptions.

In addition, Christopher and Peck (2004) propose identifying the critical paths (e.g. long lead times, a single source of supply with no short term alternative and linkages where visibility of supply information is poor) and pinch points (bottlenecks where there is a limit of capacity and where alternative options may not be available e.g. ports, factory). The smooth operation of these critical paths and pinch points are significant for the continuity of the supply chain because they provide little alternative if they are disrupted, leaving the company exposed until the problem is resolved. Additionally, Kleindorfer and Saad (2005) recommend listing the operational controls of the supply chain, which must also include the emergency responses. Listing where there are already risk controls helps the

SCDM members identify the possible vulnerability gaps that require RM processes.

4.2 Identification Phase

In the identification phase, after the product supply chain map is constructed and explained, the sources of risks in a supply chain are identified. Then, the level of impact of risks on both the company and the supply chain is determined at a broad level, so the decision makers in different departments and/or company levels will choose the sources of risks to be assessed during the next phase. Additionally, the identification phase also helps managers identify and classify events that are potential direct and indirect risks to the operations of the network. Following are the processes that can help decision makers through the identification phase.

4.2.1 Sources of Risks

First, a company needs to consider the range of potential risks and their possible impact on operations. Sources of risks can be related to materials as well as execution modes of the supply chain itself (Kleindorfer and Saad, 2005). Basically, sources of risks can be detected in the sourcing, production and distribution of components. Furthermore, it is important to identify secondary sources of uncertainty associated with responses by questioning how a particular response, once implemented, will affect other activities (Chapman and Ward, 2003). Each response strategy adopted may have an impact on other sources which need to be identified and considered. Thus, the links which require a systematic search for dependencies between sources need also to be tracked by posing the question: could this source initiate problems in any directly or indirectly related response? (Chapman and Ward, 2003) Sources of risks can be interrelated; therefore, interrelated risks need to be identified and understood so their importance is determined.

Additionally, identifying sources of risks depends on the level of detail the company has access to along the supply chain, which depends on the supply chain partnerships it has developed. The risk identification team should examine the

suppliers' resources, procedures and management processes and if possible, a further in-depth analysis to be carried out on the suppliers which provide the critical products (Gilbert and Gips, 2000; Norrman and Jansson, 2004). The supplier examination should be completed at the beginning of a supplier partnership, so the company is positive of the supplier's operational and financial soundness. The company, though, should perform continuous monitoring of the suppliers, so it is aware if a supplier is having problems such as production capacity.

Based on the fact that the list of risk sources may be long, it is advisable to consider risk with potentially significant impacts (Gilbert and Gips, 2000). After identifying possible risks based on their most obvious operational impacts, these risks should be carefully examined to assess their less obvious effects so that countermeasures will appropriately address all concerns (Gilbert and Gips, 2000). The company needs to investigate further than just looking for the obvious risks along the supply chain. Links between the risks should be developed, in order to capture their combined impact, which may lead to a disruption. Certain high severity risks such as economic crises or political unrest may be less obvious and this is why the SCDM process members need to be trained in identifying them.

To identify exposures, the firm must identify not only direct risks to its operations, such as the loss of a critical raw material, but also the potential causes of those risks at every significant link along the supply chain (Gilbert and Gips, 2000). Deloach (2000) proposes asking why, how and where the risks originate, either outside the company or within its processes or activities. He proposes certain procedures that will facilitate the identification of risk sources such as risk driver analyses for key risks, process mapping for key processes and environment assessment techniques (such as industry analysis, market research and competitor analysis). All these are important measures and methods that help the decision makers identify both the 'obvious' and 'hidden' risks. It is very important for the company to be familiar with the environment it operates in and the risk effects of its transactions because they may cause a disruption to the company.

4.2.2 Pathways of disruptions

The next step, after identifying the sources of risks, is to determine the pathways by which such risks may be triggered along the supply chain (Ward, 1999; Kleindorfer and Wassenhove, 2004). The pathways help detect the phases of a disruption materializing; for example, if a port closes due to strikes, a company can stock more inventory, thus it has to order more parts in. In case though the port closes for more days than initially anticipated, the company will have to find alternative methods of transport and if unavailable due to a surge in demand, then the company will need to think of an alternative plan. Thus, pathways can help determine how a source of risk can unfold into a disruption, which can assist in developing the appropriate SCDM plans.

Another way of mapping disruption sources and effects is by using influence diagrams. Influence diagrams help the decision makers represent the causal relationships among a large number of variables affecting and characterizing the system (Haimes, 1998). Haimes (1998) explains that influence diagrams facilitate brainstorming; interested parties with varied expertise develop a deeper understanding of the interactions among the important and critical variables of the system. Firstly, a 'mess chart' is produced which may include trivial and critical components, and then through an open and constructive dialogue among the decision makers, the 'mess chart' becomes a system model with only the essential variables and building blocks (Haimes, 1998). The professional view of the involved parties is pertinent in linking the sources of risks with the causes. This process also helps identify the important risks which may cause disruptions and the pathways that may be triggered, thus aiding the focus on the sources that can have a significant impact on the company and identify the gaps where SCDM procedures need to be developed.

Norrman and Jansson (2004) also propose two methods for examining sources contributing to disruption events, the fault tree analysis (FTA) and the event tree analysis (ETA), which are logic diagrams that represent the sequences of failures that may spread through a complex system. Shown on a graphical diagram that demonstrates how a system can fail, the fault tree¹ is a graphic model of the various parallel and sequential combinations of faults that will result in the occurrence of the predefined undesired event, which is the top event of the fault tree (Norrman and Jansson 2004; Haimes, 1998). A fault tree is tailored to its top event, which corresponds to some particular system failure mode, linked with the necessary and sufficiently hazardous events, the causes and contributing factors identified together with their logical relationships in backward logic (Norrman and Jansson 2004; Haimes, 1998). On the other hand, the ETA goes the other way. It is concerned with events that could take place after a critical event and identifies and quantifies possible outcomes following initiating events by looking at potential consequences. Both methods require quantitative data, such as event probability, in order to get an idea of the final probability. In the case of supply chain disruptions, working with probabilities is difficult because the probability of an event materializing is unknown due to the fact that it is most likely to be a rare event and past experience on such an event may be limited. Moreover, the estimation of which activities will be affected and up to which degree is a difficult evaluation that can be easily miscalculated. In instances such as natural hazards, political instability and economic crises that reoccur in certain regions and their effects already witnessed more than once, there may be a better estimation of the probabilities. Probabilities of supply chain effects, however, are very difficult to calculate, because variables, relationships and markets constantly change, increasing the difficulty in calculating probabilities. The FTA and ETA methods

¹ Taken from the Fault Tree Handbook written by the U.S Nuclear Regulatory Commission (1981)

provide helpful guidance to discover the pathways linking the disruptions with their sources. They also require quantitative data which are difficult to obtain, but if they are combined with other methods such as scenario analysis and simulation models, it may be possible to have a better quantitative estimation.

Another method that can be used for identifying disruption sources is the geographic vulnerability map, which links risks to geographic locations. Sheffi (2007) describes how General Motors tracks the geographic content of parts so it can understand the company's risk to disruptions in particular areas of the world. Sources of disruptions related to the geographic content are for example: floods, earthquakes, political unrest and fluctuating exchange rates. GM tracks the bill of material, which is a list of all the parts and quantities used in the production of each product, and in this way it has a holistic picture of the total exposure of the company to countries and regions. By using the bill of material, a company can easily detect where the components originate from and then link the component suppliers with the regions they operate in. With this method it's easier to recognize which suppliers operate in regions vulnerable to disruptions though it simply shows which suppliers of what parts are located in each country.

Further, Sheffi (2007) proposes a more complex version of the geographic vulnerability map which focuses on the interconnectedness of the supply chain entities. This map demonstrates the flow of parts out of given regions, depicting the suppliers involved and the plants in other parts of the world dependent on them. Such a map can help define the extent to which a flood in Brazil will affect production in Singapore or sales in Germany. Identifying geographic disruptions is effective but not for covering all types of risks. Although combining the bill of materials with the geographic vulnerability map can help in identifying sources of vulnerability and linking their effects, they only cover the geographical effects (which production plants will be affected in another country) and neglect effects such as fires, terrorist attacks and diseases, which are not highly related to the geographic positioning of the supplier.

The methods previously presented can be used in linking the sources with the consequences of disruptions. The decision makers must be aware of the kinds of

disruptions that are linked with the processes and controls of the supply chain. Additionally, the employees' inputs from the company and the supply chain are important in determining the pathways and the interdependencies between the different kinds of disruptions. It is advisable to examine only the key processes that could significantly be affected by disruptions and to characterize the facilities, assets and human populations subject to disturbance (Kleindorfer and Saad, 2005; Gilbert and Gips, 2000). Identifying the processes, facilities and stakeholders affected provides a holistic picture of the magnitude of a disruption and the pathways it can materialize.

After developing the supply chain map with the required information on operations, capacity, emergency response systems and transportation methods, the sources of disruptions are identified and the possible pathways that connect the sources with the events of disruptions are highlighted. Attention should be given to high impact risks and critical processes for the continuity of the supply chain. The identification phase requires time and resources from both the company and the suppliers. It forms the basis for the SCDM process, and if not performed correctly, it will affect the rest of the SCDM process. Thus, the participating parties need to cooperate, collaborate and be committed in order to complete the steps of the identification phase as effectively as possible.

4.2.3 Detecting Disruptions

Detecting a disruption is challenging; disruptions do not always look as threatening as they actually are and sometimes companies take some disruption warnings more seriously than they should. Detecting a disruption means distinguishing a true potential problem from the sometimes considerable variations of daily business activities (Sheffi, 2007). The focus should be on separating the 'abnormal' activity from the 'normal' baseline activity such as deciding which containers should be checked at the port, or which natural hazard warnings are most reliable to consider. Sheffi (2007) suggests that the tools to develop such 'sensing' are based on statistical process control, but when dealing with the potential of an intentional disruption, such as terrorism or sabotage, detection must be complemented by trained human screeners who can review

suspicious outliers. Similarly, Mitroff (2001) also proposes to place ‘Signal-detection mechanisms’ that will be operating before a crisis impairs supply chain activities. Thus, the system will need early indication signals of possible dangers to the company with the necessary responses. Trained staff, formal detection processes (i.e. statistical) and plans are required if the detection of disruptions will be successful and not misleading.

Mitroff (2001) argues that the best prepared companies do not look at individual crises in isolation, but attempt to view how different crisis interconnect in an overall system and if they create additional ones. Causality and a holistic view must be sought between the different sources of disruptions along the supply chain. Usually risks are combined with other sources of risks and this connectivity must be understood before detection plans are developed.

4.2.4 Categorizing Sources of Disruptions

There are many sources of disruptions that can affect supply chain continuity arising from sources both within and external to the supply chain (Wilson, 2007). In order for a company to be knowledgeable of the possible sources of disruptions it can face along its supply chain, it can categorize them based on disruption types and identify more easily which sources of disruption are linked to each category. After grouping different disruptions, response scenarios can be developed that are suitable for each group by also identifying the relevant people responsible to mitigate the risk and develop contingency plans. Moreover, it helps the operators of a risk register group the potential disruptions they identify into predetermined categories, keeping in this way a consistent categorization system. Depending on the company and the operations it is engaged in, different categorization disruption types can be applied.

Rice and Caniato (2003a) categorize sources of disruptions by failure mode because there are unlimited sources of disruption, but relatively few failure modes. These failure modes are categorized as disruption to supply, transportation, facilities, communications and human resources which can be translated into the basic activities of a supply chain. In a supply network, there can

be numerous sources of disruptions but the critical processes and activities affected by these sources in the network are much fewer. They argue that categorizing by failure mode facilitates action for the important disruption sources and gets the organization moving towards an appropriate response. By knowing the failure modes, a company can identify the sources that lead to them. Thus, categorizing disruptions by failure mode follows a backward logic that leads from risk consequences to risk sources.

Similarly, Mitroff (2001) argues that disruptions fall into ‘families’. For instance, there are economic, informational, physical, human resources, reputational and natural disaster disruptions. Although within a particular family each type of disruption shares strong similarities with other types, at the same time, there are sharp differences between the families. This is because the consequences of different types of disruptions in the same family affect the same activities, be it economic or human resources. For example, economic risk sources are linked with economic crisis, currency fluctuations and competition, and human resources risk sources are linked with employee performance, recruiting and pilfering. Sometimes, though, sources of risks may affect a number of families and be included in, for example, two or three families such as strikes, which can be placed in the economic, human resources and reputational categories and fires within the physical and natural disaster categories. A way to deal with this is to place the source of disruption in the category that reflects it best; for example, strikes in the human resources category and fires in the natural disaster one. In addition, these categories can be better classified including, for example, both supply and transportation disruptions, so more possible disruption sources can be identified and distinctions between these categories better defined with no confusion.

Mitroff (2001) argues that organizations which prepare best for crises attempt to prepare for at least one crisis in each of the various families. This is because any type of crisis in one family is capable of sparking another type in another family. By implementing this strategy, the company may be protected from certain types of disruptions, although it cannot be protected from all disruptions lying in the

same category. The organization needs to consider which are the high impact risk sources, identify how they can interrelate and then develop appropriate risk mitigation strategies, so that important risk sources are mitigated.

Christopher and Peck (2004) follow a different categorization and suggest three basic categories of supply chain risk, which can be further subdivided to produce a total of five categories. This classification is based on the stakeholders involved and the control level the company and the supply chain can have over the drivers of risk. So risks are categorized, as risks *internal to the firm* (process and control), *external to the firm* but internal to the supply chain network (demand and supply) and *external to the network* (environmental). The risks internal to the firm are divided into processes and controls. Processes are the value adding and managerial activities that the firm performs and process risk is the disruption to these processes. Controls are the rules, systems and procedures that an organization uses to exert over the processes. These can be economic order quantities, inventory control levels, safety stock policies and procedures that govern asset and transportation management. Then, demand and supply risks are associated to the internal supply chain network. Demand risk in the supply chain is usually between the focal firm and the market. It relates to potential or actual disturbances to the flow of product, information and in this instance cash emanating from within the network. Supply risk, on the other hand, is between the focal firm and the upstream firms in the supply chain. It relates to potential or actual disturbances to the flow of product or information emanating from within the network. Finally, environmental risks are those generated external to the network. Severe weather conditions have an impact on the focal firm or on upstream or downstream suppliers and on the marketplace itself. By referring only to the environmental aspect of the risks external to the network, they exclude a number of other risks that may arise outside the supply chain such as war, terrorism and economic crises. Although these classifications divide the supply chain risks into families, they are very broad because each category may have different types of risks; for instance, the supply risk may have supplier issues and transportation problems. Though the categorization is helpful, it would be better if the basic categories had more detailed subcategories.

There has been a variety of categorizations of supply chain disruptions, based on failure modes or risk families. Derived from these, categorizations of disruptions a supply chain may face are presented:

- Operational Disruptions
- Disruptions Internal to the Supply Chain, and
- Disruptions External to the Supply Chain

The purpose of this categorization is to help decision makers, during the risk identification phase, identify the sources of disruption the company may face in its supply chain and then link them to distinct categories of failure modes. Although there may be a long list of disruption sources, a way to catalogue them is by determining the failure mode and the sources of disruptions linked to it. This categorization is based on the stakeholders involved in each category and the level of control over the sources of disruptions the company and the supply chain may have. Stakeholders may be employees, shareholders, customers, distributors, retailers, manufacturers and unions that can be affected when a risk materializes. Important stakeholder relationships must be nurtured over the course of years if a company is to have the capabilities that are required in the heat of a major crisis (Mitroff, 2001). The stakeholders must cooperate and collaborate in order to be able to manage risks that may affect them.

Operational disruptions are factors that can affect the daily operations of the company and if not managed and controlled, can expand outside the organizational boundaries, affecting with a high impact the supply chain. The failure modes can be in production and human resources, and the risk causes may be equipment breakdown, production delays, security breach, employees leaving and inventory shortage.

Disruptions, on the other hand, are events that do not occur normally in the daily activities of the supply chain and can affect the continuity of the supply chain; they can be categorized as internal or external to the supply chain network. Internal disruptions are those generated within the supply chain network, affecting

the organizations of the supply chain. Relevant stakeholders include suppliers, customers, transportation companies and unions. Failure modes may be transportation or supply disruptions and causes can be computer virus attacks, transportation limitations, strikes, system failures, and demand and supply variations. Additionally, there may be financial failure modes and the risks can relate to suppliers' bankruptcy, financial stability, capacity constraints, quality risks, single source dependency and inventory shortages. External disruptions differ from internal ones because they are caused by external factors (natural, man-made) to the supply chain network which the supply chain cannot control; they arise from the interaction of the supply chain with its external environment. Stakeholders may be supply chain organizations, governments and banks. Failure modes may be economic, environmental and facility disaster and the risk sources can be political and legal instability, economic crises, hurricanes, terrorist attacks and diseases.

By placing the failure modes in three broad categories, it's easier to link the sources in each category with the failure modes and also identify who the responsible parties in each category are. So, for equipment breakdown the company engineering employees are usually involved, but for transportation problems, the company, the logistics provider and the transportation company are involved. By identifying the involved parties they can then collaborate and coordinate to work out appropriate risk management solutions.

4.3 Assessment Phase

The assessment phase is the next phase of the SCDM process, where supply chain risks are assessed so the company can decide on suitable safeguards (Bandyopadhyay et al., 1999). At this stage the RM teams classify risks and decide for which risk types responses are advisable to develop. This is achieved by estimating the likelihood of each type of risk occurring and assessing its potential impact (Tang, 2006b). Due to the fact that a company cannot deal with all possible risks, it needs to assess for which type of risks the company prefers to develop SCDM plans.

No formula determines how much risk an organization should accept; it depends on the company's tolerance level and the risk taker's behaviour (Gilbert and Gips, 2000; Zsidisin et al., 2000). Companies with varying risk tolerance levels and risk behaviours (risk averse or risk taker) regard differently the severity of different types of risks; depending on the nature of their business, their objectives and the risk philosophy approach in the company and supply chain. For example, a fire at a first-tier supplier may be regarded as a less serious source of disruption for a company that sources multiple suppliers for a component kept in two-week safety stock than for a company that single sources a critical component and applies lean practices with no safety stock.

In order to calculate the likelihood, the duration and the potential consequences of an event occurring, the RM team must decide which method (quantitative or qualitative) is most appropriate. This depends on the team's judgment, availability of data and experience. When probabilities can be estimated Kleindorfer and Saad (2005) suggest using probabilistic risk assessment fault and event trees as well as decision analysis. Decision Trees are helpful and popular to use because they rely on an integrative approach of graphical and analytic presentations which are descriptive and simple to understand (Haimes, 1998). Haimes (1998) further highlights the need to perform a sensitivity analysis which relates to changes in the system's performance index to possible variations in the decision variables, constraint levels and uncontrolled parameters. Variables, parameters and constraints constantly change and the RM decision makers must be aware of the range of these changes that the system can accept and the effects they may have on the whole system and RMP. These business models require quantitative data and can be processed along with sensitivity analysis using simulation software and backed up by judgmental assessments. Simulations can be used for learning about the nature of potential hazards and as a training device for a number of response contexts (Borodzicz, 2006). It helps the SCDM members view how a source of risk may develop and its potential consequences, thus helping them decide which sources of disruptions the company is best to mitigate. Further, the pathways determined at the risk identification phase can be used for the probabilistic calculations required, from a source of risk to its possible effects.

For methods for assessing risk which depend on past experience, the required data may not have been collected, may not exist in sufficient quantity or detail or may not have been recorded accurately or consistently (Chapman and Ward, 2003). Companies, although incurring certain disruptions, cannot estimate the numerical impact due to missing information which disables the company to estimate possible consequences. In such situations, quantification may need to depend on subjective estimates of probability distributions (Chapman and Ward, 2003). Although experience may be a useful tool for estimating the likelihood and impact, the results may not be reliable and the scenarios developed, misleading. Additionally, it is very difficult to estimate exact probabilities and therefore, looking at different scenarios by using probabilities is effective in estimating how severe and critical a source of risk is.

Assessing the likelihood of an earthquake or flood can be calculated from publicly available data (Sheffi, 2007). The repeatability of certain types of disruptions such as natural hazards can be used to assess quantitatively the likelihood and the impact of a source of disruption on the company. This is because data and prior experience, which the development of quantitatively systems highly depend on, are available. The likelihood of large scale accidents can be developed and updated from incidents of near misses together with industry-wide data, about the interactions between near misses and significant disruptions. These data provide guidelines on the probabilities and impacts a large scale accident may cause.

Intentional disruptions, though, require a different type of assessment since business actions may affect the likelihood of occurrence. The assessment of such disruptions requires imagination (using simulations and 'war games') and monitoring of relevant events at other companies. The use of probabilities in such cases is not beneficial because not only are they very difficult to calculate but also the impacts are very difficult to estimate. Qualitative data and scenario planning backed up with simulation modelling and contingency planning are possible ways to mitigate possible impacts.

Due to the fact that disruptions are usually unpredictable, unless they are reoccurring events, the probabilities are unknown. Good estimates of the

likelihood of occurrence of any particular disruption and accurate calculation of possible impact of each disaster are difficult to acquire (Tang, 2006b). Thus, the majority of the tools and techniques proposed are descriptive and qualitative in nature and there are very few tools based on mathematical techniques. When probabilistic estimates are difficult to calculate, worst-case analysis and contingent response scenarios may be used, (Grossi and Kunreuther, 2005; Kleindorfer and Wassenhove, 2004). These are performed through group discussions and cost / benefit analysis. For the group discussions Deloach (2000) proposes to ask questions such as: How big are our risks? What is the impact on capital, earnings, cash flow, other key performance indicators, and reputation? How likely to occur are the possible future outcomes that give rise to the risks? These are examples of the questions that can be used in order to facilitate discussion and realize the severity of the sources of risks.

Cost / benefit analysis is used in both quantitative and qualitative methods and is a useful method in helping to decide if it's worth investing in an activity or not. With cost benefit analysis the total cost of a disruption occurring is evaluated in comparison to the net benefits realized from having strategies in place that significantly reduce the chance and/or effects of detrimental events within the supply chain affecting the company (Zsidisin et al., 2000). In quantitative models it is much easier to calculate this because the required data, which can be presented in mathematical results, are most likely to be available. With qualitative data a subjective estimate is used; this may be based on numbers but mostly is based on group discussions and past experience.

The most risk efficient plan for any given level of expected cost will involve the minimum feasible level of risk, and the most risk efficient plan for any given level of cost risk will involve the minimum feasible level of expected cost (Chapman and Ward, 2003). Risk efficient choices involve finding the best possible RM plans regarding the desirable level of risk and the available company funds. There may be more than one possible management solution for a relevant risk; it is best for the company to choose the most risk efficient plan regarding the level of risk it is willing to accept and the level of investment for mitigating that risk.

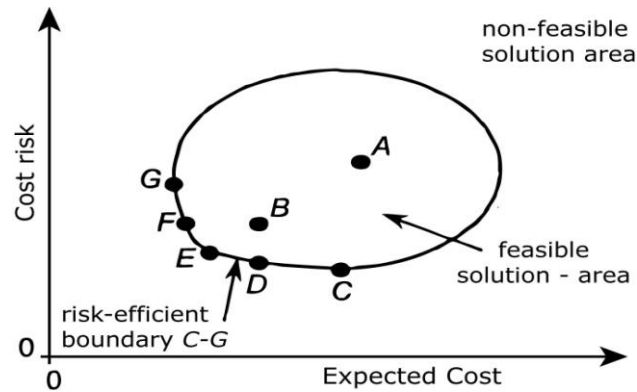


Figure 4.2 : Risk Efficient Options

In Figure 4.2 curve C-D-E-F-G portrays the ‘risk efficient boundary’, which provides a minimum level of cost risk for any given level of expected cost and points inside the boundary, like A and B, represent risk inefficient plans (Chapman and Ward, 2003). The points along the risk efficient boundary are the best possible choices a company may follow to mitigate a given level of risk or having a predetermined level of investment. Point G represents the minimum expected cost plan, with a high level of cost risk despite its risk efficiency and point C represents the minimum cost risk plan, with a high level of expected cost despite its risk efficiency (Chapman and Ward, 2003). The choices depend on the available company resources and the company’s risk tolerance level and how critical a source of risk is. If an organization can afford to take the risk, G is the preferred solution, but if the risk associated with G is too great, it must be reduced by moving towards C (Chapman and Ward, 2003). Thus, for critical risks, choice C is preferred because investments are required for the mitigation of risk. RM decision makers need to understand and calculate the trade-offs between the risk and the cost of mitigating it (Chopra and Sodhi, 2004).

A risk assessment process requires skillful risk owners, a common risk language and knowledgeable assessors (Deloach, 2000). It is beneficial to involve representatives from internal departments, suppliers and even specialist consultants who have relevant experience and who are also familiar with the assessment methods used. Their contribution to estimating risk and developing

disruption scenarios is valuable and the cooperation between them can unfold scenarios that are crucial in determining risk severity.

4.3.1 Ranking and Prioritization

After assessing the likelihood and level of impact of risks, it is useful to categorize and prioritize them, so the company is aware of the sources of risks it prefers to mitigate. There are threatening sources of supply chain risks that require immediate action and there are sources of risks that, although they may not seem originally threatening, may impact the company if they are triggered by a certain event or interact with another source of risk. In order for the company to be aware of the severity of supply chain risks, it needs to rank them, and based on their ranking, prioritize the risks which require SCDM plans.

Probability / Impact Matrix

The most popular method applied by companies in categorizing and prioritizing risks is the risk probability / impact matrix. Once risks are assessed in terms of their business impact and likelihood of occurrence, they are placed on a risk map matrix. It helps the SCDM decision makers categorize risk and then based on the company's know-how and risk tolerance level, decide on which risks it is best to focus. Norrman and Jansson (2004) believe it is a subjective process relying on specialists' judgments. In addition, Chapman and Ward (2003) state that qualitative statements of beliefs about uncertainty are of limited use and are open to different interpretations by different people. The probability / impact grids are a basic technique that categorize risks simplistically based on experience and judgments, and can be used as a starting point for further assessment, which may include numeric representations so more reliable results can be generated. A probability-impact matrix can help guide an initial 'first cut' at response development; in order to understand and assess the real importance of risks, it is best to use further iterative analysis which explores structural linkages and responses in more detail (Ward, 1999).

Risk matrices may be developed by business unit, by business process or even by major risk category (Deloach, 2000). Measures can also include impact on business objectives, failure modes and key processes affected. The decision makers need to be familiar with the measure they are using and the usefulness of the particular measure for concluding on how to rank a risk. If the measure chosen is not appropriate for risk assessment, not only will the categorization be misleading, but also the risk mitigation strategies developed may not be suitable. After risks are placed in different categories, their impacts on the measures selected are ranked based on their short, medium and long term effects. Such matrices help highlight the relative exposure to risks, leading companies to concentrate on the disruptions they may be most vulnerable to (Sheffi, 2007).

Deloach (2000) states that there are a number of benefits that risk matrices offer: focus on the most important risks which can then be measured with more accurate techniques, a focal point for developing risk strategies, aligns the achievement of business objectives with the management of risks, decreases the likelihood that important risks or opportunities are overlooked and provides a template for aggregation of risks across the firm. The risk matrix helps decision makers identify and focus on the sources of disruptions that are threatening for the company in a number of ways (e.g. finance, operations, supply chain), then these sources are assessed with more accurate methods and then corresponding strategies are developed. If in the identification phase the right measures and rankings are used, the chance of overlooking a risk diminishes. This can also be checked when all risks are grouped together, identifying if certain risks haven't been considered.

Although the risk probability / impact matrix may be widely used and easy to understand, the level of its usefulness has been criticized. Norrman and Jansson (2004) have concluded that the 'risk value' (multiply impact with probability) is not always easy to use, as the probability could be difficult to get and the value is not always 'understandable' to business people. The value is represented by a number which hasn't got detailed explanations of what the number represents except the severity of the risk in regard to other risks. Especially when the

probability is not known and is estimated based on qualitative measures, its accuracy is questionable. Even when a risk is placed in a certain box (e.g. failure mode category), it's difficult to clarify which risk between two categories is most important because there may be more than one box that have the same number allocated but differ in probability and impact numbers. Thus, understanding the value and importance of each risk is subjective. Using the risk map for risk assessment will to some extent be subjective and the degree of uncertainty that surrounds the estimation of the impact of different kinds of risk is unlikely to be uniform (Pickford, 2001). It is advisable that risk matrices are used as a general guidance tool so decision makers have a visual presentation of the range of supply chain risks a company may face.

Norrman and Jansson (2004) present Ericsson's risk matrix. First, the financial impact of a risk is calculated based on the business interruption value (BIV). BIV equals the gross margin multiplied by the 'business recovery time' (BRT) plus extra costs such as idle capacity, labour and equipment and inventory transportation. BIV is divided into four classes:

- (1) Severe: BIV, greater than \$100 million.
- (2) Major: BIV, \$50 million-\$100 million.
- (3) Minor: BIV, \$10 million-\$50 million.
- (4) Negligible: BIV, smaller than \$10 million.

This categorization is then used as a basis for the risk matrix and with the probability of occurrence, the impact if an interruption occurs is classified as very high, high, medium or low. For each of these risk levels, different actions are required. Presented in Figure 4.3, the unlikely likelihood – severe impact risks are categorized as the same with the almost certain likelihood – minor impact risks. Although they are classified as having the same impact on business, the RM actions needed defer considerably. In Figure 4.3, though, we do not see this distinction and only propose actions based on the degree of risk. General guidelines are provided, but a further categorization depending on the types of

risks should be performed so that the company can then develop risk mitigation plans.

Probability	Almost Certain	MEDIUM	HIGH	VERY HIGH	VERY HIGH	DEGREE OF RISK	RISK LEVEL	ACTION REQUIRED
	Likely	MEDIUM	HIGH	HIGH	VERY HIGH	VERY HIGH	Red	Risk mitigation required to level medium or low. If the risk is not mitigated monitoring and making a Contingency plan I required.
	Unlikely	LOW	MEDIUM	HIGH	HIGH	HIGH	Orange	Risk mitigation required to level medium or low. If the risk is not mitigated monitoring and making a Contingency plan I required.
	Rare	LOW	LOW	MEDIUM	HIGH	MEDIUM	Yellow	Risk mitigation to level low is optional, monitoring required.
		Negligible	Minor	Major	Severe	LOW	Green	No further risk mitigation is required.
	Consequence							

Figure 4.3 : Ericsson Risk / Impact Matrix

Depending of what type of risk/impact matrix the decision makers decide to adopt (qualitative or quantitative), they need to carefully consider in which quadrant they place the risks. Typically, companies arrange workshops or seminars involving multidisciplinary teams for risk mapping, where decision makers interact, debate and share information until a facilitator (good knowledge of the company’s industry) brings the process to an agreement (Deloach, 2000). Sometimes, however, consensus is not possible, which indicates there are concerns as to the degree of the exposure and/or extent of the uncertainty. This is why it is very important that the procedures and methods proposed during the assessment phase need to be implemented correctly, so the decision makers obtain a good understanding of the risk effects. Risks that are considered harmless can develop to become threatening for the company and its supply chain. Decision makers need to have this in mind before implementing a SCDM action; what processes will be affected negatively and if these raise any issues of concern, they need to be minimized to an acceptable level.

4.4 Implement and Manage

After the assessment phase, sources of risks which require further actions need to be managed. Two key dimensions which can be applied for managing sources of supply chain disruptions are: (a) strategy and action planning to reduce the frequency and severity of risks at both the company and the supply chain and (b)

increasing the capability of supply chain participants to sustain/absorb more risk without serious negative impacts or major operational disruptions (Kleindorfer and Saad, 2005). When deciding on the RM strategies to adopt, the RM members will choose those that reduce the level of risk but also do not cause severe negative consequences on other parts of their business. Additionally, the strategies the company will be developing need to increase the robustness of the company and even that of its supply chain partners, by also decreasing the company's vulnerability levels.

4.4.1 Risk Management Actions

Following the identification of sources of risks the company chooses to manage is the development of the appropriate RM actions for these sources. Managing supply chain risk is challenging because individual risks are often interconnected and actions that mitigate one risk can end up exacerbating another or excluding each other (Chopra and Sodhi, 2004; Chapman and Ward, 2004). Due to this interconnectivity of risks, before implementing management plans, the company must decide what type of risk management actions it will follow and the benefits of these. Further, economies of scale or synergies between possible responses that offer opportunities for further improvements in performance may be identified (Chapman and Ward, 2004). Having similar responses for a group of risks helps optimize cost effectiveness of the RM plans. The possible RM actions a company may choose from are classified into avoid, mitigate, transfer, or accept, where each action is a different approach to the management of risk.

Avoid

The avoid action prevents a company taking a risk that has no potential for benefit or removing the types of events that could trigger the risk (Borge, 2001; Norrman and Jansson, 2004). This is succeeded, for example, by terminating a contract with a supplier in a political unrest country and cooperating with more reliable suppliers, changing or avoiding transportation routes where strikes are often evident and avoiding entering into a market where legislation for a foreign company is unfavourable. These examples demonstrate that the avoid action is an

action that offers two alternatives: either withdraw from a current situation already engaged in where the costs are much greater than the benefits, or pull out if considering entering into an activity where it increases the sources of disruption with no financial or long-term gain.

Mitigate

With mitigation, actions are implemented that will reduce the impact and probability of an event occurring. Probability could be reduced by improving risky operational processes both internally and in cooperation with suppliers, having risk managers and emergency teams appointed and to improve related processes, e.g. supplier selection (Norrman and Jansson, 2004). Risk mitigation needs to be embedded in company and even supply chain activities and processes, so proactive handling of risks is achieved. Developing a risk mitigation culture along the supply chain reduces the probability of a risk materializing considerably. Zsidisin et al. (2000) propose improvement activities such as: forming alliance relationships (working with suppliers on mitigating risk); having suppliers responsible to develop risk mitigation plans; maintaining common platforms for products; establishing both direct access to 'brain ware' of suppliers and industry standards. Likewise, Zsidisin et al. (2000) propose buffer activities such as developing multiple sources for strategic items and holding safety stock.

Transfer

The transfer action is chosen when the company decides to transfer the risk partially or fully to another party more suitable to manage it, usually a company with specialist skills in that particular activity (Pickford, 2001). Usually risk is transferred to insurance companies, supply chain partners (VMI, outsourcing) and customers (make-to-order manufacturing) (Norrman and Jansson, 2004). The risk can be transferred in different ways to suppliers or customers but continues to be present in the supply chain. Uncertainty may not be eliminated for the transferor, unless the party receiving the uncertainty adopts appropriate RM strategies, and the consequences may include secondary sources that fall on the transferor (Chapman and Ward, 2003). The company needs to transfer the risk to partners

that have the necessary capabilities to handle it so it does not affect the company operations. If liability for an unquantifiable potential loss is simply shifted on to a weaker party, who may subsequently fail, then the risk has not been transferred but simply shifted off the balance sheet (Peck, 2006).

A method widely used by companies to transfer risk is insurance; although it can provide financial comfort to a company in the case of a disruption, it can't protect the company from the portion of business lost while inactivate or from the bad reputation it may earn due to the lack of the procedures it should have had in the event of a disruption. Thus, companies shouldn't fully rely on insurance because it can't cover by itself the company's reputation and business operations in case of a disruption. The company is still liable for having controls in place to manage the RM plans.

A risk can be partially transferred to other suppliers and/or customers so the consequences of a disruption won't affect only the company. By sharing risk, the parties involved are more interested in RM strategies than if they weren't involved in the process. Risk sharing is essential when building strategic production networks because it encourages trust between supply chain partners, maintaining in this way the effectiveness and long-term viability of the network (Jarillo, 1988). Peck (2006) proposes certain sharing actions which include VMI, inventory pooling of high-value items (e.g. capital equipment spares) and forecasting. Involved parties need to clarify the roles of each party and the procedures that need to be in place so they can perform the operations jointly. If one part does not perform to the expected level, then the risk prevention strategies won't be highly utilized.

Accept

With the accept action, a risk is accepted by doing nothing about it (Chapman and Ward, 2004). With the accept action the organization does nothing, usually concerning very small negligible risks that have a small impact and investments to deal with them are inefficient. There are also risks in attractive opportunities where the organization can benefit from them because the potential gain

outweighs the risks (Borge, 2001). In the situation when a risk can provide more benefits than negative outcomes, the company may consider accepting it. For example, continuing with a current supplier that, although bankrupt, will be purchased by a bigger global company.

A description of each RM action has been presented, along with the situations they best suit. Although they are four distinct actions, there is an interrelation between mitigate and transfer activities. Strategic stock (e.g. pooling resources with suppliers) and types of supply chain visibility (e.g. collaborative planning and forecasting) can be included in the RM actions of mitigation and transfer. Hence, there are interrelations between the mitigation and transfer actions, where supply chain members collaborate for the reduction of the probability of a disruption occurring. A systematic examination of a range of possible responses with a view to applying several responses in parallel may be helpful (Chapman and Ward, 2003). More than one action may be applied for critical sources where responses need to be robust and even flexible, for instance, the potential of a flu pandemic, where the risk needs to be transferred to government agencies but also the company needs to mitigate the potential effects it may have on company operations.

4.5 Monitoring and Control

Monitoring is a flexible and creative proactive task for understanding what is happening in real time in relation to what was planned, anticipating future deviations from plans and initiating all necessary revisions to earlier plans (Chapman and Ward, 2003). Monitoring and control is the supervision of the effectiveness of the SCDM process, which identifies adjusted changes that need to be made in relation to defined goals. It's an ongoing process where changes when needed are implemented either when the RM strategies are altered or there is a deviation from predetermined goals. The monitoring and control phase, involves very important informal monitoring as well as formal monitoring and change control processes at various levels, and is about making decisions by collecting and updating data about probabilities of occurrence, anticipated effects and

additional sources of uncertainty (Chapman and Ward, 2003). It ensures that the monitoring phase is based not only on judgmental assessments but also on formal processes so the ongoing progress of SCDM is continuously updated and reviewed, so changes are managed, depending on the targets and the new information obtained.

Deloach (2000) suggests that reports on the most important risks should include lists of key risk drivers and relevant key performance indicators as well as progress reports on RM strategies. This helps in tracking the effectiveness of the RM strategies for key sources and in tracking the performance of the strategies against pre-determined performance targets to spot where changes need to be made. Chapman and Ward (2003) propose using an update of the classical statistical control chart (plotting actual outcomes within pre-plotted confidence bands) by plotting actual outcomes (in cost, duration, or other performance terms) in relation to the pre-plotted target, expected and commitment values. This is a helpful method in identifying processes that do not perform as planned and also those in the boundaries that can be further improved.

The monitoring and control process continually assesses existing and potential exposure, which includes reporting, periodic auditing, management and legal reviews of implementation plans and on-going results (Bandyopadhyay et al., 1999; Kleindorfer and Saad, 2005). How often risk sources are monitored depends on the severity of the risk, but higher level risks are best monitored more often than lower severity risks. Norrman and Jansson (2004) propose which kinds of risks are more appropriate for monitoring: (1) if the risk level is very high, or high and not mitigated, (2) if the residual risk, after mitigation, is not reduced to an acceptable risk level. Further, sources of risk regarded as 'not threatening' but, due to a change i.e. in supplier contracts, legislation and company strategy, have advanced to potential threats, also need to be considered during the monitoring phase. Monitoring helps identify how risk sources are developing and if any changes in their risk mitigation strategies need to be applied. If the monitoring phase isn't performed correctly, the company won't be fully aware of the SCDM

process outcome and the potential changes it has to make in order to respond to emerging and changing challenges.

4.6 Barriers to a Formal SCDM Process

Although developing SCDM processes can be both beneficial for the company and the supply chain, managers are reluctant to deal with supply chain disruptions. Managers' attitudes towards supply chain disruption are recorded in a number of different empirical studies. Tang (2006b) presents results from two studies. The first study was conducted by the Computer Sciences Corporation in 2003, where 43% of 142 companies, ranging from consumer goods to health care, reported that their supply chains are vulnerable to disruptions and 55% of these organizations have no documented contingency plans. The second study is a survey conducted by CFO Research Services, where 38% of 247 firms recognized that they have too much unmanaged supply chain risk. In another study conducted by Zsidisin et al. (2000), although most of the purchasing professionals expressed the need of their companies to have greater involvement in SCDM, many of them invest little time or resources pursuing these activities. Zsidisin et al. (2000) identify reasons for this, such as return on investment and lack of knowledge and experience about these activities. Additionally, if a risk never materializes it becomes difficult to rationalize the time and resources spent on RM. For this reason, purchasing professionals may be more willing to engage in familiar activities than to spend time on evaluating worst-case scenarios which they are not familiar with or are reluctant to think about.

Based on case studies conducted by different researchers, Tang (2006a) concludes that most companies invest little time and/or resources for SCDM. One reason is that estimating the likelihood of a certain disruption and the impact of it are difficult to calculate. Working with unknown probabilities and possible impacts renders the exact calculation of a disruption impossible. This makes managers unwilling to invest in activities where the outcomes are unknown and the investments unjustified.

Managers avoid spending time and resources on RM because organizations usually reward managers for good outcomes but usually not for taking good decisions (Tang, 2006a). If managers invest in SCDM actions and this shows as expenditure for the company with no apparent rewards of their actions, they will not be credited by the company as they would if successfully introducing a new product into the market. If a manager implemented a set of effective procedures in the case of a supply chain disruption, these would only be validated in the event of a disruption. As a result, managers usually overlook unlikely disruptions because, as Repenning and Sterman (2001:81) stated, 'nobody ever gets credit for fixing problems that never happened'. Sheffi (2007) argues that it is difficult to measure the economic benefits of cost avoidance, because avoided disruptions do not show up as revenues, profits, assets or in any other form on the company's financial statements. The only thing that shows is the cost associated with disruption avoidance. Disruptions, though, do materialize and can be quite damaging. This is why it's pertinent that top management supports RM actions, by both recognizing the negative economic effects of a disruption and realizing the exposure and damage to the company from such an event.

Rice and Caniato (2003a), based on a broad range of responses from the 'Response to Terrorism Study', concluded that most of the twenty companies in the study, with operations in the U.S. from high tech and aerospace to pharmaceuticals and consumer package goods companies, were reactive, meaning that the actions taken were in response to government regulations and other mandates. Legal requirements such as the Sarbanes-Oxley Act 2002 in the U.S. have forced companies to become more risk aware and develop RM processes. If these regulations weren't in place, the companies may not have even considered applying RM practises. In a few case studies, however, Rice and Caniato (2003a) observed companies polishing and refining their supply network for security and resilience. These were companies that had already experienced a disruption and understood the importance of having RM actions in place. Zsidisin et al. (2000) also concluded that it is more likely for purchasing organizations that experienced a supply risk to conduct supply chain risk management than those that haven't experienced such problems.

Rice and Caniato (2003a) characterized the companies that take RM actions as leaders because they have the ability to learn from experience and take the necessary actions to make their supply networks both resilient and secure by emphasizing supply chain collaboration, intensive training and education and sound strategy development. Further, companies that implement RM processes can enhance their reputation, facilitate their insurance coverage and have better legal protection (e.g. due-diligence). Moreover, SCDM enhances networking and collaboration with the supply chain partners, thus increasing the efficiency and the effectiveness of the supply chain network. It is important to involve in the process representatives from all internal departments, suppliers, customers, intermediaries and unions. These groups are interested in the continuity of the supply chain and will be willing to contribute towards the SCDM process.

4.7 Conclusions

The SCDM processes proposed are based on SCM and RM literature. These two bodies of literature combined provide useful insights for the development of the SCDM processes which help increase the robustness and resilience of companies in the presence of supply chain disruptions. This is because RM provides the formal models, techniques and tools that can be followed based on each phase, and SCM the strategies that can be developed to handle proactively sources of disruptions along the supply chain.

From the literature it can be concluded that most companies do not follow formal proactive SCDM processes that help reduce their vulnerability to supply chain disruptions, but are implementing SCM activities (e.g. VMI, inventory pooling and multiple suppliers) which also help reduce risk. A formalized procedure though, does not only increase the awareness of the possible supply chain risk threats a company may face, but also guides the decision makers in developing risk efficient plans.

The SCDM processes although formal, are flexible because each company based on its supply chain operations may choose the tools and techniques that are best suited for each phase. Also, the information availability and personnel experience

are important on how the SCDM processes will be analysed and undertaken. This is because employees and top management are a very important factor for the successful implementation of SCDM processes who are the driving force on how SCDM will be developed and which are the necessary procedures that need to be followed at an organization-wide level. Thus, the development of a RM culture in the company and the training of employees are pertinent, if the SCDM processes will be developed and implemented successfully.

5 Research Methodology

SCDM is a research area that covers and interconnects the areas of SC, SCM and RM. Thus, when conducting the literature review, reading material from these areas was considered helpful in understanding the concepts and issues related to SCDM. Key Words that were used in the literature search engines were risk, risk management, disruption, supply chain management, and supply chain disruption. After identifying certain useful papers (e.g. Tang, 2006b) and books (e.g. Sheffi, 2007) related to SCDM, it was then easier to identify additional journals and books that were related to the research. Also, when identifying a paper the quality of the journal was also considered, but this was not a determining factor when a highly related paper to SCDM with helpful and useful insights which could inform the research, was identified and classed as important.

The literature review was also important in understanding issues and practices adopted by the case study companies, and also in highlighting useful issues to be discussed during the interviews such as risk and disruption perceptions, supply chain disruptions, formal RM processes, proactive and contingency planning. The literature was helpful in conceptualizing better issues related to SCDM and provided guidelines in identifying which areas were important which may not had been initially considered as research related, thus helping shape the research questions and objectives and develop the research methodology.

5.1 Research Philosophy

With research philosophy, the researcher adopts a research strategy and methods which contain important assumptions about the way in which he or she views the world (Saunders et al., 2007). Based on the research questions and the subject of study, the researcher identifies and uses the approaches that are most useful for the research. There are three major ways of thinking about research philosophy: epistemology, ontology and axiology. Each contains important differences influencing the way in which the researcher performs the research process (Saunders et al., 2007). There are important differences in each approach, and on

that account the researcher will have to choose the philosophical position that best suits the research.

A paradigm is a way of examining social phenomena from which particular understandings of these phenomena can be gained and explanations attempted (Saunders et al., 2007). The way the researcher performs the study and the assumptions used provide a different insight and understanding of the phenomena, than if a different paradigm was used. Burrell and Morgan (1979), based on the assumptions about the nature of science (subjective – objective dimension) and the nature of society (regulation – radical change dimension), propose four paradigms: functionalist, interpretive, radical humanist and radical structuralist (Figure 5.1).

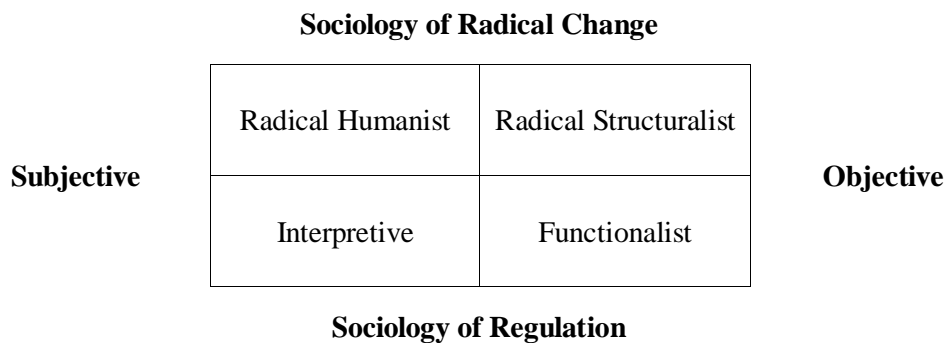


Figure 5.1 : Four paradigms (Burrell and Morgan, 1979, p. 22)

They underscore that the four paradigms are mutually exclusive, in the sense that one cannot operate in more than one paradigm at any given point in time, since in accepting the assumptions of one paradigm, we defy the assumptions of all the others; thus to be located in a particular paradigm is to view the world in a particular way. Approaching a phenomenon within a particular paradigm means viewing and understanding the world in a particular way.

Saunders et al. (2007) suggest that Burrell and Morgan’s (1979) four paradigms help researchers clarify assumptions about their view of the nature of science and society. Offering a useful method of understanding the way in which other researchers approach their work, these paradigms help researchers plot their own route through their research: understanding where it is possible to go and where

they are heading. When the assumptions fall in a certain paradigm, the research design is more easily developed, being based on previous research studies, but later it may also be used as a guidance tool for new researchers in the subject area.

Epistemology

An epistemological issue concerns the question of what is (or should be) regarded as acceptable knowledge in a field of study and an important question is whether or not a natural science model of the research process is appropriate for the study of the social world (Bryman, 2004; Saunders et al., 2007). Depending on the aim and the field of study, the researcher may adopt a natural science approach, or not, when the research is performed in the social world. These assumptions determine what is valid and acceptable knowledge for the research when adopting a natural science model and what is not. Therefore, epistemology is a general set of assumptions regarding the best ways of enquiring into the nature of the world (Easterby-Smith et al., 2002).

The two extreme positions on the issue of whether knowledge is something which can be acquired on the one hand, or is something which has to be personally experienced on the other, are predicated upon a view of the nature of knowledge itself (Burrell and Morgan, 1979). Whether, for example, it is possible to identify and communicate the nature of knowledge as being hard, real and capable of being transmitted in tangible form, or whether 'knowledge' is of a softer, more subjective, spiritual or even transcendental kind, based on experience and insight of a unique and essentially personal nature (Burrell and Morgan, 1979). These two extreme positions underline the nature of knowledge acquired by adopting a natural scientist stance or not. When the natural science model is followed, knowledge is based on 'hard' techniques where the researcher is independent from that being researched. On the other hand when the research does not follow a natural science model, the knowledge is more subjective because the researcher interacts with that being researched and does not maintain a clear stance from what is being researched. The two extreme epistemological positions are positivism and interpretivism. The epistemological position of this study is based between these two, leaning towards the interpretivism position.

Positivism is an epistemological position that supports the application of the natural sciences methods to the study of social reality and beyond, the ‘observable social reality’, which seeks to explain and predict what happens in the social world by searching for regularities and causal relationship between its constituent elements. (Burrell and Morgan, 1979; Bryman, 2004; Saunders et al., 2007). Positivism implements techniques that are used by the natural sciences in order to observe social phenomena, where quantifiable relationships are developed and explained. The main idea is that the social world exists externally, where only phenomena that you can observe will lead to the production of credible data and the view that all true knowledge is scientific, and can be pursued by scientific methods rather than being inferred subjectively through awareness, reflection or perception (Easterby-Smith et al., 2002; Leary, 2004; Saunders et al., 2007). It is believed that, by viewing a phenomenon from an objective position and keeping an external stance to what is being researched, knowledge is more credible than when knowledge is based on more subjective methods.

To generate a research strategy to collect these data, it is likely to use existing theory to develop hypotheses; key factors are measured precisely in order to test predetermined hypotheses, which will be tested and confirmed, in whole or part, or refuted, leading to the further development of theory which then may be tested by further research (Saunders et al., 2007; Easterby-Smith et al., 2002). Existing theory is used to test a hypothesis which will then lead to new theory development through measured variables. When testing a hypothesis, the researcher maintains an external position from the data gathered so it cannot be changed by the researcher. Thus, data analysis and results are presented from an objective standpoint which is based on the natural science methods.

Interpretivism, is predicated upon the view that a strategy is required, one that respects the difference between people and the objects of the natural sciences, and therefore scientific knowledge comes from subjective interpretation of phenomena by both researchers and their subjects (Creswell, 1994; Bryman, 2004). Knowledge is not derived from the objective meaning the natural science models provide but through the subjective understanding of phenomena from both

researchers and their informants. Researchers have their own perceptions, their own beliefs and their own conceptual directions because they are part of a specific culture at a particular moment. In addition they will be unquestionably affected by what they listen to and observe in the field because an interview will be a 'co-elaborated' act on behalf of both parties, not a gathering of information by one party (Miles and Huberman, 1994). Although researchers will have their own way of viewing and understanding the social world, when they interact with what is being researched, they will be affected on the understanding of the phenomenon. The social world is essentially relativistic and can only be understood from the point of view of the individuals who are directly involved in the activities to be studied. One can only 'understand' by occupying the frame of reference of the participant in action, because one has to understand from the inside rather than the outside and try to enter the social world of the research subjects, comprehending their world from their viewpoint (Burrell and Morgan, 1979; Saunders et al., 2007). In order to understand a phenomenon from the participant's point of view, the researcher needs to interact with the participant who is involved in the phenomenon studied and grasp the meaning the participant is referring to.

The present empirical study does not follow clearly a positivistic or interpretivistic position, but it is partly influenced by both epistemological positions, mostly leaning towards the interpretivistic position. During the case studies, the researcher tried to keep in certain instances an independent and objective stance from the interaction with the interviewees, so the communication of the nature of knowledge could be passed on in a tangible form. This was because the researcher was mostly interested in the actual RM processes and supply chain strategies the companies have in place. During the interviews, though, the nature and presentation of the questions asked and discussion of the answers presented, had an effect on the interviewee answers and the subjective understanding of the interview questions. Additionally, some of the answers heavily depended on the working experience of the interviewees, such as risk perception, which were based on the subjective understanding of the interviewees.

Ontology

Ontology is concerned with suppositions that people make about the nature of reality and whether the social world is considered external to social actors, or as something that people are in the procedure of fashioning; whether ‘reality’ is of an ‘objective’ nature, or the product of individual cognition (Burrell and Morgan, 1979; Easterby-Smith et al., 2002; Bryman, 2004). Ontology is concerned with whether the nature of reality is singular and objective external to social actors, or whether it is subjective and multiple as understood by the participants. So, the central point of orientation here is the question of whether social entities can and should be considered objective entities that have a reality external to social actors, or whether they can and should be considered social constructions built up from the perceptions and actions of social actors (Bryman, 2004).

Objectivism is an ontological position asserting that social phenomena and their meanings have an existence independent of social actors (Bryman, 2004). There is one reality that is not dependent on social actors’ subjectivities, where social entities have a reality external to social actors. In this way, it implies distance between the researcher and the researched, in order to prevent personal bias from ‘contaminating’ results (Bryman, 2004). Results are objective because social entities’ reality is not affected by the social actors’ perceptions about the nature of reality. With objectivism, judgments, findings and conclusions are completely independent of personal subjectivities (Leary, 2004).

Social phenomena are shaped from the perceptions and resulting actions of those social actors concerned with their existence. This is a continual process because through the procedure of social interaction, these social phenomena are in a continuous state of revision (Saunders et al., 2007). The nature of reality of social entities is subjective, depending on the perceptions and beliefs of the social actors who are constantly revising and changing it, thus producing multiple versions of the social entities reality. Researchers need to articulate both the knowledge that is likely to result from the process, the researchers’ agenda for change and the background and rationale of the study to demonstrate the positioning of the researchers, so they understand the reality or perhaps a reality working behind

them (Remenyi et al., 1998; Leary, 2004). It is significant that researchers describe and explain how they derived new knowledge and the position they chose in order to identify the nature of reality. This is important so others can then be in a position to critically evaluate the nature and credibility of the knowledge produced, given named agendas and subjectivities (Leary, 2004). Based on the social actors the researcher interacted with, the nature of reality is subjective, depending on whom the researcher interacted with and the credibility of information provided.

The nature of reality in the empirical research is between an objective and subjective approach. Objective because the organization has a reality that is singular and external from its employees. Thus, the employees are required to conform in a standardized way to the processes and controls the organization has in place. The study seeks to identify these formal processes that are in place and used by the employees. Yet the description of some of these processes, the way they are performed and of course managers' perceptions result in a subjective and multiple reality as seen by the participants. The study tries to identify the formal processes as placed by the case study company and the requirements the employees need to follow, but the description and execution of these processes sometimes depend on the subjective view of the participants.

Axiology

Axiology is concerned with what role the researcher's values play in all stages of the research process so that research results are credible (Saunders et al., 2007). If the researcher adopts a positivistic position, then the research is undertaken as far as possible in a value-free and un-biased way; the researcher is external to the process of data collection in the sense that there is little that can be done to alter the substance of the data collected (Easterby-Smith et al., 2002). If the researcher is adopting an interpretivistic position, the research is undertaken in a value laden and biased way. So, the researcher's values affect the research results. Although the case study results aim to be as value-free as possible, they are affected by the questions the researcher posed, the significance assigned to certain issues and the

way information is categorized and analyzed, thus tending to produce more biased than totally unbiased results.

5.2 Research Approach

The two research approaches generally used during the empirical research are the deductive and the inductive approach. Depending on the philosophical position of the researcher, he or she can use either position or a combination of these two approaches. With a deductive approach, the researcher usually follows a quantitative research approach and with an inductive, a qualitative one.

The deductive approach is the leading research approach in the natural sciences, applied when theory guides research; a theoretical or conceptual framework is developed, which the researcher subsequently tests using data by choosing large samples for the generalization of conclusions (Collis and Hussey, 2003; Bryman, 2004; Saunders et al. 2007). The deductive approach is usually linked with techniques from the natural science models used to test a theory by designing the research strategy for data collection, analysis, validation and determination of whether a theory stands or not. Thus, the researcher on the basis of what is known in a particular domain, deduces a hypothesis or hypotheses that must then be subjected to empirical scrutiny, and then designs a research strategy to test the hypothesis (Bryman, 2004; Saunders et al. 2007). The basic steps followed are: 1) Theory, 2) Hypothesis, 3) Data Collection, 4) Findings, 5) Hypotheses confirmed or rejected and 6) Revision of theory, (Bryman, 2004). The deductive approach follows a structured framework as in the natural sciences for the generalization of results.

With an inductive approach, theory is the outcome of research; generalizable inferences are drawn out of observations (Bryman, 2004). The inductive approach follows an opposite approach from the deductive approach, by firstly collecting data and then developing a theory which is based on the analysis of these data. Thus, during the empirical research, the researcher collects data and develops theory as a result of the data analysis (Saunders et al., 2007). Due to the use of qualitative data, the inductive approach is not as highly structured as the deductive

approach; modifications of the research process can be made as the research progresses and data is gathered and analyzed. With an inductive approach, the importance is placed on the generation of theories, on the ways in which individuals interpret their social world and on the view of social reality as a continuously shifting emergent property of individuals' creation (Bryman, 2004). Thus, due to the collection and analysis of words, reality is subjective and dependent on the perceptions of the social actors in the way they interpret their social world, where the researcher tries to understand the meanings the social actors attach to it.

During the empirical research, the researcher applied an inductive approach with an element of the deductive. The deductive approach element was that the empirical research was driven partly by an already constructed and widely applied RM process, which may be considered theory, whereby interview questions were asked relating to this process. The researcher didn't test theory, but tried to build on existing theory which was derived from the literature. An inductive approach was followed because the research was concerned with the collection of qualitative data, therefore allowing a more flexible structure to permit changes of research emphasis (selection of people and questions asked) as the research progressed and data were obtained; the researcher was part of the research process by trying to coordinate and understand the whole research process and subjective context. Due to the fact that the literature and empirical research available for the topic studies were limited, as Creswell (1994) rightly suggested, it was more appropriate to work inductively by generalizing from data, analyzing it and reflecting upon what theoretical themes were being suggested by the data.

5.3 Case Study Methodology

The case study methodology was chosen because it was believed to be the most suitable methodology according to the philosophical position, the research questions and the phenomenon studied. Robson (2002:178) defines a case study as 'a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple

sources of evidence'. The case study approach was chosen because a deeper understanding of the practical issues and problems in achieving effective SCDM needed to be achieved. It is also an effective way of understanding the complexity of the issues involved and of identifying useful approaches to the problem. The case study methodology is preferred when 'how' or 'why' questions are used, when the researcher has little control over events and when the focus is on a contemporary phenomenon within some real-life context but when the relevant behaviours cannot be manipulated (Yin, 2003). The two research questions are 'how' questions and the research is interested in the RM processes and supply chain strategies companies use, which are processes and controls adopted by a company which the researcher cannot control and manipulate. Additionally, the study for developing processes for SCDM is a contemporary phenomenon, where the study tries to identify these processes in a way that is as unbiased as possible.

The case study's unique strength is its ability to deal with a full variety of evidence documents, interviews and observations (Yin, 2003). During the case studies, the researcher conducted interviews with a variety of employees and viewed and analyzed related documents. For one case study, the researcher also visited the company's warehouses and assembly plant and performed observation of the supply chain analysts. Encompassing such methods, a case study can identify the causal links in real-life interventions that are too complex for the survey or experimental strategies, where the researcher can investigate deeply into a particular case and comprehend what is happening and why (Hussey and Hussey, 1997; Yin, 2003; Bryman, 2004). Thus, a case study by using a variety of methods is useful in providing detailed understanding and explanation of how different causal relationships and processes are performed in the companies and their supply chains, and the reasons that certain procedures are adopted.

When available literature is limited and there is no knowledge base provided for the development of good theoretical statements, the empirical study is likely to assume the characteristic of an 'exploratory' study (Yin, 2003). The research is basically exploratory because it is a contemporary study with limited knowledge available and it relies on the case studies to develop theory. An exploratory study

is used in order to determine ‘what is happening, to seek new insights, to ask questions and to assess phenomena in a new light’ (Robson, 2002:59). The empirical research is interested in identifying processes the case study companies are using and how companies could benefit from having formal SCDM processes in place. A salient advantage of case studies is that they are flexible and adaptable to change because the researcher can alter their direction in the presence of new data and insights that occur (Saunders et al., 2007). This flexibility helps the researcher investigate broadly into the subject and when more information and data are acquired, place emphasis on the areas that are mostly interesting and insightful. Additionally, an exploratory case study can contribute to new understandings to the fore (Leary, 2004). Different companies and their employees comprehend and realize certain processes, issues and terms differently than in other companies. For example, the research tried to identify the managers’ perceptions of risk and disruption, which differed between the case study companies.

On the other hand, the research also has certain features of an explanatory study where it uses existing theory to explain some issues and results resulting from the case study findings. It is also explanatory because it provides the RM process that theory will be built on. Furthermore, the case study is descriptive because after the necessary information is obtained, a description of the processes and controls they implement needs to be obtained. Descriptive research helps portray an accurate profile of persons, events or situations (Robson, 2002).

5.3.1 Multiple case studies

Two U.K based case studies in two different types of companies were performed. Even though additional resources and time are required over a single case study, the evidence multiple case studies offer is usually considered more compelling and robust (Herriott and Firestone, 1983). Single case studies view only a company without having a second input from a similar or a different type company, in order to understand the reasons for their similarities or differences. By studying the same phenomenon in at least two companies, the researcher can provide

conclusions that are applicable to not just one case or similar cases but will have a much broader application, especially if the companies are from different sectors.

The two case studies, auto-manufacturing and water utilities, are two privately owned companies that operate in different types of supply chains. After the auto-manufacturing case-study, where understanding of the supply chain and RM processes they have in place was achieved, the water-utilities case study was undertaken. Based on the literature and the findings from the initial case study, interview questions and data gathered during the second case study were more targeted to the themes that had been previously developed by the first, but also differences between the two case studies were identified and researched.

The results from the two case studies will be compared and the findings will add to the development of SCDM processes. By studying the RM processes they have in place, examining their usefulness, and their general applicability, the researcher can determine which are attractive enough to be included in the SCDM processes and contribute to the development of theory.

5.3.2 Case Studies

For the empirical research, finding and gaining access to case study companies was a time consuming and challenging task. This was mostly due to the sensitivity of the subject, as companies were concerned about disclosing information of their contingency plans and processes for dealing with disruptions. Additionally, it seems that a great deal of companies are not implementing SCDM processes and did not even see the benefit of being proactive to disruptions because they are rare events and are not related to the daily activities that provide immediate earnings to the company.

Suitable companies were identified based on their supply chain operations, services and products offered. Self – selection sampling was used in each case where companies were willing to take part in the research (Saunders et al., 2007). In order to approach possible case study companies, a letter was prepared (Appendix V) informing the companies the research area, about the importance of

the subject and the need for researching it, what the study involved up to date and the issues to be researched during the case study. The letter was sent by e-mail to companies that the University of Southampton's Schools of Management and Mathematics collaborate with, to professional sites such as CIPS (Chartered Institute of Purchasing and Supply) and to personal contacts.

A total of four companies showed interest in the study. Although one of them, an airline company, showed initial interest in the study, it decided that no further collaboration could be developed after a discussion with them about the detail of the research requirements and how the company could contribute. This was because the airline company was going through a major reorganization and therefore didn't have the time to work on the project. Three companies agreed to collaborate: an auto-manufacturing, a water utilities and an oil company. Due to the fact that the oil company contact was achieved through a personal contact, the contacts in the company weren't at managerial level and after two interviews it became evident that it would be difficult to access the necessary departments, and especially those at managerial level. Thus, two case studies were completed with the auto-manufacturing and the water utilities companies.

5.4 Data Collection

Data collection from the two case study companies was performed from March 2007 until October 2008. Firstly, the data collection period from the auto-manufacturing company was between March 2007 and November 2007. For the water utilities company the data collection period was between April 2008 and October 2008. The data collection methods used in both case studies, were interviews and document analysis, and for the auto-manufacturing company observation was also used. Qualitative research inherently uses multiple methods which help add complexity, richness and depth to an inquiry of a study and can provide actual and true information (Flick, 1998; Miles and Huberman, 1994). The research does not depend only on one method to understand and analyze the phenomenon studied, but uses other methods that will provide a richer picture and a better understanding of what is studied. Moreover, one method may back up

another method, because the data from one method are validated with similar data collected with another method. Additionally, the data from method A may enrich what is lacking from the data collected with method B.

The original objectives and design of the case study are based on propositions which reflect a set of research questions and the literature review. The propositions form a data collection plan and provide priorities to the relevant analytic strategies, thus they help to focus attention on specific data and to ignore other data (Yin, 2003). Based on the literature and the research questions, the useful data that need to be collected for the relative themes are identified. Based on the themes and the data collection methods that are used, the researcher may design the research strategy so that it focuses on the required information that needs to be gathered and ignores information that does not add any more value to the study.

A researcher should be adaptive and flexible, so that the newly encountered situations can be seen as opportunities instead of threats (Yin, 2003). During data collection the researcher tried to be flexible, so when information was gathered on a particular theme but the interviewee, for example, provided information on a related theme that would also be valuable to the research, the researcher then tried to continue the interviews including the emerging themes. Then, the importance of the emerging theme was defined and placed in relation to the overall study, so during the next data collection session, this theme was also considered. The researcher needs to be 'alert' to emerging themes so they can enrich and add value to the case study findings.

Data collection is stopped when no additional information can be gained and the necessary information has been acquired. According to Leary (2004), the researcher should stop the collection of data when additional data do not offer any richness to understanding or aid in building theories. Thus, when the relevant informants have been interviewed, when the helpful documents have been analyzed and when the interesting social actions have been observed, then there is no further need to continue with data collection. A problem, though, is when additional information is difficult to access, such as, confidential information,

managers located overseas with no relations with the current contacts, compounded by lack of available time to continue with additional interviews. As a result of these factors, the interviewer based on the available information may draw conclusions stating the limitations of the study.

5.4.1 Interviews

The principle data collection method was interviews. This is a data collection method that involves researchers asking respondents open-ended questions in order to obtain information (Leary, 2004). Researchers acquire information by asking questions which haven't got any predetermined answers, but the answers are based on the experiences and/or knowledge of the interviewee on the social phenomenon studied. Due to this, the researcher needs to be very careful about the way the questions are asked, their explanation and making sure that the interviewee understands the questions. Interviews help the researcher focus directly on the case study topic and also provide insightful information and uncover new clues, open up new dimensions of a problem and secure vivid, accurate, inclusive accounts (Burgess, 1982; Yin, 2003). The researcher needed to be informed and to understand the company's supply chain operations and processes in order to handle disruptions. This is most effectively done by discussing with company employees who are familiar with the themes studied.

The empirical research was based on unstructured and semi-structured interviews. In total, 15 interviews were conducted which normally lasted from 90 – 120 minutes. The interviews took place at the companies' facilities either at the interviewee's office or in a meeting room. They were all Dictaphone recorded and the interviewees didn't have any objections to being recorded. There were 11 interviews conducted with the auto-manufacturing company and 4 interviews with the water utilities company. The interviewees' positions were managers, analysts or consultants. The participants were chosen based on their jobs and experience, which usually related to supply chain or RM, but certain interviewees were selected after some questions were asked when the interviewee wasn't knowledgeable of the subject and in such instances the researcher was directed to the suitable person.

Table 5.1 lists the interviews performed in each company. All participants were interviewed once except the material planning and logistics manager from the auto-manufacturing company who was interviewed 5 times. This was because in the company, he was the initial contact who also put the researcher in contact with the other interviewees. Additionally, he was mostly familiar with a variety of themes such as warehouses, inventory, logistics, supply chains and disruptions that occurred along the supply chain which couldn't be covered in one interview. Moreover, clarification on certain issues was needed, ones that either the other interviewees were unable to provide or issues identified after talking to them, and he was the expert to talk to.

Table 5.1 : Participant's Company Position

Participants' Company Positions	Sequence of Interviews
Auto-manufacturing Company	
Material Planning and Logistics Manager	1 (5)
Supply Chain Supervisor	2
Logistics Supervisor	3
Logistics Analyst	4
Supply Chain Analyst	5
Manufacturing Engineer Manager	6
Purchase Manager	7
Water Utilities Company	
Operations Manager	1
Risk Consultant	2
Business Continuity Consultant	3
Supply Chain Manager	4

The interview questions (Appendix VI) were developed based on the research questions, research objectives and the related literature, which helped focus the questions on the subject studied and identifying related issues. During interviews a list of themes and questions were covered, although these differed from interview to interview. Some questions in specific interviews can be left out, due to a particular organizational context that is encountered in relation to the research topic (Saunders et al., 2007). Specifically, the interview questions for each

interviewee were tailored towards their position and the specific information that could be gathered from an interviewee. Additionally, depending on the structure of interviews and as more information was gained about the company practices, certain interview questions became more specialized and more targeted. The interview questions focused on the company's supply chain, sources of disruptions, RM strategies and practices implemented, current contingency plans for disruptions and key problems and issues for management in implementing formal SCDM processes.

Unstructured Interviews

Unstructured interviews were only used in the auto-manufacturing company where the researcher was trying to become familiar with and understand the nature of the work and the tasks of the supply chain team. This was also the researcher's first case study and the auto-manufacturing supply chain includes a number of elements that the researcher wasn't fully familiar. The unstructured interviews provided the opportunity to the interviewee to talk freely about the range of topics and events related to the research (Saunders et al, 2007). This is very useful when the researcher tries to understand the company situation and operational processes when not much information is available.

The empirical research started with the visit to the auto-manufacturing company's facilities, where the researcher started interviewing the supply chain team, not by using a predetermined list of questions to draw out information, but having themes for discussion, discussing job tasks and risk related issues (identified from literature) associated with the company's supply chain. With unstructured interviews no predetermined list of questions is used, but the interviewer should have some idea of what issues are to be explored in order to gain information, attitudes, opinions and beliefs around particular themes, ideas and issues (Leary, 2004; Saunders et al., 2007). Having an idea of the themes to be discussed, the interviewer drew information from the interview as the discussion progressed while keeping the interview to the point.

Additionally, the researcher was flexible and adaptable as new issues were uncovered that weren't considered, so when the interviewee referred to them, the interviewer could grasp the opportunity to focus on them. Interviewers achieve this by using a more conversational style and attempt to prompt, probe and develop questions during the conversation in order to encourage dialogue (Leary, 2004). The order of questions and the manner in which questions are asked as the interview progresses need to follow a physical flow that will not affect the continuum of thought, which can provide more insightful and related information than if it is interrupted. Bryman (2004) suggests a conversation can begin by posing a single question that the interviewer asks and the interviewee simply responds to points that seem worthy of being followed up. Thus, the initial question needs to be a basic one which will help initiate the discussion and also pick up information for the further development of the interview. During the unstructured interviews of this study, the opening question was: 'What does your job entail?' This helped initiate discussion and then pick-up points when they referred to, for example, supply chains, suppliers, transportation and disruptions.

Semi-structured interviews

The majority of the interviews were semi-structured. In the auto-manufacturing case study, semi-structured interviews, which had more focused and tailored questions, followed the unstructured interviews. Semi-structured interviews were also used at the water utilities case study. The researcher had a list of themes and questions to be covered, but the interviewee had a great deal of flexibility in how to reply (Bryman, 2004; Saunders et al, 2007). The flexibility the respondents have enables them to provide rich information on themes studied because they describe and explain them in depth. Additionally, themes were identified that weren't considered initially but were related to the study and important for the findings.

A list of questions or themes may not follow a predetermined order, and also depending on the context of the interview, questions that are not included may be asked as the interviewer picks up on things said by interviewees (Hussey and Hussey, 1997; Bryman, 2004). The researcher arranged a predetermined list of

questions that were useful for discussion, but as the discussion developed and some interesting points were raised, additional questions were posed, leading to a natural flow of conversation. Also, the order of some questions varied in different interviews to maintain this flow.

5.4.2 Observation and Document Analysis

Document analysis and observation were performed alongside interviews for the auto-manufacturing case study. The interviews with observation and document analysis provide a useful approach in comprehending better the processes the interviewees describe. Additionally, with observation the researcher can understand the way certain processes are performed. With document analysis researchers have the time to read, analyze and understand certain themes from their point of view instead of depending solely on the interviewee to describe it. Although observation and document analysis are helpful methods to back up interviews and understand a phenomenon better, access to the companies' facilities and company documents are difficult to obtain. The main factors causing reluctance of companies to allow access are confidentiality issues and busy employees' time schedules. The researcher was provided access to observe at the auto-manufacturing company's site, the operations of the supply chain and logistics team, the assembly line and the warehouse operations. During observation, the researcher listened and watched how the different jobs and procedures were performed, asking questions when more information or clarifications were needed, all of which were written down or recorded. During observation, recognition and recording of facts, situations and occurrences was carried out (Leary, 2004). This helped in understanding better the company's supply chain operations and production techniques that were described during the interviews. Additionally, the researcher had the chance to view in practice procedures that were referred to in literature, becoming familiar with supply chain practices and understanding more fully the issues related to SCDM.

Document analysis was performed on documents from the logistics division, with information on the supply chain of the case study company, the location of the distribution centres and details of the volume and location of materials by country.

With document analysis the researcher is trying to explore written documents for content and/or themes (Leary, 2004). This information was analyzed and used for understanding and analyzing the inbound logistics operations. In addition, it was helpful having figures that identified the critical suppliers, where the distribution centres are located and from where component parts were supplied. With document analysis, not only was a better understanding of the logistics network obtained, but sources of vulnerability were also identified which informed more targeted questions during the interviews.

The water utilities company also provided documents related to the RM process. Specifically, they included the criteria used for assessing risk impact and likelihood. Maps were also provided which are used for placing the different types of risks depending on their overall score, which also included the existing and proposed responses. These documents helped in understanding better the tools the different individuals and groups use in order to identify, assess, manage and monitor risk. They were also used to comprehend more effectively the respondents' description of the risk processes and maps.

5.5 Data analysis

Data analysis occurred during and after data collection. The two case studies were analyzed independently and then findings were compared with further analysis. Data collection and analysis were a continuous process which was refined as more information was gathered. When the initial data was gathered and analyzed, it was easier to identify gaps of information, thus making the later data collection processes more effective with a focus on the required information. Data analysis was conducted based on Miles and Huberman's (1994: p12) interactive model of qualitative data analysis. The activities included data collection, data reduction, data display and conclusions drawing/verifying. Data reduction, data display and conclusions drawing/verification, are three concurrent flows of activity as shown in Figure 5.2 (Miles and Huberman, 1994: 12). In Figure 5.2, the arrows that connect the different activities demonstrate that data analysis is a continuous

process that refines analysis and that activities are mutually dependent, making the process iterative, parallel and cyclical.

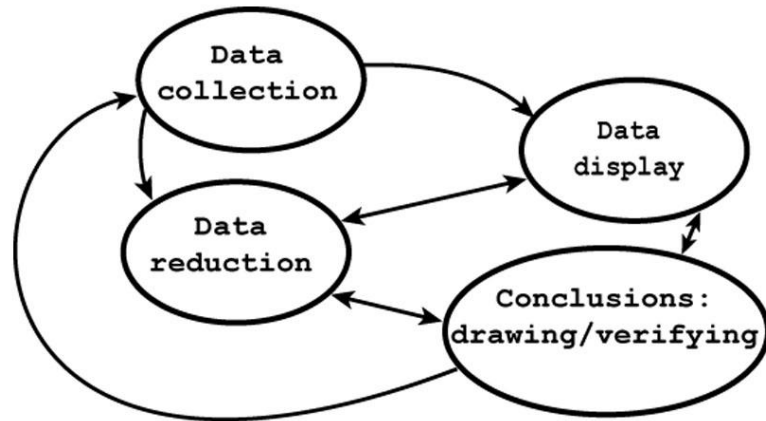


Figure 5.2 : Components of Data Analysis: Interactive Model

Following data collection through the methods of interviews, observation and documents, the data acquired needs to be selected, edited and corrected so the useful information is abstracted and organized. Raw field notes need to be corrected, edited and typed up; tape recordings must be transcribed and corrected (Miles and Huberman, 1994). When written notes were used during observation, these were edited and simplified so they could be better read and understood. Dictaphone notes were transcribed on a word document where editorial mistakes were corrected and useful information identified. With document analysis, the important information was also abstracted so the researcher could focus on it.

Data display was also used, so useful information from the three methods was organized and presented (e.g. tables); in order for the researcher to view the findings from the data gathered and assess what additional information was required to assist in the drawing and verification of conclusions. A display is an organized, compressed assembly of information that permits conclusion drawing and action (Miles and Huberman, 1994). At the beginning of the data analysis process, information display helps in drawing preliminary conclusions, and as

data analysis progresses, it allows verification of conclusions amongst the different methods as well as a chance to see what other information is required.

5.5.1 Summary Forms

During data collection, summary forms were produced. Written after an interview occurred, these forms were helpful in summarizing the findings. They also consisted of issues identified, information missing and further interviews that were required. Box 5.1 provides an example of a summary form produced after an unstructured interview with the supply chain supervisor of the auto-manufacturing case study.

Box 5.1 : Interview Summary Forms

Interview Summary Form
Date: 25-04-07
Location: Assembly Plant – Supply Chain Team
Contact Method: Interview – Supply Chain Supervisor
Duration: 90 minutes
Themes Covered
Job description, general information on assembly line and production volumes, lean practices applied, number of suppliers, single – dual – multiple sourcing, critical and non critical parts, transportation methods of materials, stock levels, issues in supply chain team, disruptions mostly concerned of, contingency plans for disruptions
Important Observation
Supply chain supervisor was transferred from a similar assembly plant in another country that manufactures the same car models. A possible way to deal with disruptions is to increase stock levels from e.g. 1.1 to 1.5 days. In assembly plant abroad, they keep 3 days of stock, because it is a much bigger plant and has more space. Try and find an optimal solution of stock, cost and risk.
Further Data Collection
Production forecasting and the possibility of increasing stock – Materials Planning and Logistics Manager Supplier Selection – Purchase Manager Critical and Non-Critical parts: Manufacturing Engineer Manager

More information on contingency plans if a disruption materializes

Observation forms were written after an observation and generally describe the information gathered, any important issues observed and any questions raised during observation. An example is provided in Box 5.2.

Box 5.2 : Observation Summary Form

Observation Summary Form

Date: 31-10-07

Location: Assembly Plant – Warehouse - Market places

Related to: Stock Storage and Management

General Observation Points

Market places next to the trim process of the assembly line and warehouses next to the assembly plant. Some warehouses are located outside the plant due to space limitations.

Special location where they keep their pilfer-prone parts – risk of theft by employees.

The new level parts before they go into production, they are stored and then tested on the line.

Card market place

Call button to call parts

No receiving inspection in the plant, instead ISN is used

Check numbers of boxes after the truck leaves because they do not have the time to check when the truck is delivering. They check the number of boxes but not what there is in each box.

Significant Observation Point

The company implements lean practices for stock levels

Document summary forms (Box 5.3) were also produced, which summarized the findings after data analysis of the obtained documents. Summary forms were helpful in viewing what documents included and how they could be used concurrently with other collected data.

Box 5.3 : Document Summary Form

Document Summary Form

Date: 17-07-07

Document: Inbound Network

Related to: Logistics team

Company: Auto-manufacturing

Contents Summary

Inbound Network designed for meeting production level of car units per day.

Description of inbound network

Total number of parts

Total Average Volume per day (m³)

Total Average Weight per day (kg)

Total number of suppliers

Distribution centres locations

The 75% of inbound volume comes from the top 20 suppliers.

In addition to summary forms, memos were also used. Memos (Box 5.4) were ideas and thoughts developed, which were linked with themes during data analysis. They were additionally used to record the research progress on a particular theme so the researcher was aware of how a theme was unfolding. The memo was updated as more information was obtained and new thoughts developed. This helped develop a comprehensive audit trail, how a theme developed and recording the thoughts and concerns of the researcher linked to it.

Box 5.4 : Memo

Memo

Company: Auto-manufacturing

Theme: Managers' Risk Perception

Updated: 14-11-2007

Although managers were very comfortable and confident in describing their job activities, when they were asked on 'how they perceive risk', they needed some time to think about the question before answering. From the descriptions of risk perception, I conclude that managers from the auto-manufacturing company perceive risk and disruption as the same, and the only risks they consider are usually related to operational risks, because they are risks related with their daily jobs.

5.5.2 Coding

During data collection, coding was implemented, which helped group the data into categories and themes. Codes are tags or labels for assigning unit of meaning to different sizes of information such as words, phrases, sentences and complete paragraphs, which are compiled during a study (Miles and Huberman, 1994). Portions of text were assigned a description code which related to the research questions and objectives. Coding was applied to interview transcripts, observation information and document data. Codes are astringent; they pull together a lot of material, thus permitting analysis (Miles and Huberman, 1994). During coding, all relevant information aimed to be included in the relevant code, thus information was coded as analytically as possible. Additionally, any thoughts, comments and remarks were added as annotations or memos to a portion of text, so that all important information linked to a code was gathered and the researcher could view it. As a result, coding helped bring together data from different sources which were assigned the same code. In this way, it was easier to retrieve and compare data and draw conclusions from different sources that were gathered together under the same code.

Before starting the fieldwork, the researcher created a provisional list of codes based on the literature, the research questions and the case study company type. An example of a provisional list of codes is presented in Table 5.2. These helped form the interview questions and provided focus during interviews on the important issues without blocking any new helpful information being gathered. The researcher was open to new information and themes as data gathering progressed and information was gathered, thus creating new codes which were basically new themes. Thus, the initial list of codes gradually altered in order to embed all the relative research themes identified during data collection. Certain codes that proved not to be useful or descriptive enough were removed, renamed or embedded in another code. Codes with a large amount of information gathered around certain themes were broken down into sub-codes so information could be processed more easily.

Table 5.2 : Example of Initial Codes

Illustration of an Initial List of Codes	
Code Names	Research Questions
<i>Supply Chain Descriptions</i>	1
Important Processes	1
<i>Suppliers</i>	1,2
Single Source	1,2
Dual Source	1,2
Multiple Source	1,2
Information Sharing	1,2
<i>Stock</i>	1,2
Stock Levels	1,2
Warehouses	1,2
Buffer Zones	1,2
Stock handling	1,2
<i>Logistics</i>	1,2
Logistic Processes	1,2
Transportation Types	1,2
<i>Risk and Disruption Perception</i>	1,2
Analysts	1,2
Managers	1,2
<i>Disruptions</i>	1
Disruption types mostly concerned of	1
Contingency Plans	1,2
<i>Risk Management Processes</i>	1,2
Risk Identification	1,2
Risk Assessment	1,2
Risk Management + Implementation	1,2
Risk Monitoring	1,2
<i>Insurance</i>	1,2

During different times of data analysis, there were three types of codes used: descriptive, interpretive and pattern codes. During the initial stage of coding, descriptive codes were used. These codes are appropriate when a class of phenomena is attributed to a segment of text which entails little interpretation

(Miles and Huberman, 1994). At the beginning of fieldwork, data was just assigned a code which described a piece of text. As more data was gathered and the researcher became more familiar and knowledgeable about the case study, interpretive codes were used instead of descriptive. Additionally, later on in data collection as patterns became clearer, pattern codes were applied. The pattern code signals a theme that accounts for a lot of other data by grouping disparate pieces into a more inclusive and meaningful whole (Miles and Huberman, 1994). Pattern codes can be used after a substantial amount of information has been gathered and the researcher can distinguish patterns in the data.

Ongoing coding reveals real or possible sources of bias and surfaces incomplete or unclear data that can be clarified next time out (Miles and Huberman, 1994). Coding was performed before, during and after data collection (Table 5.3). Before the researcher went to the next fieldwork visit, codes were read, and after the fieldwork where more information was acquired, certain codes were revised. In this way, the researcher could identify missing and biased data, so that during the next fieldwork visit, the researcher knew which themes to focus on and also which to clarify.

Table 5.3 : Example of a Final List Codes

Illustration of a Final List of Codes	
Code Names	Research Questions
<i>Suppliers</i>	1,2
Single Source	1,2
Dual Source	1,2
Multiple Source	1,2
Information Sharing	1,2
Suppliers Origin	1,2
Cost Efficient Suppliers	1,2
Suppliers' Financial Stability	1,2
Supplier Contracts	1,2
Supplier Insolvency	1,2
Possible Suppliers	1,2

Quality Standards	1,2
<i>After Sales Division</i>	1,2
Dealers	1,2
Customer Clinics	1,2
<i>Business Continuity Management</i>	1,2
Reasons for Implementing	1
Work done so far	1
Procedures Involved	1,2
<i>Stock</i>	1,2
Stock Levels	1,2
Warehouses	1,2
Buffer Zones	1,2
Market Places	1,2
Vendor Managed Inventory	1,2
Parts Management System	1,2
<i>Lean practices</i>	1,2
Production	1,2
Stock	1,2
<i>Approaches to disruption</i>	1,2
Customization	1,2
Information Sharing – Electronic Data Interchange	1,2
Insurance	1,2
Standardization	1,2
Tooling	1,2

For the coding of data, the qualitative data analysis Software QSR NVivo7 was used. This software proved to be helpful during the coding process to code and group the data in word files. It also provided useful procedures for creating codes and searching for codes within various segments of the data. Codes were first created as free nodes and then as the fieldwork progressed, the free nodes were placed on tree nodes. The visual display of the coding system in the form of a hierarchical tree (Easterby-Smith et al., 2002) helped identify the major categories and sub-categories and in recognizing themes missing.

5.5.3 Cross-Case Data Analysis

Each case study was analyzed independently in order to explore, describe and explain the SCDM processes that the participating companies implement and the important elements that relate to these, such as risk perception and supply chain description. During the first case study, a pattern was developed based on the theoretical framework and research questions. The second case study had certain similarities and certain differences with the first case study, thus the pattern from the first one was adapted for the second. Of course this brought about replication up to a certain point, but when there were completely different procedures between the two case study companies, the pattern followed in the second case study was changed accordingly.

Cross-case data analysis is a synthesizing interpretation process across cases (Noblit and Hare, 1988). A cross-case data analysis focused on the similarities and differences between the two case studies, aiming to understand and explain the reasons for these. The differences mostly related to the company's supply chain type, the product offered and the practices each company implements for managing disruptions. These variations produced two different RM processes implemented by the case study companies. The results are presented in Chapters 6 and 7.

5.5.4 Data Display

A useful method of viewing the data that has been collected and analyzed is to display it in a coherent way in a reduced and focused format such as tables, lists and diagrams. Displayed information is presented systematically in a visual format, enabling the researcher to make valid conclusions and take necessary actions. From the full range of persons, events and processes under study, the information is organized onto a single page (Miles and Huberman, 1994). The information gathered on one page help the researcher reach conclusions regarding the data gathered up to date and spot missing data so as to assess further data collection required. Only necessary information is contained on this page, so the researcher can have an overall view of the variables displayed with no added

information attached. Additionally, the information needs to be organized so that an understanding can be gained from the displayed information.

Data display is also helpful for cross-case data analysis, where similarities and differences may be displayed, so the researcher can identify them and reach to conclusions more easily. The display facilitates careful comparisons, detecting differences and noting patterns, themes and trends (Miles and Huberman, 1994). Careful organization and presentation of data can assist the researcher in not only drawing more credible conclusions by comparing different data sets but also viewing if any patterns arise from the two case studies.

Tables instead of networks were designed for each case study and for cross case study analysis. Although networks are helpful when there is a need to focus on more than a few variables at a time (Miles and Huberman, 1994), tables were more helpful for the purposes of this study in drawing conclusions and viewing the data gathered. This is because information in tables was displayed in a more structured way. The columns included the themes such as risk identification, risk assessment and contingency plans, and the rows included the information gathered for each theme such as multiple suppliers for the contingency plans. The themes were linked with the theoretical framework and the research questions. After having displayed the important and relevant information, it was easier to identify what further data was required and to draw conclusions on the data.

Tables were designed at an early stage during data collection, but these were modified as fieldwork progressed and more information was gathered. A number of iterations were performed so the display provided valid, relevant and concise information. Tables for cross case analysis will be presented and explained more thoroughly in Chapter 8.

5.6 Credibility of research findings

During fieldwork, the researcher tried to gather and analyze valid data. Validity is concerned with whether the findings are actually about what they seem to be about (Saunders et al., 2007). Thus, the information obtained through interviews,

observations and document analysis should not contain any biases and must provide as much as possible credible information. Easterby-Smith et al. (2002) argue there are three main kinds of validity: construct, internal and external, and Yin (2003) also adds reliability. As research design aims at obtaining valid and reliable data, there is a greater possibility of this during data collection if all the necessary procedures are developed and followed.

Construct validity is concerned with whether a measure of a concept developed actually reflects the concept that it is supposed to be denoting (Bryman, 2004). The concepts being studied need to be translated and understood as to what they are implying and their validity can be tested through effective measures. Measures that can be applied include using multiples sources of evidence, establishing an evidence chain and arranging for key informants to review the case study report (Yin, 2003). Throughout fieldwork, multiple sources of evidence were used such as interviews, observations and documents, the three methods normally used during data collection and writing up (Yin, 2003). In this way, the researcher tried to gather reliable data so the findings were credible. The data derived from these three methods were validated through triangulation. Data require converging in a triangulating fashion by using a variety of data collection techniques for the research intended to confirm the same information (Patton, 1987; Yin, 2003; Saunders et al., 2007). After the case study findings were written up, these reports were given to key interviewees to check for any misinterpretations and/or omissions.

Internal validity is usually applied during explanatory studies (Yin, 2003), and because this study is also explanatory, the data gathered were matched and explained with already existing theory (risk management and supply chain practices). Internal validity was performed during data analysis. Internal validity is whether the research design is capable of removing bias and the effect of irrelevant variables (Easterby-Smith et al., 2002). When responding to questions, interviewees' answers may be biased because they may promote a different situation than the actual one. During research, there may be subject or participant bias, due to the fact that interviewees have poor recall or hindsight bias, reply

according to what they think their managers require them to say, and provide the information the interviewer wants to listen to (Robson, 2002; Yin, 2003). Furthermore, sometimes despite not knowing the answer, or even not remembering a certain process, an interviewee may answer a question anyway. In order to validate the interview data, the researcher tried to achieve triangulation between the different interviewees on the processes a company uses and the policies in operation. Additionally, when an interviewee didn't know a particular area well, they informed the interviewer, but the interviewer could also understand that they didn't have the appropriate knowledge by posing more detailed questions that they were unable to answer. A further problem during data collection is that unneeded information can be gathered which may have an effect on data quality. This needs to be removed so that the facts collected can provide reliable data based on important variables without being affected by biases and irrelevant variables.

External validity is determining the fields of a study which may be generalized (Easterby-Smith et al., 2002). It comes about when deciding which results can be generalized to a larger set beyond the case study companies. A normal objection is that it is difficult to generalize from one case to another (Yin, 2003, Bryman, 2004). Thus, case studies have limited external validity, although the case studies chosen are considered to be typical examples of the companies in their industries.

Reliability is also important for data quality and the credibility of findings. Reliability is whether data/results collected, measured, or generated are the same under repeated trials (Leary, 2004). How reliable are data collection and analysis depends on (Easterby-Smith et al., 2002:53):

1. Will the measures provide the same results in other instances?
2. Will similar observations be attained by other observers?
3. Is there clarity in how sense was reached from the raw data?

Positive answers to these questions denote that the data collected is reliable because when collected, analyzed and described, it will always provide the same

findings. Data reliability in this study depended on the researcher's philosophical position, which was based on the social actors' reality; the researcher tried to achieve consistency between findings based on the other three validity types.

5.7 Conclusions

The empirical research provided useful insights in seeing how literature blends in with real business contexts, why is it difficult for companies to implement SCDM, what processes companies use for supply chain disruptions and if a formal RM process can improve SCDM.

Two case studies were chosen, although a larger sample would have been even more helpful in identifying processes that can contribute towards a SCDM process and also in making comparisons between case studies. Finding the case study companies and gathering the necessary information, which was based mostly on interviews, was time consuming. This was because interviewees in both case studies were busy, and finding a suitable time slot for the interviews required advance arrangements of even two months. Moreover, regarding the auto-manufacturing case study, there was a gap of approximately three months between interviews because a disruption caused from a fire at a second tier supplier impacted the auto-manufacturing company's operations. Until normal operations were resumed and interviews arranged due to summer holidays taken by employees, three months had passed. Although these limitations occurred, the case studies were useful in studying a contemporary phenomenon in two different business settings, which helped determine the similarities and differences between the two companies and the literature regarding SCDM.

Based on the research questions and objectives, the necessary information from the two case studies was obtained, which helped in understanding the companies' supply chain operations better, but also facilitated looking into different variables regarding the implementation of SCDM processes.

6 Auto-manufacturing Company Case Study

For the empirical research two case studies were conducted that aimed in providing insightful information on how they handle sources of supply chain disruptions, if they apply any formal RM processes and if yes, the usefulness of such processes. The case studies are from two different industries and will help compare practices, concepts and processes related to SCDM, not only between the two case study company contexts but also with what is already applied in the literature. First, the case study with the auto-manufacturing company is described.

Alpha (imaginary name) is an automaker company and a subsidiary of the Company (imaginary name). Alpha company was chosen because it is a global company, operates in a rapidly changing environment and faces global competition. Additionally, it is a well organized company that in the past has dealt with a number of disruptions and its experience would help develop useful approaches to dealing proactively with supply chain disruptions. During the case study three managers were interviewed; the materials planning and logistics manager, the manufacturing engineer manager and the purchase manager. The supply chain supervisor, analysts and logistics supervisor were also interviewed. In Table 6.1 the job descriptions of the interviewees are presented:

Table 6.1 : Job Descriptions of Interviewees

Job Descriptions of Interviewees
<i>Materials Planning and Logistics Manager:</i> manager of the supply chain and logistics teams. Any issues the teams have with suppliers not sending, stock issues and transportation problems are reported to him. If a new part is needed it is discussed with purchasing and the assembly plant engineering teams. Also, is in charge of authorizing decisions of thousands of pounds, such as alternative transportation methods (airfreight).
<i>Manufacturing Engineer Manager:</i> in charge of supervising the assembly line and ensuring it is running smoothly. Resolve any issues that arise such as defective parts and implementation of a new part. Also, coordinates with the materials planning and logistics manager for requirements or problems that may arise with the materials used.

Purchase Manager: mostly involved with program purchase. Each vehicle line has a program purchase team which interfaces between the engineering and the purchasing groups. So, if there are any questions from a vehicle's line business office or engineering group, they go through the program purchase team which then feedbacks to the responsible commodity groups. The team deals with supplier issues the vehicle line has, interacts with suppliers if a new part is needed and makes sure that the part is supplied at the right time, quantity and quality.

Supply Chain Supervisor: in charge of the supply chain analysts, makes sure that all parts arrive on target date and tries to solve any problems that arise with suppliers not shipping. Liaises with the logistics team when changes to the transportation network are needed for the delayed parts to arrive on time or when parts are needed immediately. Also, is involved with stock levels in the assembly plant and tries to make sure that the correct levels of stock are kept by sending cycle checkers for regular counting of parts and when there are discrepancies in what the system says compared with what is actually in stock.

Supply Chain Analyst: each analyst looks after approximately 500 parts and the target is to make sure the parts come on time and do not have excess stock in the plant. Thus, analysts interact continuously with suppliers and check through the system that parts are sent on time and that there is no excess stock but enough parts for production.

Logistics Supervisor: part of the logistics' team that has been outsourced to a third party. Designs and controls the inbound network for Europe and makes sure that carriers arrive to the assembly plant on time. Sometimes there is heavy traffic or suppliers are not sending on time, so the logistics team has to reschedule the network.

Logistics Analyst: overviews logistics network and is in constant communication with carriers especially when there is a need to handle any logistics problems such as transport rescheduling.

Interviewees' input was valuable to understand Alpha's supply chain operations, to identify possible sources of disruptions in the supply chain, to determine whether Alpha makes use of formal processes to handle these sources and to consider how these processes might be useful for SCDM.

6.1 Alpha Supply Chain

Toyota Motor Company was the originator of the 'lean approach' adopted by a number of automotive firms (Slack et al., 2007). Lean is an approach towards the removal of anomalous and wasteful practices in order to develop faster and more efficient operations which produce better-quality products and services at lower cost (Lamming et al., 2000; Slack et al., 2007). Alpha's production system is also based on the lean philosophy and tries to achieve the elimination of inefficiency

and waste in the production process by being cost effective and keeping limited stocks.

A simplified map of Alpha's supply chain (Figure 6.1) is presented in order to capture the basic operations and the global supply chain it operates in. The simplicity of Alpha's network design is based on not only confidentiality issues but also the need to identify sources of disruptions which are mostly not involved in the daily operations but in unexpected and rare circumstances occurring internal and external to the supply network. The supply chain map begins from the first-tier suppliers because Alpha isn't involved in any form of communication or contracts with its second tier-suppliers. As Fawcett and Magnan (2002) rightly noticed, few companies are actually engaged in extensive supply chain integration and most companies' supply chain practices are with their direct supply chain partners.

Alpha uses with its suppliers an information system which monitors what parts are in the plant or in transit (update where the trailer is) and how many pieces to use on a daily basis. In addition to the flow of materials and vehicles through the network from suppliers to end customers, there is also information, orders and capital flows moving in the opposite direction. In order to achieve a better understanding of Alpha's supply network, brief descriptions of the main actors and processes are presented.

Suppliers

Alpha cooperates with over 300 suppliers in total; Europe: 79%, Turkey: 15%, North America: 5% Africa: 1, and South America: 1. The majority of the suppliers supply more than one carline in the Company and also have more than one manufacturing site. The suppliers by having multiple manufacturing sites are more resilient because they can switch production between plants and one plant may back up a disrupted plant.

The Company has started applying a new supplier program in which it is reducing the number of suppliers for the different components but is increasing its level of

cooperation and commitment with these preferred suppliers. Through this program the Company is also increasing the use of common parts for multiple vehicles. This helps the Company's assembly plants cooperate in case of a disruption to assist the disrupted facility. But in case the supplier that provides the common parts is disrupted, the problem takes larger dimensions than if only one carline depended on the supplier, because a bigger volume of parts will need replacement but also production may be stopped in a number of assembly plants causing a huge negative economic impact on the Company. The Company, however, by having fewer suppliers can achieve lower costs, higher quality, improved communication, transparency on costs and volume data and increase innovation and teamwork with their preferred suppliers. The new supplier program is also similar to the Japanese model, where the buyer and the supplier develop a long-term mutual dependency, close communication and interaction between them (Wasti and Liker, 1997).

Quality Standard

The suppliers the Company is dealing with are Company quality certified suppliers and most of them are large global companies. The Company always encourages its suppliers to push all of the quality disciplines back into their tier-two suppliers as well. When a part is supplied to the Company, most of the suppliers, have to fill in a part submission form for the components stating that they can provide the components, that the part is completely production representative and that it meets all the specifications of the drawing. It may not be exactly the same Company documentation the suppliers use with their suppliers, but it draws upon the same processes and view of the specific product requirements from their tier-two suppliers. This procedure helps encourage quality of products along the supply chain and cooperation with suppliers that provide quality certified products to the Company.

Single Source

Originally the Company had three to four suppliers per part, but now for each part they have one supplier, aside from tires and rear springs, which they multiple

source. The single source suppliers provide competitive prices, quality assurance, technical innovation and higher levels of assembly. The Company, although using one supplier for a component part, is also knowledgeable of other suppliers in the market and certain of these suppliers may already be providing other parts to the Company. By having alternative suppliers for a component part, the Company may achieve lower costs at better quality if the single source supplier is aware that the Company may cooperate with another supplier. By maintaining competition between small numbers of suppliers and helping them develop, an automaker can ensure that the parts have the desired quality, performance and price levels (Wasti and Liker, 1997).

Multiple sources

Alpha multiple sources tires from up to six different suppliers. They chose tires due to the high volume required, to facilitate customer choice and reduce freight cost if vehicle plants are located in different continents. Alpha also dual sources rear springs because the company they originally sourced from couldn't meet the capacity, so they divided the required capacity between the original company and another.

Logistics

Logistics is the process of strategically managing the procurement, movement and storage of materials, components, finished inventory and information flows through the firm and its supply chain, in order to maximize current and future profitability through the cost-effective fulfilment of orders (Christopher, 1998). Alpha has outsourced its inbound logistics services to two major logistics provider companies, one mainly for Europe and one for America. The company for Europe is the lead logistics partner for the Company and takes control of the inbound network, trying to manage it efficiently. It also designs the network, chooses the most optimal distribution centres and then Alpha chooses the carrier (e.g. affordable cost, balance between quality and cost) and makes certain changes to it. The Company prefers to outsource inbound logistics to companies that have many years of experience and logistics is their core business activity, thus the companies

have the knowledge and experience to perform effectively and efficiently the related activities. Also, because the assembly plants maintain low levels of inventory, good planning of the transportation network and delivery of goods is essential for lack of delays. For the procurement site of the business, the purchase department of the Company is in charge of the supplier contracts. For outbound logistics the Company uses its own carriers because it is aware of the processes and is a core function.

Transportation

A multi-modal transportation system is operated through the network. This provides flexibility because Alpha can change transportation methods if, for example, there is a strike at a port or bad weather conditions that block rail. The different methods of transportation normally used are: *Americas and Africa*: ship, *Europe and Turkey*: train and trucks. Airplane is an alternative method of transportation in case there are delays in receiving the parts which can affect production.

From Europe and Turkey the trucks go to the different Origin Distribution Centres such as Prague, Paris and Madrid, where full load of supply materials to these centres is achieved and then distributed to the scheduled plants. Trains, on the other hand, although follow the same process as the trucks, typically follow different routes.

An additional two truck transportations are used: Milk Runs and Less than Truck Load. Milk Runs are used when there are two to three suppliers located in the same area and together comprise enough materials to make the full load e.g. one truck that goes gradually to each supplier. Most of the milk runs go to an ODC, but some of them go to a train terminal. On the other hand, with Less than Truck Load, a truck goes to one or possibly more than one supplier and then goes to an ODC.

In America the trucks and trains go to Canada and then are loaded on a sea container which usually goes to the nearest U.K port to the plant, but sometimes

due to reasons such as heavy traffic, the ship goes first to a neighbouring country and then to the U.K port.

Inventory

As soon as the parts inventory leaves the supplier's plant and is on the Company's truck, it is on Alpha's inventory. When the material is in the plant and is built into a vehicle, the vehicle is still on Alpha's manufacturing inventory until it is gate released, and when the vehicle starts its outbound journey is on Alpha's sales company inventory. The vehicle then goes to the dealer and once the dealer buys the vehicle, it is on the dealer's inventory.

When a supplier forwards the materials, an ISN (in-advance supplier notification) is entered into the system, which takes into account that the load is on its way because the supplier inputted it into the system, saying it has left the supplier and is on route. So, the stock control system shows what is in plant and what is in transit.

For each part they keep different stock levels. The stock kept is based on the calculation: average daily use of part * cost of part. From the calculation, the lower the number the more stock is kept. Where the stock will be located in the warehouse is governed by the point of fit and the type of part.

The majority of the stock is in the plant (warehouse, market-place), but they also have limited stocks outside the plant. As an example, exhausts are sequenced by a place 20 minutes away from the plant. The need of having parts (e.g. engines) outside the plant is because there isn't available space in and around the plant, so they can't expand at all. As space is a constraint, they have to utilize other warehouses. This is also helpful in case the plant is disrupted by a natural hazard because not all parts will be destroyed.

Alpha Supply Chain Map

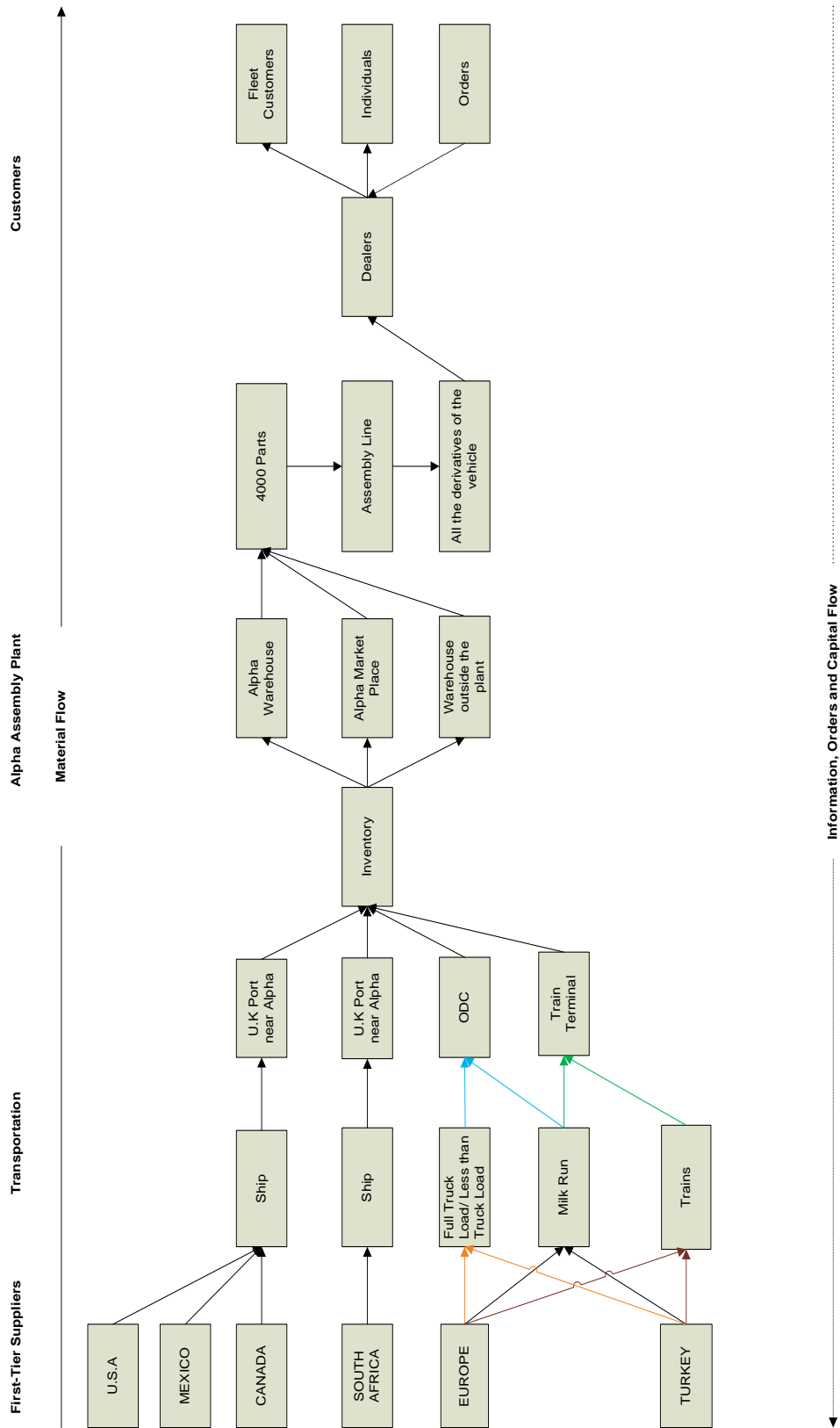


Figure 6.1 : Alpha's Supply Chain

Production

'What I have to recognize with this vehicle is that it is a unique animal. If you go into a dealer to order an Alpha, there are over a thousand different types you could order'. Purchase Manager

The time required to build a vehicle is about two days and 90% of all the vehicles they produce are customer orders. Alpha's production line operates 18 hours from Monday - Thursday and 12 hours on Friday with the potential for extra shifts on Saturdays with a reduced workforce.

There are nearly 4,000 parts for the assembly plant. A number of parts are usually supplied by the same supplier, for example, they may supply a type of valve with different configurations. They set the sequence at the beginning of trim, to call the parts from sequence suppliers and they keep that sequence until the vehicle comes off the line, so they can't take without physical intervention any vehicles outside the sequence. Sometimes they stop for a quality stop and if it is serious, they may halt the whole line.

In the assembly line the employees are not as flexible in workstation rotation as Alpha would desire. Although there is labour mobility, it's not always easy to move employees around different jobs because there are restrictions such as medical restrictions where certain employees can do certain operations at a certain height and use certain parts of the body. Thus, Alpha has to make sure that workstation rotation takes into consideration these restrictions.

Parts

Significant and non-significant parts are classified in terms of line stoppage, whether it can keep on assembling or not. In case a significant part is unavailable they have to stop the assembly line because they cannot build the vehicle without it, or leave the vehicle in the buffer zone. The buffer zone has a certain capacity and it depends on the part (e.g. engine) on how much capacity will be allocated to it. If it is a part for every vehicle, then production must stop if it cannot be fitted later on. Engines, instrument panels and insulations are critical parts and if not

available, they stop production. Alpha can still build the vehicle but there is so much repair time that it's not worth carrying on. If it is a non-significant part, Alpha can produce the vehicles and fit it later. When the vehicle is finished, although it may fail the end of line tests, parts can be fitted later on. Sometimes and very rarely because it is very expensive, dealers may fix a parts problem.

Dealers

The dealers are companies that market and sell the vehicles on behalf of Alpha, thus they directly face the customers. They also provide after sales services to the customers such as vehicle repair and warranty services. Ultimately the Company pays for changes needed under warranty. When a vehicle is returned to the dealer to change a component under warranty, that component should be returned to a central location in the Company, which they would then send back to the manufacturer that would try to identify what caused it (e.g. design issue, manufacturing problem) and actions to improve the manufacturing process. Additionally, the dealers provide the company with important feedback such as customer satisfaction.

Customers

After the vehicle is sold, the after market customer service maintains extra capacity for the parts that are required in case, for example, a vehicle breaking down or a part needing to be changed. Trying to achieve and maintain customer satisfaction, the Company operates customer clinics, mainly for their fleet customers, where it listens to the critiques about the current products and how they would like the Company to enhance them. In addition, it performs benchmarking against competition, and in conjunction with customer clinics, tries to understand what the needs of its customers are. Then, the feedback is pulled together to establish what the content of the next generation vehicles should actually be.

6.2 Sources of Disruptions

When a risk materializes and it is threatening to stop the production line, Alpha will try to implement alternative actions (e.g. airfreight) that will help maintain the continuity of production. If the production line stops, it will cost Alpha millions of pounds. Sometimes though with disruptions such as fire, strike, flooding and terrorist attack, it is very difficult to keep production running. In this case, the company needs to already be implementing plans that will make the company and the supply chain more robust and resilient to supply chain disruptions.

Based on the interviews with Alpha's personnel, disruptions that Alpha has encountered and their sources were identified and listed. These are:

- *Strikes*: Alpha usually has to deal with an industrial action in its supply chain about two or three times a year with some countries being more prone to industrial action than others.
- *Transportation*: rail is not robust due to engineering work on lines, breakdowns of network, traffic and bank holidays (every country different). Moreover, there are risks of crossing the different national borders until a vehicle enters the European Union where the boundaries are tariff free. Even then there are still sometimes problems in the tariff-free E.U. network. Furthermore, suppliers that are long distances away (e.g. exhausts that come from Africa, petrol engines from America) are a risk because sea freight is unpredictable, particularly the transatlantic route because it is so busy and Alpha is a small buyer of transatlantic sea freight, so it cannot affect the routes and times followed by a ship.
- *Natural Hazards*: bad weather conditions especially in Europe. For example, bad weather conditions at the North of Spain in February 2007 affected transportation routes and revised transportation plans needed to be developed on a day to day basis in order to maintain the continuity of the production line.

- *Supplier Issues*: fire at a second – tier supplier: as they weren't able to make any parts, the first tier supplier had to find an alternative supplier in order to continue supplying parts to Alpha.
- *Production Problems*: equipment breakdowns
- *Stock*: The information system sometimes shows stock on screen that there are, for example, 300 pieces of part A in stock but in fact there are physically only 50 pieces in stock due to employees' not updating the system and misallocating parts.

The sources of disruption of most concern to the materials planning and logistics manager are: (1) Supplier did not send the materials, (2) Transportation issues and (3) Industrial action. The supply chain supervisor is most concerned with: (1) Supplier issues, (2) Transportation issues and (3) Insufficient stock for the assembly line. Supplier issues that result in not sending the part and transportation issues that also relate to not delivering the part have the same importance for both managers. The managers are familiar with these types of disruptions because they are linked to their daily business and the managers are aware of the possible consequences, such as closure of the assembly plant. Further, the materials planning and logistics manager ranks as an important source of risk industrial actions which require supply chain reorganization. In the wake of these, production planning with suppliers needs to be arranged and changes in transportation routes have to be made, translating into additional cost and time and, despite these changes, production may be stopped due to the unknown duration of the strike. If the industrial action is in house, there is an immediate effect on production, which may be halted, with millions of pounds lost. On the other hand, a source of disruption the supply chain supervisor is concerned with is the limited stock levels kept, a key feature of the lean practices Alpha employs. If the materials planning and logistics manager decides to increase the stock levels, justification to senior management is needed, explaining why more stock (millions of pounds) is required when increased stock levels do not comply with the Company's lean production system to keep limited stocks. Although

additional inventory would decrease Alpha's vulnerability to supply chain disruptions, it would also disregard the Company's lean philosophy (e.g keep limited stocks, removal of wasteful activities, development of best practices), which guides the operation practices in Alpha.

Although at Alpha they have encountered and are aware of disruptions such as supplier issues and transportation problems, there are also other disruptions that can cause a high impact on the supply chain. Alpha may not have considered them because they haven't experienced such types of disruptions so far. Some plausible potential sources of disruptions can be an economic crisis, which was highly evident in 2009, computer virus attacks and diseases. These are sources of disruptions which haven't been considered and may cause the closure of the assembly line for an extended period of time if no contingency and risk mitigations plans are developed.

Interconnectivity between different sources of disruptions may be evident and the occurrence of one disruption may initiate in parallel another source of disruption. For example, a closure of a Canadian port due to strikes which may continue for more days than expected and may cause transportation limitations because available airfreight is unavailable or too expensive. Transportation limitations means goods caught up in transit leaving manufacturing companies unable to produce their products because they are short of the necessary materials. Thus, when developing proactive RM processes, not only does the variety of the different sources of risks needs to be identified, but also the interconnectivity of these sources needs to be determined. Sources of disruptions are not static points in a stable environment. They materialize in a dynamic and changing environment which affects the relations between these sources.

6.3 Managers' Risk Perception

The purchase manager, the materials planning and logistics manager and the manufacturing engineer manager were asked about how they conceptualize risk and disruption, and if they distinguish any substantial difference between the two. Their replies heavily depended on their position and experience at Alpha. Whether

the managers concerned are operational supply chain specialists or CEOs with an eye to shareholder value and corporate governance requirements, research suggests that each will perceive supply chain risk through the subjective lens of their own goals and performance measures (Peck, 2006).

First, the purchase manager conceptualizes risks and disruptions as the same, with no basic difference between them. Risk is related with supplier issues that Alpha usually encounters. These can include the supplier not supplying the parts, poor management and capacity planning at the supplier's organization, not having sufficient capacity on their machines, not getting the right return from their machines, not maintaining the tools properly and machine breakdown in the facility. These risks were attributed to the lean practices companies are trying to achieve by avoiding holding stocks. These risks, though, will be present even if the supplier keeps larger stock levels because suppliers, by having limited stock, can detect the operational problems and try to solve them than depending on stock which will contribute to unresolved operational issues, which can affect production and product quality. The risks the purchase manager referred to, if not controlled and handled at an early stage, can develop into a disruption and affect the continuity of Alpha's supply chain. Due to this, the Company needs to work more closely with certain suppliers in order to resolve issues that can negatively affect the availability and the quality of parts.

The manufacturing engineer manager, by having an assembly plant position, visualizes risks differently from the purchase manager but also views risks and disruptions as the same. Risks from his point of view are those that can arise in the assembly line such as volume loss because Alpha can't produce, quality risks because the vehicles have to come off line which means extra repair time and extra time for vehicles on wheels, health and safety risks and also risks to damaging equipment which lead to risk in volumes. From his examples of what risks are, they may be considered possible sources of disruptions due to the effect they may have on the loss in production volume, and anything that causes this may be considered a source of disruption. No other types of risks are considered

because they haven't materialized until now inside the assembly plant and the manufacturing engineer manager is only familiar with risks that were encountered.

Finally, for the materials planning and logistics manager, risk or disruption is anything that will either stop production or cause Alpha to build vehicles with parts missing. Anything that may cause production to stop is a source of disruption. Thus, the manager defines disruption as the result of a number of sources materializing which will have an impact on stopping production or building vehicles with parts missing. The manager also recognizes that there is a potential of risk in every single supplier they have, in every aspect of the supply chain and from whatever country it is coming from. The most likely risks that can affect the continuity of the assembly line are: sea freight which is unpredictable, some suppliers' performance which needs to be monitored and long-distance of suppliers, thus long lead times. Disruptions such as September 11, 7/7 in London, flooding in the north of England, or even a tsunami are never considered, because, the manager can't plan for those. If they happen, Alpha will find a way around them. The materials planning and logistics manager demonstrates that Alpha is reactive to rare events with a high impact that cannot be controlled by a company. A company though with the necessary plans and by being proactive can be protected by such events.

From these three descriptions of risk perception, we can conclude that Alpha managers perceive risk and disruption as the same because there is no clear distinction between the two concepts, and the only risks they consider are usually related to their daily operations. For most cases, Alpha has already developed contingency plans and capability teams to respond to operational disruptions because these are disruptions they come across often which affect their daily business. For rare disruption events which they cannot plan for are not considered, thus, in a rare event situation, a reactive response is implemented and in case such events materialize, the negative impact will be huge for Alpha and its supply chain.

6.4 Current Disruption Management Strategies

‘Something that the company is good at is fighting fires, if things go wrong they are very good at reacting and fixing it. I would prefer we would get better in our upfront planning.’ Materials Planning and Logistics Manager

This statement from the materials planning and logistics manager underlines the company’s effectiveness in dealing reactively with operational risks, risks that are in their daily activities. But what happens in the case of a disruption materializing that they have never handled and that is unfamiliar to them? That’s why the manager stresses the need for upfront planning. Upfront planning will help Alpha develop competencies and familiarize the personnel with handling sources of disruptions proactively.

Alpha is aware of the operational risks accompanying its business, and has in place reactive and contingency plans such as technical assistance to suppliers, cycle checkers, incremental tooling and vehicle pre-production processes. This case study focus, however, is supply chain disruptions and the proactive processes Alpha employs that help the company be more robust and resilient to disruptions. Strategies that are currently operated by Alpha and can mitigate supply chain disruptions are listed in Table 6.2 and then described.

Table 6.2 : Alpha’s Disruption Management Strategies

Risk Mitigations Strategies	Benefits
<i>Unions:</i> collaborate and discuss with unions, collective bargaining process, develop agreements	<ul style="list-style-type: none"> ▪ Satisfied employees ▪ Good relation with unions ▪ Avoid strikes
<i>Warehouses:</i> hire a warehouse, stock in the Origin Distribution Centre, trailer parks, number of warehouses used inside and outside the assembly plant	<ul style="list-style-type: none"> ▪ Alternative warehouses ▪ Limited stock in warehouse ▪ Lesser possibility a disruption affects all stock
<i>Stock:</i> same type of stock kept at Alpha and Zeta plant, plants exchange stock if needed but usually of smaller parts, stock parts in case of disruption, stock pilfered parts in special secure place	<ul style="list-style-type: none"> ▪ Cost effective ▪ Continue production ▪ Avoid disruption for a period of time ▪ Secure pilfered parts
<i>Common Parts:</i> reduce complexity of components	<ul style="list-style-type: none"> ▪ Exchange stock

across vehicles lines, employees flexibility, customer packs	<ul style="list-style-type: none"> ▪ Continue production ▪ Simpler manufacturing processes
<i>Spare Capacity:</i> suppliers provide extra 10% production capacity above Alpha's requirement, incremental tooling	<ul style="list-style-type: none"> ▪ Deal with uncertainty ▪ Hold less inventory ▪ Flexible production rates
<i>Employees Flexibility:</i> 10% absence rate cover, team leaders	<ul style="list-style-type: none"> ▪ Maintain production rates ▪ Flexibility in production
<i>Flexible Sourcing Strategies:</i> single source, multiple source, alternative suppliers, global suppliers, demerit points	<ul style="list-style-type: none"> ▪ Necessary back-up ▪ Continuous supply of materials ▪ Quantity flexibility
<i>Supplier Assistance:</i> assistance the Company provides to suppliers, importance of supplier	<ul style="list-style-type: none"> ▪ Continuity of product supply
<i>Flexible Transportation:</i> multi modal, special truck, airfreight, transportation networks	<ul style="list-style-type: none"> ▪ Prevent supply chain operations stopping ▪ Flexible logistics strategy ▪ Switch carriers quickly
<i>Insurance:</i> self-insured	<ul style="list-style-type: none"> ▪ Protection against accidents

Unions: The Company works closely with labour unions to develop agreements and governance plans through a collective bargaining process. This collaboration and discussion of the employees' problems and requests may result in avoiding strikes that may affect production for several days.

Warehouses: If a warehouse catches on fire or is destroyed partly by a storm or flooding, they will try and find an alternative warehouse straight away. Alpha can hire a warehouse, stock in the Origin Distribution Centre or at the trailer parks. Alpha hasn't got in place prearranged agreements but believes there are several available warehouses that it could hire. If it is a warehouse run by another company, then it's up to them to address it. To illustrate, the people who store exhausts for them are another company, so they would have to find another location to store the exhausts and Alpha would have to fly some extra stock in, and they would try together to salvage what they could from the wreckage. Due to the JIT principles Alpha adopts, the amount of stock kept in the warehouse is very limited, and thus most of the parts are regularly in transit. In case of a disruption, production won't be affected as much as in the case where more stock was kept in

the warehouses. Additionally, all parts are not kept in one location, diminishing the probability of having all parts destroyed in one place.

Stock: The same type of vehicle is assembled in two plants, Alpha and Zeta. Thus, on the occasion that Zeta requires a part that is in stock in the Alpha plant, and Alpha plant has enough stock for its production, then Zeta buys the stock from Alpha. For example, a supplier in France had a quality issue that lasted for 12 days. The Alpha plant had used all the defective components from the French supplier so Alpha decided to solve the problem at the dealers. Alpha plant's transit time is two days from the French supplier, and Zeta's, 9 or 10 days. The entire stock Zeta had was quality defected stock, so they requested from the Alpha plant to send them 500 parts. Alpha, having enough stock at the plant and knowing there was stock in transit, decided to provide them the requested parts. To deliver them, an employee placed the parts in a bag and travelled by plane to the Zeta plant. Having two assembly plants that use the same parts is very helpful in situations where one plant needs parts that are missing and the supplier can't provide them immediately without incurring extra costs and time. A problem though, is that if the supplier sending the part to both plants faces a disruption, the effect is to both plants much greater because the two plants will be competing for finding parts from an alternative supplier or getting available parts from the existing supplier.

On occasions when Alpha is notified that transportation will be affected, impacting on Alpha's production, then stock will be built up, and if it is threatening to stop production then higher levels of stock will be kept. For instance, since all the Portuguese and Spanish materials pass through France by train, if there is a major rail strike in France, then all the Portuguese and Spanish vendors will send an extra two- day stock to protect Alpha from staying without stock. However, the problem is that if the strike continues for longer than predicted and the stock levels are not adequate for continuing production, then production will be halted. The most typical solution Alpha applies in such situations is expedited transport.

Pilfered parts: Alpha uses a special secure place where they keep parts that can be stolen, usually from their employees. Parts that are considered pilferable such as radios, phones and gears are counted once a month instead of the audit requirement which is once a quarter, so that Alpha can monitor stocks more frequently and be aware if such parts have been stolen.

Common Parts: A process Alpha is currently working on is to reduce the complexity of components, by standardizing components across vehicle lines of the Company. Components may be used across vehicle lines; thus if one plant has stock problems another plant with excess stock may provide the required components rather than waiting for the supplier to send them, which may take longer. Additionally, employees may be able to move between plants if one plant needs extra workforce because they will be familiar with the parts they need to install. Also, the Company is trying to minimize the variations between vehicles by developing customer packs; the customer may choose the comfort pack which may have five or six different characteristics in it although the customer may have four options of characteristics to choose for a vehicle. Thus, the complexity of the product diminishes and manufacturing processes will become simpler and more cost effective because lesser variations between vehicles will be used.

Alpha has common parts with other plants in the Company, such as switches and steering wheels. If a disruption affects a few automakers supplying the Company, the decision is made centrally to which automaker to allocate the limited resources. The decision is usually based on which vehicle line makes the most profit, and the vehicle line Alpha manufactures is considered the most profitable one across the Company, meaning that Alpha will be the first plant to receive the parts.

Spare Capacity: Alpha expects suppliers to have an extra 10% capacity above what Alpha's normal requirement are regarding the supply of components. The extra 10% is mainly for Alpha's after market demand. Based on what the supplier agrees to have installed for the Company, the supplier is advised to have an extra 10% capacity, which the Company pays if any incremental tooling is required to accommodate this extra 10%. If a disruption materializes, Alpha can use this extra

capacity from the supplier's plant and order the extra parts needed. Incremental tooling can increase production at the supplier's plant only when the supplier has enough resources to support the extra production required.

Employees Flexibility: If there are employees absent or extra capacity is required at a certain workstation, an employee from another workstation will be required. Alpha has a 10% absence rate cover in order to have available employees cover the required jobs and also has group leaders that perform all the job tasks that are executed by their team. Thus, employees can be replaced without affecting the production rate unless the absence levels are greater than 10%.

Flexible Sourcing Strategies

Alternative Suppliers

There is a list of alternative suppliers the Company can refer to in case a supplier becomes idle. This list is not for each part independently, but for a particular commodity product (number of parts together) such as discs and shock absorbers, which helps identify other suppliers that are able to supply the commodity. So, if there is a problem with a supplier, the Company is knowledgeable about the best suitable alternative suppliers that can provide the commodity product. In this way, the Company does not spend time and effort identifying a suitable commodity supplier. In fact, the alternative supplier may already be providing commodity products to the Company.

Global Suppliers

If there is a fire at a supplier, maybe the business would move to one of the suppliers' other manufacturing facilities. Global suppliers have manufacturing facilities throughout the world and in order to protect themselves from such instances, they try to install machine commonality in all of their manufacturing facilities, so they have the flexibility to move production from one plant to another. Having global suppliers reduces the probability that Alpha will not have a part or component when needed.

Demerit Points

Usually suppliers notify Alpha in case they are unable to send the agreed upon parts. If they do not notify them, Alpha issues them demerit points which are built into a scoring model affecting them negatively, which may terminate their contract if the score is high. Also, if the supplier is late, Alpha may expedite transport which is paid by the supplier. If the supplier does not agree to pay for the transport, legal actions are taken.

Supplier Assistance: the level of assistance the Company provides to suppliers depends on who the supplier is, how willing they are to help the supplier recover and how long it will take the Company to find another supplier. The Company helps suppliers depending on the commodity product they offer and how difficult it is to find an alternative supplier who can provide the required quantities at the price and quality needed.

Flexible Transportation: Bad weather conditions were present in the North of Spain in February 2007. In order to deal with it, monitoring at 2-hour intervals was set up, dealing with each component on a case by case basis. When the network breaks down, the logistics team finds an alternative route and then asks the materials planning and logistics manager for cost approval. Depending on the cost required for the alternative route, the decision in Alpha goes up hierarchically. The maximum airfreight the materials planning and logistics manager had to pay was a six-digit number. If it is the supplier's fault, then it usually pays for the airfreight. Airfreight is generally very expensive so Alpha only uses it in an emergency situation.

In a case where changes in the network or changes due to time constraints have to be made, these following possible solutions are usually used:

- Special Truck
- Airfreight

1. Normal airfreight with a company that has a scheduled flight every day from different airports.
2. Air Charter (hire a plane) to go solely to an airport next to the Alpha plant. This is applied if it will stop the production line.
3. Hand Carrier, e.g. screws

Communication is generally good through the supply network and in the possibility of a disruption, Alpha can be notified by transportation networks and emails. In the possibility of a strike, the unions have to notify plant management a few days before.

Insurance: Alpha is self-insured with a very high deductible that runs well into excess of 7 figures. They have a legally binding agreement declaring that in specific events, Alpha is self-insured. There are parts of the business that Alpha insures outside, but for the bulk of their business is self-insured. Most of Alpha's stock in the network is covered by self insurance, so in the contract with the carriers this is made clear.

Alpha has contingency plans in place and is very effective in reacting to operational risks and certain sources of disruptions such as strikes and transport limitations. This is because these are disruptions they have encountered in the past and they have developed response scenarios which they have executed more than once. For other disruptions such as fire at second-tier suppliers and natural hazards affecting suppliers, although unusual, Alpha eventually finds a solution. When a fire affected a second-tier supplier, Alpha was lucky because the part affected could be supplied by other suppliers; thus the first-tier supplier easily found an alternative supplier. In case of a disruption with a steel supplier or a supplier of a unique critical component, the situation becomes much more difficult because even if they find an alternative supplier, it may not have the capacity for the volume needed by Alpha, and until the supplier builds the necessary capabilities and capacity, Alpha may lose many days of production.

Alpha has many similarities with those presented in Table 3.1, which are the usual practices companies follow such as flexible transportation, sourcing strategies and spare capacity. Table 6.2 in relation to Table 3.1 also refers to supplier assistance and unions, which demonstrate the good relations Alpha wants to have with both suppliers and employees to avoid unnecessary disruptions. Having warehouses inside and outside the plant decreases the possibility of all goods being destroyed by a disruption at the assembly plant. A drawback is that extra handling and storing costs incur in maintaining the warehouses. Additionally, Alpha is self insured, so instead of paying premiums to insurance companies, it has a deductible amount that can be used in case of accidents or financial losses. Table 6.2 is not as detailed and informative as Table 3.1 regarding strategies such as standardization. These additional SCDM strategies which Alpha can apply are proposed in Table 8.5 with the related benefits and drawbacks.

6.5 Conclusions

Alpha does not implement formal RM processes so it can identify the possible sources of vulnerability as most of their SCDM strategies are based on experience and ignore potential threats to the company that haven't been realized. Therefore, effective and efficient RM strategies could be developed. Alpha could apply processes that will serve dual purposes, processes that will be applied not only for the smooth daily operations of the company but also in the rare event of a disruption, these procedures will help the company deal with the negative effects of a disruption.

However, barriers exist for the development and use of proactive formal processes for disruption management. First, in order to overcome these barriers, the support from the Company's senior management is required. Managers are busy with specified duties that there isn't available time to think beyond their everyday activities. Even if managers want to initiate a different way of thinking, this mindset must be applied throughout the whole Company, which requires top management's approval and the development of a RM culture.

Alpha though has started developing business continuity plans as is a requirement from the Sarbanes – Oxley Act. Alpha needs to develop plans in order to respond to situations such as:

- Fire in the paint shop; would they halt production, would they make the auto bodies and take them to be painted in a different location and then bring them back to the plant for the trim phase?
- Failure of the vehicle scheduling system which controls 90% of the plant; would they be able to work through it manually?
- The information systems network goes down and information is not accessible from the suppliers; could employees be sent home, able to work via laptops and telephone?

Each department in Alpha requires a business continuity plan for its important operations, so in the case of a disruption, the important processes, controls and activities will continue to operate. Alpha has not completed this yet, but they are in the process of doing it. Business continuity is related to predicting things that may go wrong and taking planned and rehearsed steps to protect the business and hence the stakeholders' interests. It is about co-ordinating and incorporating all the planning processes across departments and presenting a confident image to the outside world (Reeves, 1999).

Thus, by trying to maintain the continuity of basic operations in case of a disruption, demonstrates that a RM culture has started developing in the plant; this can be the basis for the development of proactive RM processes, thus moving away from the phase of just having a reactive culture in the case of a disruption. Managers and employees are getting involved in a process in which they need to think about 'what if' scenarios and plausible solutions to such scenarios. Additionally, due to the fact that the Company has a strong presence in the market and suppliers count on its business, the Company can wield this market power by expanding their RM culture to their supply chain partners to achieve mutual benefits such as decreased operations costs and better information sharing.

7 Water Utilities Company Case Study

Following the auto-manufacturing case study which provided information on the strategies for handling disruptions by applying reactive and proactive approaches, a second case study company applying formal RM processes was considered helpful in understanding the usefulness of a formal process, the complexity of the issues involved, and how this process is applied in a company setting. This would help in understanding how two different types of companies handle possible sources of disruptions and the reasons for this. Also, the RM processes and tools the water utilities company uses for SCDM were considered useful for informing the RM iterative process in figure 4.1. This analysis will help view the application of SCDM in a real-life context environment and identify the challenges and benefits of having a formal SCDM procedure.

The second case study is Beta (imaginary name), a water utilities company, which provides water services to customers. Beta's stakeholders are direct customers such as households and large water users such as schools, universities, hospitals and banks. Beta tries to ensure constant delivery of water at the best possible quality. Due to this, projects are being undertaken to ensure network integrity and to satisfy increased water demand due to increased population in the next few years.

Beta Company was chosen because inability to offer the product which is water, a basic need for a person, will result in serious disruptions to customers such as health and safety problems. Additionally, Beta is a well organized company that has incurred disruptions in its distribution network and this experience of dealing with disruptions will help develop useful approaches to dealing proactively with supply chain disruptions. Furthermore, because it has to comply with regulations regarding the continuity of water supply 24/7 all year around, Beta has developed RM processes to try and avoid disruptions affecting them.

For the required information, four employees of Beta were interviewed, chosen based on their position in the company and their knowledge and experience related to SCDM. In Table 7.1 the job descriptions of the interviewees are:

Table 7.1 : Job Descriptions of Interviewees

Job Descriptions of Interviewees
<i>Operations Manager:</i> responsible for the clean water sides where they abstract and treat water from rivers and bore holes. The operations manager has a team, who will monitor, maintain and check all the plants and equipment that are associated with the water production and distribution sites.
<i>Risk Consultant:</i> first contact in Beta for anyone that wants to use the RM software. The risk consultant ensures that anyone using it is trained, knows how to use it and the reason for using it. The risk consultant also manages and facilitates the hierarchical process of the operational risk meetings, although the risk consultant does not manage any specific risk. The job is to aid and assist employees so they know how to look after their department's risks.
<i>Business Continuity Consultant:</i> looks after the business continuity management for Beta. This entails facilitating departments rather than front line operational to carry on in the event of disruption or an event as it is called in Beta.
<i>Supply Chain Manager:</i> managing the purchased-paid side, which involves the physical buying of materials and payment of suppliers.

7.1 Beta Supply Chain

Beta's supply chain is different from Alpha's supply chain regarding the physical flow of parts. In this case 'parts' is the water which is abstracted and then treated through a number of processes and then delivered for customer consumption, thus having one operator for the entire network instead of having hundreds of suppliers as in Alpha's case. However, the water supply chain (Figure 7.1) is supported by the products' supply chain used to maintain the integrity of the network.

7.1.1 Water Supply Chain

There are two main sources the water is abstracted from: rivers or bore holes.

When the water comes into the works from a river source,

- It will be pumped into the works

- It will then be passed through a filtration unit (to remove some of the big sentiments)
- If there are a lot of problems with some of the pesticides, an ozone treatment helps take out some of the pesticides. If the water is quite clean, the ozone process is bypassed.
- A number of different chemicals will be added, depending on the starting water quality, and it will then have another filtration process.
- At the end of the process chlorine is always added; this is the final disinfection point before the water is taken off site.
- The water is pumped off site into the network.

With bore holes, ground water is normally much easier to treat as it is generally very clean, so with water from a bore hole, Beta abstracts ground water which passes through a simple treatment with some chemicals, then chlorine is added before the treated water goes off site. Some of Beta's bore holes sites are small sites that only supply a small number of people and others can be much larger, supplying thousands of customers.

When the water is initially taken offsite (river or bore hole), it's placed into a storage reservoir. There is a control centre that controls the water levels in the storage reservoirs. There are a few storage reservoirs which are used as buffers. One site may have many reservoirs. The water from a water treatment site, for example, may go to two large storage reservoirs holding water that will last for 8 to 12 hours, and then it will gradually feed out into the supply zone. They fill the reservoirs overnight when there is low demand, so during the day there is flexibility in the water system.

After the water is treated, it may either go to a service reservoir or directly to a trunk main. After the water is treated, it is stored in service reservoirs in between the main works and the customer before it is distributed to the latter. Trunk mains

are large pipe works that run with treated water across the clean water network feeding the demand zones by supplying the smaller pipes in the zones.

Treatment Works

As the water goes through the treatment procedure, it will pass through a different process each time. One part of the process can be isolated from another part. At the end, there is a contact tank with the chlorine at the end, and when the water comes out from the contact tank, there are two pipes which then go out into the network. Generally most of the sites have one pipe coming in.

Some water treatment works typically used at 20% capacity are run at 80% capacity during the summer. Decisions must be made about when to start ramping up the treatment from particular sites and whether more pumping is needed overnight to get the reservoirs to a higher level, enabling adequate supply during the day. Occasionally some sites close down because no water is available because it has dried up and alternative sites must be used. In some instances pipes interconnect different works.

Some sites are more cost effective than others; some sites are very cheap because they do not need many chemicals and there are other sites where expensive treatment is needed because the water quality coming in is very poor, due to sentiments in the river and farming land around the river, for instance.

Certain treatment works interconnect. Depending on the water quality that is being produced from the works, one works may be putting 30% of the water one day and the other works, the other 70%. In some district areas they do not have this flexibility. There are some district areas where there is no other way of getting water into that area aside from a bore hole, which can supply, for example, a few hundred customers. In such instances Beta must continue to pump and treat the water, sometimes having to use more chemicals that make the treatment more expensive.

Beta's Water Supply Chain

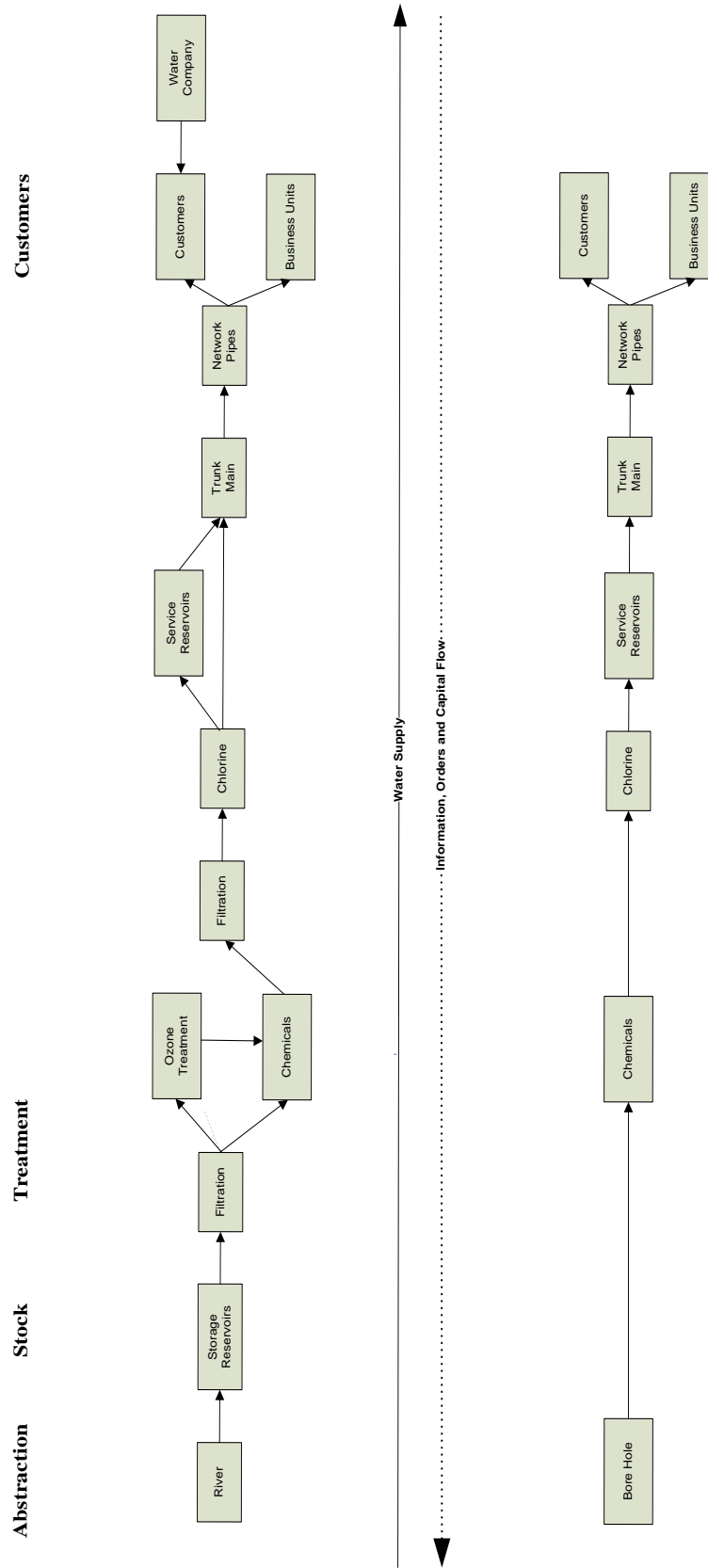


Figure 7.1 : Beta's Water Supply Chain

Cooperation with other Water Companies

Beta cooperates with other water companies to import water into some areas in order to supply a small number of customers, and then Beta exports water to one or two areas to supply customers of other water companies. Beta charges for such exports and pays for imported water though this is done on a small scale. During times of high demand, Beta will stop exporting water and normally the other companies will stop taking water from Beta so they can conserve their water usage.

Capacity Constraints

The water Beta is allowed to abstract depends on the abstraction licences from the Environment Agency, which sets the maximum amount that can be abstracted in any one day and the permitted annual average; more water can be pumped in one day as long the average of the year is not exceeded. In order to know how much water is abstracted, they use a meter that shows the amount taken. Moreover, there is a maximum amount of water that can flow through the water works at any time which can't be exceeded because it depends on pumping and the capacity of tanks.

Capacity constraints are not a major issue for Beta. In some areas where there are constraints, either new treatment works are being built or the capacity of the works has increased. In certain areas though with capacity constraints, no investments have been performed because it is too expensive to invest money for a small number of customers.

7.1.2 Product Supply Chain

Beta's product supply chain team negotiates with the suppliers and provides the inbound supply chain with key products and larger spend items. There is also a network of smaller, low cost, local and quick response suppliers that Beta does not get involved with in a formal procurement process because the value spent is not significant. Smaller suppliers are used if, for example, pipe freezing is needed

for installing pipes. Individual sites have their own network of suppliers for the day to day jobs. In Figure 7.2 the product supply chain is presented.

Procurement

Procurement has two distinct arms, operational procurement and capital delivery. The capital side is about formal strategic contracts, investing in building and maintaining assets such as new water treatment works. Operational support procurement is mainly built around framework agreements with suppliers and contractors to provide goods and services to the business. What the business spends its money on is aligned to demand. This includes product repairs, pipe fittings to keep distribution running and operational site support and security.

Suppliers

The suppliers are mainly from the U.K, but there are some suppliers in Europe, China, Russia and Korea with a ratio of 85% U.K suppliers and 15% international suppliers. Beta has agreements with U.K suppliers for pipes, fittings, electrical cables, chemicals, pumps and valves. A lot of the U.K. based suppliers have been providing Beta with products and services for many years. Furthermore, a few of the key product suppliers are international names; to illustrate, one supplier manufactures in the U.K. and in France.

Every time there is a new bid for a product or service, the suppliers are assessed financially and their capability is scored, for example, technically and operationally. Beta tries to make sure that suppliers are financially viable and that they are not likely to default in the near future. Very often they visit the suppliers' factories for health and safety as well as capacity issues before they get to the final assessment. When alternative suppliers are needed, they are identified based on the supply chain team's experience. Therefore, the supply chain team is aware of suppliers that Beta used before or suppliers that may have a register locally.

Single Source

The majority of the operational type products are either single sourced or single sourced with a back up supply, so if needed, Beta can switch suppliers. In the framework agreements there is flexibility to be able to source elsewhere. Beta prefers to single source items such as network pipes because the commercial side is normally advantageous to do so.

Dual sourcing

For chemicals and key treatment products, Beta has a main supplier and a reserve supplier because there is a key responsibility to treat water and maintain continuity of supply. There are two circumstances: one would be a formal dual sourcing for a chemical with 60% going to supplier A, and 40% going to supplier B. The other circumstance would be a single supplier with an agreement to fold back to supplier B with some capacity to produce at short notice. The formal agreement would state that in the event of supplier A being unable to supply, Beta would like to bring supplier B online within a short space of time.

Supplier contracts

A contract is usually for three years with an option to extend it to five years. The option to extend it to five means that the product needs to follow the quality standards and that Beta would do formal market testing before the end of the three years, to ensure that the product and the supplier are still market competitive. Market tests are performed twice a year on a product.

Beta's Product Supply Chain

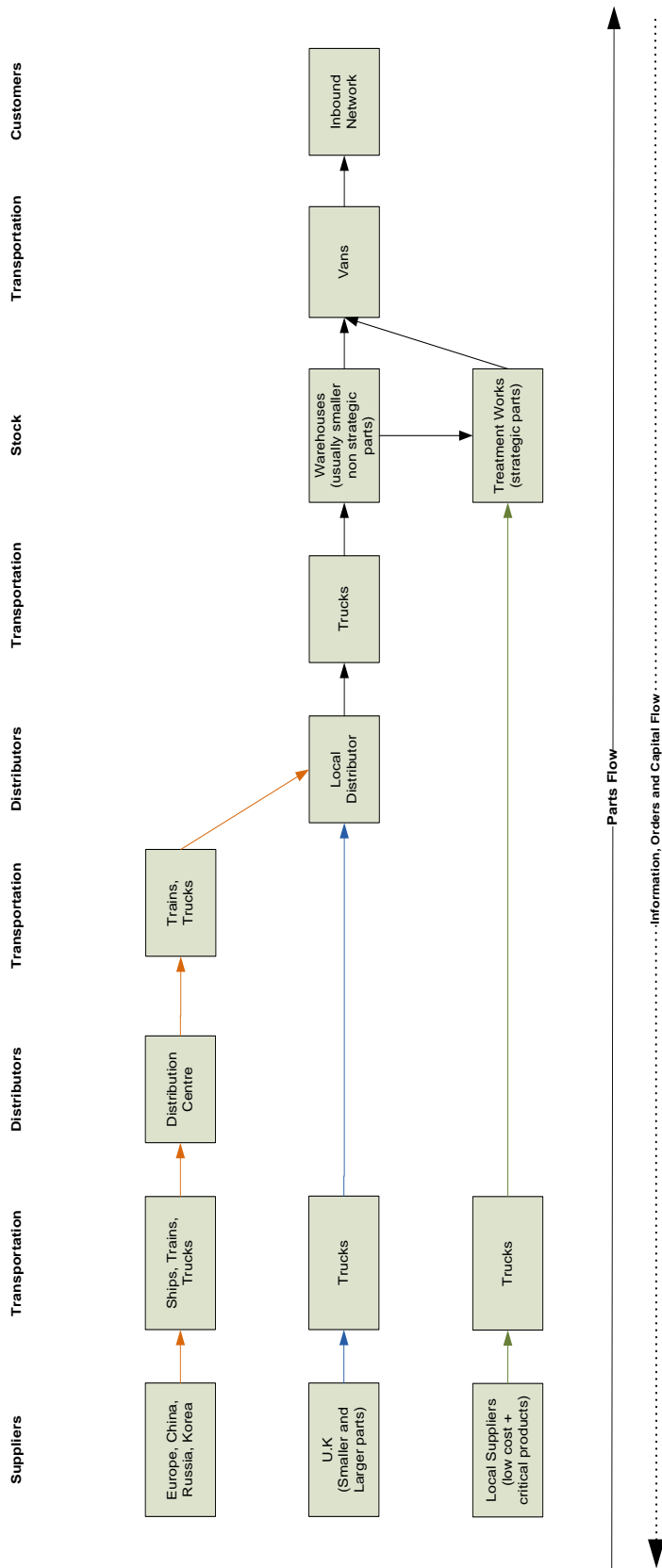


Figure 7.2 : Beta's Product Supply Chain

Critical and Non-critical Parts

A critical part is mostly linked with the maintenance side of the business. Parts that are used daily such as pipes, valves and fittings are critical to daily operations. Additionally, the spares of a particular pump that is critical to a pumping operation to keep water flowing are considered critical. Critical spares will be held directly on site or have very quick access to a local supplier. With the possibility of an event, for example a burst main, the supply chain team would look at the history of the sizes of mains that burst and generally these are the larger diameter mains, so it would stock critical parts such as valves and large diameter pipes. The lead time for large diameter pipes is from 10-13 weeks, so such critical parts are stocked. The larger diameter critical products are stocked at the water sites rather than in the warehouse to avoid their unavailability in the case of the warehouse being disrupted.

Logistics

Beta has outsourced the logistics function which looks after the running and stocking of the warehouse and the distribution of products within Beta as well as operating the urgent despatch of spares to certain parts of the business.

Suppliers are responsible for getting products into the warehouse, if it is a warehouse stock product, and are also in charge of the distribution and transportation of the product to the warehouse. Products sourced in the U.K. and also products sourced outside the U.K. that pass through an international distribution centre, are stocked by a local distributor who then transports the products to Beta's warehouse.

Stock

Stock is held on a just-in-time basis, which is the suppliers' stock on Beta's premises. Beta will inform the suppliers what it has used and Beta pays for it when the suppliers replenish it.

Warehouse

Beta has one warehouse which is located next to a good transport network for getting parts to any Beta site within a short period of time. At the warehouse they stock the smaller fast turnover nonstrategic parts and products. The more strategic parts and products are close to the sites that will need them.

In some operational sites there are areas that can be used for storage of parts. There are designated depots where the equipment is stored, and for each area there will be a central place. At the major sites, spares such as common sizes in pipes, valves and connectors critical for the daily operations are stockpiled.

7.1.3 Supply Chain Constraints

Beta's water supply chain has certain constraints such as storage and service reservoirs, for which Beta has identified and developed measures and back up plans in case of emergency, which lowers the likelihood that these constraints will cause a disruption. But if the measures and plans were to fail, it would cause a major interruption to water supply.

Chlorine: when there is complete failure of chlorine, water can't be taken off site. To mitigate this, Beta has more than one dosing point in the chlorine process in case one dosing point fails.

Storage Reservoirs: if the water level in the storage reservoirs drops too far, it becomes a constraint because water levels can't get back up in times of great demand. The control centre has minimum level alarms and if those alarms trigger, then employees are notified that there is a problem, as the level needs to be raised in the storage reservoirs.

Service Reservoirs: If there is water quality failure at a service reservoir (develops a leak resulting in some bacteriological failures in water quality) and it can no longer be used, it's not always possible to rezone the water (take water from another connected water site), especially in a rural area where they may be a few

villages and one service reservoir. In order to deal with such problems, more chemicals are used to improve water quality.

Network: in certain areas when the weather changes, pipes can become very cold and the ground can move. Ground movements can actually cause the pipes to move and to crack, which may cause a leak and then supply to customers may be impacted.

7.2 Sources of Disruptions

In Beta the majority of sources of disruptions are operational, such as burst water mains which lead to customers having no water supply, water quality, flooding and power failures. Water supply network risks are important because there are a lot of unknown factors like third parties damaging water pipes. Beta places great importance on risks related to security and continuity of supply regarding supply of chemicals, pipes and key products that would affect daily business and costs. Usually, the supply chain team has very few problems in actually providing products and services to the rest of the company. In the daily supply chain side of parts and products, there are few disruptions because it's very rare for suppliers to have any problems regarding their ability to supply Beta. 'I suppose we are quite lucky, we do not have big issues with disruptions' *Supply Chain Manager*. Below are certain examples of disruptions and their sources that Beta has had to deal with in the past:

Damage by Third Parties: a third party was working on the road and hit a water main. This was an unplanned event which caused major disruption to the services of the street and also in supplying water to customers. This was classed as a very high impact incident, but the likelihood of such event is fairly low.

Quality: quality problems arise when there are difficulties with chemicals on site and very poor water quality coming into the works, which prevents water being treated.

Fires: one of the small sites burned down due to a faulty electric heater and since then all electric heaters have been removed from Beta.

Flooding: one treatment works was flooded which became an emergency situation. The works had been flooded before, but this was a higher level flooding than previously experienced. To deal with it, a temporary connection from another works was made to supply customers. Customers did not see any impact, but it meant putting a lot more pressure on the other site, which then became a vulnerable and high risk site, because if anything happened to it, there weren't any other contingencies. This situation persisted for a number of months. To deal with the high risk, lots of extra spares were ordered and employees were kept on standby so that if something went wrong with the operating site, it could be dealt with very quickly.

The employees in the control rooms contacted the Environment Agency on a daily basis to be aware of potential nature related problems, such as flooding and physical damage to water sites. Proactively, much more frequent monitoring was set up at the sites, in order to measure water levels. In certain instances, where works were close to flooding, production was stopped at some of these sites and the works were shut off until water levels subsided. In some instances, a site could continue running because it was self-contained and water could not actually enter. Additionally, daily conference calls were set up in order to detect what has become medium risk, low risk and high risk and what could be done, such as sandbagging and turning off the treatment works.

Beta has dealt quite effectively with disruptions, due to experience with repeated events and also due to having most of its suppliers in the U.K. with an ability to switch easily from one supplier to another should one supplier be unable to supply parts. But some disruptions are uncontrollable and can impact the customer, such as terrorist attack and flu pandemic. In order to deal with such events, Beta needs to have RM procedures in place.

7.3 Employees' Risk Perception

The words risk and disruption have different meanings to different people. It was important to understand how interviewees conceptualized these words and if they perceived any difference between these concepts. This would help in

understanding how Beta applies these two concepts in its RM plans, because risk may refer to any possible event that may affect operations and disruption is the actual interruption event caused by a possible risk.

Risk Consultant

At Beta, risk used to be called risk and opportunity due to the positive or negative effects, but the opportunity side has been forgotten. In risk registers, only negative risks are inserted, rather than also inserting positive risks that can, for example, save money or provide new opportunities for Beta. It could be risk around the inability to supply water or risk related to the quality of the water and water pressure.

Disruptions in Beta, on the other hand, are called interruptions to supply and are not necessarily a risk because there are processes in place to deal with these. So, if there was a small pipe burst, the employees would know exactly what they would be supposed to do and they would deal with it, so such disruption wouldn't need to be placed in the risk register. Thus, disruptions can take the form from minor to major incidents and if there are processes in place, they are not considered a risk. On the other hand, disruptions with no response scenarios are considered a risk and will be placed on the risk register.

Business Continuity Consultant

Risk is the potential of what could happen, whereas disruption tends to be around what has happened. Risk and disruption are very similar; disruption is the consequence that actually happens whereas risk is the potential impact.

A disruption is something that has the potential to stop providing water services to customers. If there is a failure at the water treatment works, the customer still has water supply, because there is a buffer in between the water treatment works and the customer. But, if the problem isn't dealt with at the water treatment works as a matter of urgency, then there may be no water at the service reservoir and customers will not have water. So, disruption is anything that has an impact on the customer if it is not dealt with on time.

Operations Manager

Risk for Beta has a variety of meanings. Risk in terms of health and safety: if the employees perform a job which is not an every day one, they think about the risks in case the job goes wrong and what are the implications and the consequences to Beta. Beta is generally risk averse in that it tries not to take a lot of risks, but whenever a big job is planned, questions are raised concerning the risks in the job and therefore what are the mitigations that are needed in place to make sure that they eliminate as much risk as possible.

Disruption probably has two meanings; one would be disruption to the site. This is when there is a failure with the process and the water cannot be treated or it cannot go off site. The other element is disruption to the customers. Something may have infected the water and there in no supply of water as expected.

Supply Chain Manager

The SCM's view was that risk is a financial implication either from security problems, financial loss or adverse publicity. Disruption is actually something that happens.

From the interviewees' responses, we can conclude that Beta employees distinguish the terms of risk and disruption. Risks along the water supply chain can vary, from water supply failure to reduced water quality, or anything that can have a possible impact on the operations of the supply chain. At Beta risk is linked only to the negative impacts on performance and the potential for disruptions in supplying water or parts are not necessarily identified or recorded as risks. If there are measures in place to deal with certain disruptions, then the disruption sources are not recorded as risks. But if Beta hasn't developed plans to mitigate a risk, then the risks are possible sources of disruptions. Generally, though, disruptions are considered as events that happen and may cause a negative impact to Beta with or without mitigation plans in place.

7.4 Risk Register

Due to the nature of Beta's operations which are linked directly with the health and safety of customers, Beta has developed a formal RM process which tries to minimize risks and disruptions to its customers. The risk register is a key part of the formal RM process that is used by Beta from a local level up to the executive team. The risk register assists in identifying unmanaged risks or making more efficient already applied RM plans, so the continuity of water supply is ensured at the best possible performance levels. The information regarding the risk register was gathered from the descriptions of the interviewees and the study of risk register documents. Table 7.2 summarises the basic steps of Beta's risk register.

Table 7.2 : Risk Register

	Risk Register
<i>Risks</i>	Operational + Business Continuity Risks
	Risks Entered + Reviewed + Monitored + Updated
	Hierarchical Meetings: which risks to escalate + contingency plans
<i>Identify</i>	Individually, Team level, Regional, Executive Team
<i>Assessment</i>	Experience
	Repeated Disruptions
	Risks Rescored at the meeting with the water services director
<i>Categorization</i>	Risk Impact - Likelihood Matrix
	Each category has consequence scenarios
<i>Risk Management</i>	For Risk Register Risks
	Expertise Knowledge
	Contingency Template: standard format, central depository, template variations depending on operations area
<i>Heat Map</i>	Escalated Risks
	Severity and Actions needed
	Risk Movement
	Individual for each region + production
<i>Funding</i>	Emergency Capital Application
	Local Improvement Need - Cost Benefit Analysis
	Sign off at different levels depending on the investment

	If regulator approves project - ultimately paid by the customers
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The risk register helps classify risks which, according to their importance and cost of mitigation plans, are dealt with at different management levels. Any Beta employee can access the risk register but needs some basic training on how to use it. If the employees would like to view the risk register only, they can have an account and access it, but they can't change anything. Usually one person records risk for the department team. At a low level such as the water treatment works employees, anyone can input a risk onto the risk register. So, in the local meetings it will be a team leader and the operatives, and at the next level up, can be a peer review between areas.

In these meetings employees agree which risks are best to escalate, so the selection becomes more objective than subjective because it does not depend on one person's decision to escalate a risk. In an area meeting, managers discuss the risks in their areas, for example, if someone wanted to escalate a particular risk for their area and there was a similar risk in another area, a comparison would be made between the risks in order to determine which risk should be escalated and which shouldn't. The hierarchical meetings are about prioritization of risks for investing money to obtain the best possible results. If a risk has mitigation or a contingency plan, it may not need to be escalated because it can be dealt with. If the team cannot mitigate it and there is no contingency plan, then the risk needs to be escalated because an investment is needed in order to have a contingency plan or mitigate it.

Not every risk is necessarily on the risk register. If there was a possible risk on a low consequence area, where there were just domestic properties with no hospitals, a small sized main could break but be easily repairable, workers would repair that within a few hours and there would be no consequences from the regulator. If there is a small burst, there is a timescale before Beta incurs a black mark for every household that it has failed to supply water to. Assuming a small disruption to supply, the problem should be fixed within the specific timeframe as long as Beta fully follows their procedures. If, for instance, there are 2,000 houses that have no water for more than the allowed time limit, Beta will incur 2000 dg3

points. On the other hand, if it were a high risk main and if a burst could cause flooding on a busy road, then it would be on the risk register if there weren't any means of mitigating it. An employee would enter a risk on the risk register when, for example, a burst isn't fixed within the time limit. Thus, if the teams believe they have the necessary procedures to deal with the risk, the risk is not entered.

The risk register is a piece of software that has been tailored for Beta and it is based on the internet. With the software, one of the first steps is to choose the risk category and then the scenarios that the software offers would be different for each category. It offers different scenarios to help score, which are tailored quite specifically to the water industry. The person that owns the risk would be the best person to decide what is needed to be done. The action plan includes who is responsible, when it is due to be completed and how the risk will be managed. A risk that someone inputs is pinned to a location or an asset at a location and it can link them together. The risk register also includes the preventative solutions which are around investments, but the company can't invest money on everything. This is why risks are ranked; in order to decide on which risks to invest.

7.4.1 Risk Register Description

Identification

The identification process is the basic step for the effective development of the RM process. If the identifying process is not performed correctly at the very beginning, it's very difficult to pick it up later on at the hierarchical meetings. This is because identified risks are escalated and if a risk is not identified at the start, it will be very difficult to add at a later stage, because the meetings are based on different teams at different hierarchical levels. First, an individual needs to understand what the risks in his or hers area are and then write them down. Then the risks go up the reporting process, beginning at team level and then to different levels where they are assessed.

Assessment

After risks are identified they need to be assessed, so their severity is determined against the scores they have on the risk register. On the risk register operational and business continuity risks are logged and a number is assigned from low to high with the score ranging from 0 to 29. Accordingly, if something scores a 29 it is a very high risk, 20 medium risk and 10 and below is low risk. The operational risk register does not deal with risk of fire or flood at the water treatment sites. These are dealt by the business continuity team, which uses a similar risk register. In the risk meetings, decision makers will discuss, compare and validate with the people that have identified the risks, the likelihood and impact of the risks materializing. In addition, if there is a major disruption which has occurred more than once, a risk assessment is performed to understand the likelihood and the consequences at a local level; there will be a discussion around the event, how much it has cost already and if there are contingency plans in place that need to be reconsidered and developed.

At the hierarchical meetings with the director of water services, risks are rescored and they are also given a secondary impact category; the sum of the risks is added, but this function is not included in the software, it is done manually. For example given a risk of not supplying water and a risk of flooding, the consequences are added which provides a much better picture of what the risk is about and the severity of it. This provides a better picture of the combined impacts on the water supply chain a risk or risks may have and helps in deciding on which risks it is more efficient to invest money, especially when large amounts of investments are required to mitigate them.

Risk Reporting

After risks are identified, they are inputted in a risk reporting format under predetermined categories. The operational risks are calculated based on the consequence and the likelihood. The consequences (Table 7.3) are grouped in five categories and in each category the risk can be graded from insignificant (1) up to critical (5). Each grid has a description and depending on which grid the risk

agrees with, it is assigned a score. For example, if a risk is categorized as a management effort and agrees with the description (business critical but manageable with external support) it is then placed in the major consequence box.

Table 7.3 : Consequences of Risks

	Insignificant 1	Minor 2	Moderate 3	Major 4	Critical 5
Profit / Asset Value	0 - 1% impact	>1% - 3%	>3% - 5%	>5% - 10%	>10%
Company Reputation or Perception					
Health, Safety and Environment					
Management Effort					
Regulatory / Statutory					

Then, the likelihood of a risk (Table 7.4) materializing needs to be assigned into a category, ranging from improbable to highly probable. The decision makers need to choose based on the three criteria, descriptive scale – timescale of occurrence – and probability of occurrence, the category that best suits the risk. One risk cannot be in more than one category, thus the rule of thumb is to pick the category that the risk scores the most in.

Table 7.4 : Likelihood of Risks

	Improbable 1	Remote 2	Possible 3	Probable 4	High Probable 5
Descriptive Scale	Event may occur in exceptional circumstances	Event could occur at some time	Event should occur at some time	Event will probably occur in most circumstances	Event is expected to occur in most circumstances
Timescale of Occurrence	1 to 20 years	1 to 10 years	1 to 5 years	1 to 2 years	Less than 1 year
Probability of Occurrence	1% to 10%	11% to 25%	26% to 50%	51% to 75%	76% to 99%

These scorings are used for base level risks that are inserted on the risk register. So, based on likelihood and impact, a risk is placed in a category and from the options for that category the likely scenario is chosen. Within the risk register another device gives potential scenarios of how a risk can be resolved, giving several solutions but it depends on the team what to do. So, for a water quality failure it would propose

- intervention from the regulator but no further consequences,
- intervention from the regulator with further consequences,
- intervention requiring fundamental strategic change and objectives.

For the business resilience and security risks, risk reporting (Table 7.5) is slightly different from the operational reporting format, because the legal impact category is added and health and safety with environment are separated with independent impact descriptions. They are categorized based on impact into regulatory, profit/asset value, environment, health and safety, legal, management effort, reputation and stakeholders. The risk is then assigned a likelihood of occurrence, divided into insignificant, minor, moderate, major and critical.

Table 7.5 : Business Resilience and Security Risk Reporting

Impact Category	Insignificant	Minor	Moderate	Major	Critical
Regulatory					
Profit/Asset Value	0 - 1% impact	>1% - 3%	>3% - 5%	>5% - 10%	>10%
Environment					
Health and Safety					
Legal					
Management Effort					
Reputation and Stakeholders					
Likelihood Category	Improbable	Remote	Possible	Probable	High Probable
Probability of Occurrence	<5%	>5%<25%	>25%<50%	>50%<75%	>75%

Then, based on the scoring of the level of impact and likelihood, the risk is assigned a risk status (Table 7.6), so the team knows which risk to escalate at the hierarchical meetings.

Table 7.6 : Risk Status

Risk Status	
I= Ignored	The risk is too small, no risk provision made.
P= Passed	The risk is an issue to be addressed at a more senior management level.
C= Current	The risk is live and needs to be managed.
R= Realised	The risk was realised and had an impact on business objectives.
K= Closed	The risk did not occur.

Meetings

Meetings regarding inputting risks on the risk register are held from a local team level up to the executive team. During these meetings at the local level, risks are identified for each area and placed on the risk register. Whether risks are escalated

or not depends on the higher management level risk meetings, where risks are assessed and possible mitigation plans proposed. The hierarchical process of meetings begins with the local risk meetings, then progresses to the regional risk meetings, and then slowly up the pyramid to the head of the water risk meeting. The director of water services has the top level risk meeting, and then the output from that goes on to the executive management team.

After water operations have a risk meeting where they have identified risks on the risk register which are serious enough to be escalated, they should develop contingency plans. In the risk meetings they will debate how best to deal with a risk. During the risk meetings they will discuss with the people that have identified the risks the likelihood of them happening and also from experience if they have already happened, agreeing as a group how best to deal with them. After the meeting, two people, for example, are taken off line for a week to write a contingency plan, find out who would be impacted and determine the key accounts affected.

During the local risk meetings a standard agenda is followed, where one of the tasks is to discuss new risks that have been added on the heat map since the previous meeting. When risks are added, each risk has a status quote, and it starts off as new risk added, with the date that it was added and it has to be reviewed within 90 days of going onto the system. When risks are inputted the employees discuss them as a group. The status quote is changed depending on which action they will take, so risks sit on watching brief with a review date allocated according to the severity of the score of the risk. If its score 29, for instance, it needs to be reviewed every three months, between 10 and 20, six-monthly reviews and anything less than 10 is annually reviewed, so risks are not just inserted on the risk register and forgotten about. The risk owners have a duty to look after their risks and keep them up to date.

Risks are not only placed on the risk register but also need to be monitored and updated according to their severity. For a risk to escalate up to the executive team where decisions are made for investing large amounts of money for mitigation, it

has to pass through different hierarchical meetings, where it is assessed by different teams and against other risks.

Heat Map

After risks are categorized, the ones that are escalated are placed on a ‘heat map’. The heat map is a five by five matrix (Appendix VII) and depending on the impact and likelihood, is divided into green, yellow and red areas. The areas define the need for action; if the risk is in a green area then it needs to be monitored, yellow equates observation action if necessary and red suggests urgent need for action. When the risks are placed on the heat map, they are given a colour which is independent from the risk area they are placed in. The colour shows the risk movement; white is a new risk, green is improved, blue is stable (unchanged) and red means it has deteriorated. Where the risk is currently positioned also reveals its pre-response position, its current and then its target position. The old software showed the locations, so the icon’s progress to its target position could be monitored. The new software does not display this; the information is on a different table and thus does not show visually on the heat map.

Each risk on a heat map is based on the critical success factors, and when it moves into target position, it comes off the map. Most critical success factors are around engineering projects, like a new main being laid or a new plant being built. The engineers issue every month an update on their project, using a traffic light system: green denotes on schedule, amber reflects something gone slightly wrong and red predicts missing its target. The project report will contain a completion date, a take over or a commissioning date, milestones and responsibilities, all of which are translated into the heat map by the risk consultant.

Each region for network and production has its own heat map, so any risks that teams feel they can’t control, are placed on an *escalated heat map*. For example, if things are serious enough they escalate risks from the regional heat maps onto the water services heat map. Thus, at the top level heat map the executive team has an overview of all the escalated risks related to each category, which then helps them compare and decide which risks are worth investing in. So, for power resilience,

there will be risks around power supplies to sites not being robust and the top level heat map will include all the base levels risks feeding to power resilience.

During risk meetings, nothing will be mentioned about the critical success factors unless one is not going to make its target due to a certain reason. At this point, the director would only be aware if a project was going over its schedule; if it's on schedule nothing is mentioned until it's due to finish. Due to funding, they have to complete the project within certain timescales because funding comes ultimately from the customers and if the project is not delivered on time, Beta might be penalized.

Contingency Plans

Contingency plans are proposed by the teams that identify the risks and place them on the heat maps. Expert knowledge is required, because the contingency plans are specific to the risk a team would like to mitigate. They are placed on a contingency plan template that is developed by the business continuity team.

Contingency Plan Template

There is a standard template for the contingency plan whereas previously the contingency plan was in a non-standard format which depended on who had written it and what information it contained. Before, it was randomly stored rather than being placed in a central depository which is currently implemented. The standard template tries to make sure that all the necessary information is entailed and also helps the teams think in a structured way for the proposed contingency plans.

Across a number of water companies, there is a contingency planning setup, which the business continuity team improved and tailored towards Beta teams' requirements. First, the team started with a generic template and then changed it so as to be used specifically by a number of teams. Several variations of the template have been made available around the company. Specifically they contain:

- what scenario they are planning for
- what triggers they are going to use and not just model through
- if the plan can be authorized who would be using it
- what the actions are that will be carried out to keep the business running
- what actions will be implemented to recover the service

The last point, though, may not be applicable to everybody in a team. For example, an office team wouldn't necessarily be part of the recovery that would be facilities and property, so they could leave this point blank; however, they would need to worry about their actions to ensure the continuation of their jobs in the meantime. Conversely, if operational actions were needed, then getting the asset back up and performing their operations would be part of their job. Certain additional features the template includes are essential maps and diagrams, contact lists and review periods.

It is part of the role of the risk consultant and the business continuity team to make sure that business teams have contingency plans, and that they are using the standard format and the central repository for storing them. The team operates at corporate level and provides policies, standards, templates and support to help the business teams understand where they are, what gaps they have and what resources they might need to solve the problems. But the team cannot provide enough resources to actually write the plans, so it depends on the operational resources to actually put the plans together.

Contingency plans are required for risks that have been recognized as serious enough to be entered on the risk register. When a risk is on this register, the business unit applies for capital funding, which may take up to three years to come through and actually be realized. In the meantime a contingency plan based on the template or not, is needed to cover that risk for the time period until the risk is mitigated. If the funding is not provided, a contingency plan is still necessary because there is a known risk and therefore a back-up plan is essential. This is how the business continuity team would like to see contingency plans working prior to being formalized and signed off by top management. It is important to

have temporary contingency plans in place for a known risk even if funding is not granted, because this risk may materialize and have negative consequences on Beta's stakeholders.

7.4.2 Risk Mitigation Funding

For funding purposes, risks are classified into two different types: a local improvement need, which is an enhancement to a sight to mitigate risk, and emergency capital applications. If a pump has blown up and due to the emergency, Beta requires another pump immediately to keep the site running, with an emergency capital application Beta will just order it regardless of costs.

When a risk is identified and an investment possibly is required to handle the risk, a level one study (a desktop study) is first performed, where a team will go through what they believe the possible risks are. Then the study gets put forward for an engineering study where the engineers will propose, for example, a larger treatment works at which time they will apply for the funding. When a solution is identified, cost benefit analysis is used to estimate the cost of the solution versus the benefits of having a mitigation plan. If mitigation benefits outweigh the expected cost of risk, then Beta implements the mitigation plan.

Funding decisions are made at every level because each level will need to decide which risks they are going to escalate or not. There are sign off levels for different levels of funding. If it is an operational budget which requires small amounts, then decisions can be made at a lower level, but anything over a certain amount, the more expensive it gets, the higher up hierarchically the decision needs to be made. There is a separate capital expenditure board which makes decisions on capital funding, only looking at activities over a few thousands, and there is also another board at the next level up for more expensive decisions. The risks that reach board level are the high cost ones. Some risks are related to more management effort rather than cost because certain teams do not have many assets. If a team is responsible for a large operational area with network assets, a lot of the risks on the register will be asset related, and therefore it is likely to have cost implications.

A normal way of funding a project is through Beta’s consumers, with the cost of the project paid by the customers, but in order to achieve this, the regulator needs to approve the project. Beta is allowed to increase water charges to its customers by the rate of inflation. If it can be proven to the regulator that Beta needs to do this work costing a certain amount of money and Beta is performing well as a water company without incurring black marks, the regulator will allow Beta to increase the prices above the rate of inflation. As a result, Beta can pass the cost to the customers but within strict timescales to complete the project. If Beta can’t complete the project on time, Beta can’t pass the cost on and may also be penalised. Thus, project planning needs to be designed realistically with feasible timescales.

7.5 Current Disruption Management Responses

At Beta, a number of RM strategies are implemented to ensure continuity of water supply at the best possible quality. These are presented in Table 7.7:

Table 7.7 : Betas’ Disruption Management Strategies

Risk Mitigation Strategies	Descriptions
Stock	Storage + Service reservoirs
	Critical Products: at least two other water sites
Quality	Water Quality Checks - online monitors
	Supplier Checks - visit the plants
Water Supplies	Rezone, Tankers, Bottled Water, Static Tanks
Suppliers	Source from Alternative Suppliers
	Redundant Suppliers
Back Up Supplies	Dual feed of Electricity, Power Generator, Stand by Pumps
Network Reconfiguration	Rezone, Temporary Connection, Overland Rider
Major Equipment Breakdown	Usually recovery within a few hours
	Hold Spears
	Supplier's turnaround time
	Shut valves, sensors for critical pressure points
Fires	Operate manually the site

	Telemetry
	Fire Doors, Fire Sensors, Fire Alarms
Employees' Flexibility	Event Controller
	Multi-Skilled people
	Working from home: laptops, telephones
Hire Office Facilities	Employees redeployed internally or externally (syndicated) to Beta
Near-Miss	Health and Safety reported

Storage Reservoirs: The storage reservoirs have a minimum of half day supply in them, so there are enough buffers in the service reservoirs if the storage reservoirs cannot supply for a few hours. There is a big number of storage reservoirs that supply the water treatments works.

Critical Products: Critical products, such as the large-sized valves, are not held in the warehouse but kept in at least two other clean water sites so as to be close to the sites where needed.

Water Quality Checks: There are online monitors which check the quality of the water through the process. For example, where the water comes into the works, if the water quality entering is poor, Beta can stop drawing water in for a period of time, until the bad water quality passes. Although water can still be treated, no more can be drawn in.

Alternative Water Supplies: If production is lost at the water treatments works and bore holes, the options are to rezone and use alternative water supplies. Even if the company has rezoned as much water as it can, there is often the possibility that some customers will be left without water. The only solution is alternative water supplies, a general phrase referring to bottled water, tankers and static tanks, the main three methods of getting water to people. Bottled water is two litre bottles of portable water, which can be transported in pallets and distributed to customers. Tankers are used for two purposes; one is to directly supply entities like hospitals and prisons, where the tanker is plugged into their internal network and supplies them directly from the tanker rather than from the mains. Tankers are also used to fill up the static tanks, plastic containers which can hold about 1,000 litres. These

are placed at a site and filled up with portable water which the customer can take water from.

The tanker is a vehicle with a pumping mechanism at the back and it can either go directly into a property or it can fill up the tanks. Tanks are kept disinfected and ready for use. Normally Beta takes a number of static tanks and places them at 400m intervals around an area that has no water; the tanker follows behind fills them up and then customers gradually empty the water out into their own receptacles. The quality of water in the tankers needs to be at DWI (Drinking Water Inspectorate) standards. Hence, if the water in a static tank on the street was sampled, it should be drinking water safe. However, Beta informs customers that they have to boil the water before drinking it. The reason is that Beta cannot guarantee the integrity of the vessel the water is carried in.

Alternative Suppliers: If a supplier has problems and cannot supply within Beta's time frames or cannot supply for a period of time, then Beta has the option to source from another supplier, and if Beta has to pay more, it would charge its supplier with the difference in cost.

Reserve Extra Capacity in Suppliers' Plants: This is mostly for chemicals and strategic products (pipes, pumps). Beta may want to carry out a large scale laying of pipes at short notice, and it would like its suppliers to produce a number of pipes. This additional required supply is usually built into the contract with the pipe suppliers. In the contract there is a clause stating that in the event of additional capacity requirements, the supplier confirms that they can provide the product within 7 days notice and that Beta obtains priority treatment. It is very seldom that such clauses are invoked, because Beta's supply chain business is very predictable and very stable: x number of pipes and w body of chemicals daily into the water treatments work.

Usually, there are fluctuations in chemical demand when the weather changes during summer and winter peaks, due to the change of chemicals used to treat the water at those times of the year. Thus, Beta knows on a seasonal basis when

demand changes and the suppliers also know and they can respond when this extra demand is needed.

Back-up Supplies: A site can lose electricity supply due to the fault of either the electricity company or Beta. There are engineering projects in place at the moment to ensure that any critical site has a dual feed of electricity. Beta also owns power generators or hires them when they are needed, but they are quite expensive.

Most major sites have duty and stand by pumps; a duty pump is the main pump and a stand-by pump is a back-up pump. The duty pump runs three days and the stand-by runs for one. This means that both are always running, but one runs more than the other, with the flexibility that if one fails the other can still run.

Network Reconfiguration: When a pipe that supplies hundreds of homes breaks down, it is possible to rezone the water through another pipe. Additionally, workers can add a temporary connection in or an overland rider. Evidently everything needs to be disinfected so it's sterile before it is used.

It is not possible to rezone every zone because if customers are out in the countryside, no interconnections may be present. There might be a single point of failure that affects 200 houses and it's more cost effective to fix the main and supply the customers with alternative water than to propose a multi million pound scheme to resolve it.

Major Equipment Breakdown: Normally within 24 hours, Beta may recover from a major equipment breakdown such as major pump failure or chemical dose-in failure. Beta holds spares and with some suppliers has a few hours turnaround time if a part or product is needed in an emergency.

If there is a major burst on a large pipe, the immediate reaction is to shut it off quickly to stop the water running away. The burst is located by looking at the plans.

In the case of flooding, there are processes in place to close the appropriate valves quickly. There are sensors and critical pressure points that will send a signal back to a control room to signal that something is broken. These are placed in the high risk areas only, because of the high costs required.

Fire: If a fire burns the control panel, Beta will not be able to operate electrically or remotely. For many of the sites Beta can operate manually. Additionally, if there is a fire in a control room, Beta can operate the telemetry remotely from another site because it is backed up. All systems are backed up on a daily basis. Therefore, if a site fails, it can be accessed on telemetry.

All sites have fire doors that have to be kept shut all the time, so if there were a fire on a site it would be contained within a small area. In the major sites not only are fire doors used, but also have fire sensors. Further, all sites have fire alarms which are linked back to a control room. Chemical store rooms have alarms that are set to trigger on heat and odour. Operators will get an initial indication which does not specify what the problem is, whether fire or a chemical leak, so workers will be sent to check.

Employees' Flexibility: In a disruption event, an event controller is in charge of getting the problem resolved. There is a 24/7 duty manager posted who is one of a number of people on shift, who would be involved in setting up the management structure for that event. The event controller is usually someone who is from the operational or business area where the problem is occurring. Anyone who needs to do an-out-of-hours role may be asked to be event controller, because they are on call and they are the only ones involved at the time. For a short amount of time, they will act as event controller until they are able to hand it on to someone during the day. To clarify, an event controller is anyone who has management role in operations.

There are technical teams that can cover different geographical areas, and Beta also has multi-skilled people trained for both mechanical and electrical jobs.

Hire Office Facilities: Beta hires office space in other buildings in case there is a disruption at a Beta building, so that staff can be relocated. The plans for the hired building will consider, for example, how many people work, what kind of computers they have, what software they need and how many desks they would accommodate them. Beta has done surveys to obtain the records of its employees, collecting information on who they are, what they do, what software they need, if they have a laptop or pc and what equipment they need to function in their jobs.

Beta can either relocate internally where there are a number of desks it could occupy which use the same systems or as secondary back up, Beta has a contract with a company which provides work place recovery solutions. For the secondary back-up, there are two levels of costing: syndicated and dedicated. Dedicated means that seats are available 24/7 for a company but costs four times as much as syndicated. Syndicated is used when a room in an office building with fifty seats can be hired and connected into the company's IT systems and Beta employees can move within a short period of time to start work, but it does not guarantee that all the seats will be available on the day of the event. If another company has a problem, they might have to share the office space with Beta. When choosing which company to hire offices from, an understanding is needed of which other company within the certain area will need the same office provider. There are some confidentiality issues, a list of companies is not provided, but the interested company will be informed that there is one other company within 150 miles that will need 20 seats. Then Beta can reason that they would need 80 and, given that there are 130 in the building, the capacity would be sufficient, so it agrees to hire the office space.

Near-Miss: There is a Near-Miss telephone number and in case of a 'near-miss', it is reported and gets recorded. The health and safety team groups the near-misses which are solely health and safety related (e.g. personal injuries). If there is a near miss with an operational incident, it can be placed on the risk register.

The above range of responses demonstrates that Beta has processes in place to deal with a variety of sources of disruptions proactively and reactively. These responses have been developed through experience and the risk register which

helps identify risks and develop suitable solutions. Some of the aforementioned responses, such as reserve extra capacity and hire office facilities, demonstrate that most of its contingency plans are based on back-ups. These back-ups, though, are linked with critical operations that are needed to help Beta continue operations in the event of a disruption. Additionally, in place are responsive plans (e.g. major equipment breakdown) and network flexibility (e.g. network configuration) to ensure that customers are not interrupted to an important degree.

7.6 Discussion on Beta's RM Process

Although structured and containing helpful measures, Beta's RM process could incorporate additional methods that could be added in the different phases of the process. Presented in each phase, these proposed additions are derived from the literature which can also be applied by Beta.

Define context: although not listed at the headings of the risk register, the decision makers are aware of the aim and objectives of the risk register; to identify possible sources of risks and disruptions where no contingency plans and mitigation strategies are available to handle them.

Before the identification phase begins, it is helpful to produce product and water supply chain designs which provide a holistic view of the supply chain, to see how different processes interconnect and how risks can unfold in the rest of the supply chain. The maps should include all important information such as treatment works locations, the warehouse, transportation, critical products, critical paths, pinch points and already existing responses to risks. A supply chain design of both the product and water supply chains can help each area of expertise assign the risks linked to their area and identify what additional processes are needed to mitigate risks.

Identify: identification is an important step and the basis for the development of a RM process. The risks identified from an individual level and then at a team level are based on judgement and experience, rather than on formal procedures in

identifying possible risks. Beta can benefit from a formal process which includes guidance steps in identifying sources of risks. The following steps can be adopted:

- **Sources of risks:** based on a supply chain design, potential risks and their sources can be identified. There may be some linked to the primary source of risk; these need to be recorded and their combined effects estimated.
- **Pathways:** the path a source of risk follows until it materializes. It is not effective to examine the pathways of all risks, but it is better to examine the paths of the risks the company is mostly interested in. Critical pathways may be best examined by using influence diagrams, geography vulnerability maps, simulation and fault and event tree analysis diagrams.
- **Group involvement:** although there is an involvement between departments in Beta, the business teams do not include their supply chain partners such as critical suppliers, regulators and customers. Methods such as brainstorming and ‘what if scenarios’ can be used between supply chain partners.

Assessment: at Beta risk is estimated based on its likelihood and its level of impact. Beta’s assessment phase is very user friendly and carefully developed to incorporate all possible scenarios. In the pre-determined categories, a risk is placed only in a single category, the best possible one. In these categories the business teams can also consider the duration of a risk, because although at the beginning it may seem like a low risk, if it is ignored and not handled, it may develop into a serious risk. This helps in estimating the timeline of the effects a risk may cause on the stakeholders.

For risk estimation at Beta, qualitative techniques are adopted, which are mostly based on the judgement and experience of the decision teams, who place risks on a risk/map matrix. In order to assess more effectively the interrelation between different risks, more sophisticated techniques are needed. If there is available data, not only from Beta but also from similar companies, then simulation modelling, decision analysis and fault and event trees may be used. These methods use quantitative analysis that helps estimate the impact a risk may have. Because

disruptions are rare and unpredictable, it is very difficult to estimate exactly their effects. Beta, however, is in a more predictable industry and probabilities can be better estimated than in a company such as Alpha, which depends on thousands of production parts by globally spread suppliers.

Another possible assessment method is the 'red-blue teaming' approach, which is widely used by the military. The Red Team, comprised of a group of experts, is tasked with thinking like an enemy, exploring the vulnerability of an enterprise and simulating a set of possible scenarios that can cause serious disruptions whereas the Blue Team attempts to provide cost effective mitigation strategies against the Red Team scenarios (Kleindorfer and Wassenhove, 2004; Sheffi, 2007). In this way, the red team simulations help the defending blue team assess its vulnerability and discover unforeseen dependencies (Sheffi, 2007). The exercise begins at the process level for critical processes and equipment, goes on to manufacturing and warehousing sites and finally goes to the division or company level. At each level, red-teaming generates vulnerabilities which are either handled at that level or passed on to the next level for resolution (Kleindorfer and Wassenhove, 2004).

Simulations assist the two teams in generating scenarios and responding to them, which help test the capabilities of a company and its supply chain. Testing one company level at a time gives the opportunity to examine the resilience of the system at each level, thus ensuring the robustness of the system in this way. Kleindorfer and Wassenhove (2004) believe that multi-level exercises at each link of the supply chain can be very useful both in understanding the vulnerabilities of a supply chain to disruptions and in making members of the RM team aware of what can be done to either mitigate these or at least be in a position to respond to them. In such an exercise, people with thorough knowledge of the organization's supply chain operations and capabilities are required. Sheffi (2007) stresses that simulation 'socializes' companies that use it to think in terms of uncertainty, flexible response, responsibilities and lines of authority, thereby producing a more adaptive and resilient culture. Simulation is also a way to demonstrate the

disastrous effects a disruption may entail and help develop the appropriate risk mitigations plans.

Risk Management: classifying risks into two different funding purposes, local improvement need and an emergency capital application, helps categorize the risks where immediate action is needed. In this way, risks that require an emergency capital application do not need to wait to pass through the scheduled RM procedures but are dealt with immediately, because if not, they will impact on the continuity of operations and customers.

Risks are placed on a heat map, which is helpful because all significant risks of an operational area are organized on one map, which helps categorize the severity of the risks and additionally, their progress can be monitored where timelines and outcomes are assessed against planned actions. The heat map is a helpful tool that could be added in the generic SCDM proposed in chapter four, as an addition to the simple risk/map matrix.

Beta's RM actions usually followed are: mitigate, ignore and avoid. With ignore and avoid actions, Beta decides basically either not to deal with a risk or not to get involved in actions related to a risk. The mitigation actions, though, require contingency plans, which are displayed on standard contingency templates. Beta also adopts the share action (e.g. VMI strategy) as part of the RM activities.

7.7 Key Issues in Implementing Formal RM Processes

Interviewees agreed that the business level team members do not always have the time to get involved in risk register meetings and then update risk registers, due to their daily jobs they have to undertake. As a result, due to the workload of an employee RM is one of the first responsibilities neglected because it is not linked with the employees' daily duties.

Another issue is that individuals may be doing all the risk reporting but sometimes they may not be recording it. Every month graphs are produced that show who is not reviewing their risks and who is not looking at their new risks and these are part of the measures for the performance-related pay. They have the flexibility of

3 months, so, if they have a very busy month, they can skip one month as long as they make up for it the next month. This procedure is effective in motivating the individuals to record their risks and arrange the risk meetings. Thus, time pressure and performance level reviews need to be applied by Beta so individuals perform their risk register tasks.

7.8 Business Continuity

The BC team is interested in very specific resilience risks which are related to operational event management risks, risks that Defra (Department for Environment Food and Rural Affairs) is interested in such as planning for flu pandemic, fires and the supply of alternative water. The BC team also has a view of operational risks but it does not get involved with the detailed decision making about different mains, assets, and the prioritization of risks.

On joining the BC department, there are a number of training opportunities made available to its members, such as business continuity courses, business continuity seminars and annual symposiums. These are helpful to become familiar with the specialized terminology and concepts of business continuity management that are used. As a result, there is business continuity expertise in the team that has been developed over time.

Beta Team Exercises

The business continuity consultant described how Beta arranges its team exercises. The BC team arranges desktop exercises, whereby it gets everyone that might be part of an event team into a room and provides a scenario to resolve. It tries to involve people on the day that they might be on an event team, so for example from the press office, someone who would liaise with the drinking water inspectorate and someone from the customer centre.

Before the exercise, the event team members usually undergo training. During training, the BC team tries to help people get into a certain way of thinking and then apply their knowledge, experience and managerial skills to manage the situation. For example, the BC team tries to get the event team members to

concentrate on risk assessments, to develop strategies and to sort out their communication. Thus, the BC team provides the guidelines and basic principles that are best to follow, but implementation depends on the event team members and how well the event team coordinates. There might be some people who come to the exercise but haven't done the training for years or have moved across from another part of the business or company. Generally though, most of them have been through the training before.

The exercises are planned for twice a year. It's difficult to organize an exercise, because operational input is needed to develop the exercises. The BC team can provide the framework and the facilitation but the exercise needs to be designed realistically. For instance, in presenting information such as 'this main burst will affect these streets and it will affect these customers,' expert knowledge is needed to develop exercise scenarios.

During the exercises, the event team works through the scenario and looks for root cause analysis of events. Next, a report is written and the various sources of risks are outlined. No formal diagrams, tables or decision trees are used, but a report of the contributing causes to the simulated event is developed. In addition, the BC team also performs exercises through telephone calls. Upon receiving a telephone call, employees are informed that it is an exercise and that they need to say what he or she would do in a specified situation. This is a helpful method to check that the employee is familiar with a certain event's processes.

Although exercises can be beneficial, it can be difficult to get people to turn up on the set day. The attendees have varied feelings about the exercises. Certain people will see the benefit and try to gain the most from them and some individuals, depending on their character, may not. Across the business there is pressure on resources, so there are many people who think the exercises are a good idea and would like to participate but also feel that they are less important than other pressing duties related to current jobs, their budgets and their timescales. The problem is that there is never enough time because there's always something very important to do on the exercise day. Part of the BC team's job is to try and get the signoff from people higher up in the company that this exercise is important and

that employees will set time aside to do it, and then that message goes down to the employees. Thus, the influence from top level management is important for motivating the employees to take part in the exercises.

These exercises help the employees become familiar with the response processes in the event of a disruption, so that they know the actions and coordination needed. Furthermore, they learn how to work as part of a team and with certain team members. As stated, though, organizing a meeting that will involve the necessary employees is difficult because each person has a different schedule and priorities. This is why the influence from top management is needed, so team members realize the importance of risk exercises.

7.9 Business Continuity Vs Risk Management

At Beta, RM is the umbrella and business continuity is one function that fits under it. The risk reporting team looks at operational incidences at a treatment site or the water network. The BC team looks at non operational disruptions such as fire and security of water operations and is concerned with the continuity of water service in the case of a disruption. The risk reporting team and the BC team try to keep in touch to know what they are doing so they do not duplicate anything.

Beta's RM is about the control mechanisms in place to mitigate a risk. There are some risks, though, that will never disappear; for example, there is always going to be a risk that a building could suffer power failure because it's not possible to manage that risk out completely. Business continuity planning deals with a risk when it materializes, and contingency plans are developed to lessen the consequences of this risk on company operations at that time. At Beta the business continuity element is about what the employees are going to do if an event actually happens rather than how they are going to manage out the risk. For example, in the flu pandemic case it's very difficult to reduce the risk, so the company simply has to plan for what the impact might be. RM and business continuity planning at Beta are interdependent because if a risk cannot be mitigated, then contingency plans are developed to reduce the risk's impact in the event it materializes.

7.10 Conclusions

Generally, Beta's risk register and the processes linked to it follow a standard procedure which is followed by all departments in Beta. It is a straightforward process which can be applied easily by employees. It requires, however, the expertise of these employees so it can be utilized correctly. Moreover, it does not depend on the judgment of one person, but depending on the severity of the risk and the investment to mitigate it, the risk gets reviewed at higher levels. Generally, it follows the structure of the generic SCDM process presented in chapter 4, and through the case study, details are provided on how each phase is applied and interconnected. For example, the risk/map matrix is also linked to the heat map, where the management and monitoring of risks is performed, so that risk owners are informed on the progress of the risks and can decide if any further actions are required. In general, the risk register helps not only classify and assess risks but also monitor the effectiveness of the risk actions.

The SCDM process though, also proposes the application of quantitative techniques during the assessment phase which the case study company does not apply. The case study company relies on employees' experience and judgment when assessing a source of risk, but because it operates in an industry where quantitative analysis can be applied, could be helpful for producing more reliable estimation results if numerical applications were implemented during the assessment phase.

Employees, due to the fact that are involved in the RM procedures, conceptualize the terms of 'risk' and 'disruption' differently and define clearly the distinction between these two terms. This distinction helps develop more effective RM actions, because they are aware of what a risk source, a risk and how a risk can evolve to a disruption. Thus knowing what can lead to a disruption and the actions needed to prevent it, then possible SCDM strategies can be more easily and effectively developed.

A formal SCDM process helps the case study company build more resilient and robust water supply operations because there is ongoing monitoring of the

existing risk sources and also identification and assessment of possible risk sources. These processes and management actions help not only handle risk sources on a proactive basis but also have in place contingency plans in case a disruption materializes, thus reducing the vulnerability levels along the water supply chain.

8 Discussion on Case Study Findings

Both case studies provide insights on how disruptions are managed in two different organizational settings, with or without formal RM processes. Alpha does not operate any formal RM processes, but it mostly depends on experience and expertise developed and built up over the years to prevent or deal with incidents. Examples are supplier technical assistance, employees' flexibility and common parts across vehicle lines. Additionally, Alpha has a reactive approach to disruptions caused for example by fires, natural hazards and network problems, because its employees believe Alpha has the capabilities and experience to deal with disruptions having done so successfully in the past. But how effectively these disruptions were dealt with is not possible to know, because no proper assessment has been performed of possible threats and the best mitigation plans to deal with them. With transportation problems and supplier issues that occur quite often, Alpha has developed capabilities to deal with them, but Alpha hasn't considered a variety of other risks external to the supply chain that could have a significant negative impact on its business e.g. economic crisis.

Beta operates in a different business sector than Alpha. Beta is a monopolist in its geographical area providing a basic utility, while Alpha is a commercial manufacturer in a competitive global industry. Thus, these two companies follow different practices and regulations and have different priorities. Beta aims to be profitable as well as responsible towards its customers in order to provide a basic human need, water. Alpha tries to be market competitive, with high value vehicles at acceptable prices. If Alpha is not able to provide vehicles on time, it may incur financial costs due to a variety of reasons, such as cancelled orders, extra work time and expedited transport. On the other hand, if Beta is not able to provide customers with water after a few hours, it will not only get penalized by the regulators but the restricted supply of water may also cause health and safety issues to its customers. This is why Beta is risk averse and has a formal RM process in place that also includes business continuity management. Beta does not

only try to mitigate risks but also has plans in place to ensure the continuity of its basic operations and supply of water.

8.1 Case Studies' Supply Chains

Alpha's supply chain is very different to Beta's water supply chain but has certain similarities with Beta's product supply chain; these are presented in Table 8.1. A similarity of the two product supply chains is the process that a typical supply chain has from suppliers to customers. In Beta's case, the customers of the product supply chain are Beta's treatment works and distribution network. Beta's product supply chain provides the products needed for the smooth operation of the water treatment works and distribution network. Alpha's parts supply chain is the basic operation for the procurement, transport, manufacturing and delivery of parts which are gradually build into vehicles. Alpha also needs materials to support the key processes and robotics it uses during production, but is mostly concerned with the parts supply chain of the vehicles.

Beta's main supplier is the environment and the quality of water going into the works depends on the quality of water collected or abstracted. Alpha's supply chain, on the other hand, depends on global suppliers where the quality of parts depends on the quality processes its suppliers have. Although Beta's water supply chain is simpler than Alpha's supply chain, it cannot always control the abstracted water quality in the way that Alpha can with the parts of its suppliers. Both companies, though, have processes in place so they can achieve the best possible quality. The Company which is Alphas' parent company visits the suppliers' facilities to check their quality standards. For the water supply chain, Beta checks the chemicals of the water and for the product supply chain, visits the suppliers' plants.

Alpha's suppliers are spread out in different continents and getting all the parts to Alpha's assembly plant requires very good scheduling and network planning, whereas Beta's water supply chain is much simpler in structure. Beta's product suppliers are mostly located in the U.K. and there are suppliers situated locally which makes network planning easier than Alpha's, because most products do not

need to pass through different countries by using different transportation modes. In addition, Beta's lead times are shorter and the transportation costs are lower than Alpha's. Beta also has international suppliers but they are a small portion in comparison to the U.K. suppliers. This is why Beta has less exposure to disruptions due to network problems than Alpha does.

Both companies depend on long term preferred suppliers that are quality certified suppliers based on the standards of each company. Both companies prefer to single source except for a few parts that they dual source, reflecting common practice among many established organizations, which try to minimize the numbers of suppliers they collaborate with and build long-lasting relationships with fewer suppliers. Beta also has the flexibility to source from another alternative supplier at short notice in case the original supplier is unable to supply. Although this flexibility costs Beta more than if it only depended on one supplier, it provides agility and resilience to disruptions and helps ensure the continuity of its water supply. Alpha does not have a similar agreement and usually when an alternative supplier is needed at short notice, it has to find a supplier that is willing and can provide the products in a short amount of time. If it is a critical product, this may result in lost production and extra costs until an alternative supplier is found.

Table 8.1 : Case Studies Supply Chains

Basic Operations	Alpha Supply Chain	Beta Supply Chain
		Water Supply Chain
<i>Process</i>		Water Abstraction + Treatment + Customers
<i>Stock</i>		Storage + Service Reservoirs
<i>Network</i>		Treatment Work's interconnect + Island Zones + Water companies
	Product Supply Chain	Product Supply Chain
<i>Process</i>	Suppliers + Transportation + Distribution Centres + Inventory + Production + Dealers + Customers	Suppliers + Transportation + Distribution Centres + Inventory + Beta network
<i>Stock</i>	• Warehouses + Market Places	• Warehouses + Water sites

	<ul style="list-style-type: none"> • Average daily use of the part * cost of the part 	<ul style="list-style-type: none"> • VMI
Procurement	Commodity products for a variety of vehicle lines	Strategic Products
Suppliers	<ul style="list-style-type: none"> • Mainly European + Global Suppliers • Company's Quality Standard • New Supplier Program • Single Sourcing (most parts) • Multiple Sourcing (tires + rear springs) 	<ul style="list-style-type: none"> • Mainly U.K + Global Suppliers • Smaller + Local Suppliers - not involved in formal procurement process • Mostly Single Sourcing • Dual Sourcing - Flexible Contracts: key treatment products • Quality + Financially Healthy + Capable • Alternative Suppliers - Team's experience + used before
Supplier Contracts	5 years	3 to 5 years
Parts	<p>Critical: unavailability stops assembly line</p> <p>Non - critical: produce vehicles and fit later</p>	<p>Critical: for the continuity of a critical process + cannot be supplied quickly</p> <p>Non - critical: daily operations + locally supplied</p>
Logistics	<p>Inbound outsourced: network design</p> <p>Outbound: Company</p> <p>Transportation: multi modal (train, truck, ship, airplane)</p>	Outsourced: Operations + Stocking of Warehouse
Production	12-18 hours (Monday – Friday)	Continuous
Customers	Customer Satisfaction + Benchmarking	Customer Satisfaction + Continuous Water Supply
Dealers	Sell Vehicles, After Sales Services, Customer Satisfaction Feedback	

Both companies have outsourced their logistics function. At Alpha the inbound logistics have been outsourced but the Company is responsible for the outbound logistics. The outsourced company designs the inbound network and makes changes to it when necessary, also choosing the transportation provider on which Alpha makes the final approval decisions. At Beta the logistics function is outsourced. Additionally, Alpha employees are in charge of the operations and stocking of warehouses except the warehouses outside the Alpha assembly plant, which suppliers manage. Trying to design an optimal network requires specialized knowledge and good relations with transportation companies and networks. This

is why both companies decided to outsource logistics and provide this function to companies that have the expertise and contacts.

Both companies try and implement lean practices, thereby keeping limited stocks. Alpha's stock levels depend on the average daily usage and the cost of the part. Beta's depends on the supplier's replenishment policy, but stocks are limited by space in the warehouse. Thus in both companies, in case of a warehouse fire, the economic damages will not be huge because they store small amounts of stock, and stock is spread at different areas as well. Also at Alpha, most of the parts are in transit and in order to continue production it may expedite from a supplier if he has the extra capacity for the parts needed, or buy inventory from Alpha's sister plant. Beta has many local and U.K. suppliers that can provide the necessary parts if they have the capacity. But most of these parts support the operations of the water supply chain, so if operations are running smoothly, Beta might not be affected until the parts arrive. Additionally, parts that come from outside the U.K. are kept in stock by a U.K. distributor.

Inventory management, though, is different in the two companies. At Alpha, as soon as parts leave the supplier, they are on Alpha's inventory. Thus, Alpha is in charge of the transportation and stocking of the inventory until it is delivered as a vehicle to the dealers. Beta implements vendor managed inventory (VMI) for the warehouse stock products where suppliers are responsible for the transportation and stocking of the parts kept in the warehouses and Beta pays for the inventory when it is used. Alpha is also trying to implement VMI for all parts, but when the interviews were performed, Alpha was just discussing possible VMI agreements with its suppliers. VMI is a practice that can make the company more flexible and resilient to disruptions because it provides supply chain visibility and builds tighter relationships with suppliers, so if there is a disruption the supplier and transportation can be rescheduled to respond as quickly as possible to the situation. By knowing the required levels and the transportation network, a supplier is more aware of the most optimal plan that can be developed to respond to the disruption.

The criticality of a part is defined differently in Alpha and Beta. A critical part in Alpha is a part that, if unavailable, will cause assembly line stoppage. Thus, having it available during production is pertinent. In Beta, critical parts for the product supply chain are determined by what is needed for the maintenance of the critical operations in the water supply chain. Because continuity of water supply is needed 24 hours a day, if a critical operation breaks down, Beta needs to have available the replacement parts. Furthermore, parts that have long lead times are considered critical by Beta because if they are needed and no stock is available, the waiting time for them will be weeks, unless expedited transport is possible.

As evidenced in the supply chain descriptions of the case study companies, although they are different types of companies and have differences such as stock control and network, they have several similar supply chain practices common among companies such as outsourcing, just in time stocks and single sourcing. Therefore, although companies may operate in different industries, they may apply common practices that are applicable to a variety of companies. Due to this, risk mitigation strategies that are applied in a company, if customized depending on the company operations, may also be applied in another company setting.

8.2 Sources of Disruptions

Each company, due to its interactions with the internal and external environment, can be affected by a variety of disruption sources. Given the examples of disruptions each company has encountered (Table 8.2), the majority of disruptions were different between the two companies. Alpha has mostly encountered disruptions along the network related to suppliers, production and inventory. On the other hand, Beta has dealt with disruptions at the treatment works and along the water distribution network.

Table 8.2 : Case Studies' Disruption examples

Disruption Sources	Disruptions
	Beta - Examples
<i>Quality</i>	Poor water quality into the works
<i>Flooding</i>	Treatment Works next to river – cannot treat water
<i>Fires</i>	Site burnt down – cannot operate
<i>Supplier issues</i>	Oil prices affected supplier's operational ability
<i>Damage by third parties</i>	Damage to mains causing disruption to customers (water supply)
	Alpha - Examples
<i>Strikes</i>	Industrial Action (2-3 times a year) – stock issues
<i>Transportation</i>	Network Problems (traffic, bank holidays, borders, unpredictable sea freight, long distances)
<i>Natural Hazards</i>	Bad weather in Europe affecting transportation
<i>Supplier Issues</i>	Fire at second tier supplier, storm took roof of supplier plant, bankruptcy – cannot deliver parts
<i>Production Problems</i>	Equipment Breakdown – stop production
<i>Inventory</i>	System not showing exact numbers – no parts for production

There are two common generic sources of disruption the two companies have identified, natural hazards and supplier issues. All types of companies are at risk of natural hazards materializing. This is because companies are present in the natural world which they interact with, and thus escaping from bad weather is virtually impossible. When the weather causes adverse conditions to a company's network, it's very difficult not to affect, for example, transportation and the company's facilities. Both companies are concerned with natural hazards where they have witnessed the results and they have developed procedures to be able to deal with such instances.

Supply chain issues are also similar between the two companies because they depend on their suppliers; Alpha for the continuity of production and Beta for the continuity of water supply. Nevertheless, Alpha has a longer and more complex supply chain than Beta and is highly dependent on its suppliers to have the products JIT so it can continue production. This is evident by the more incidents Alpha has faced with its suppliers than Beta. Beta's water supply chain depends

on parts for maintenance and also requires certain parts such as chemicals for the treatment of water, but it hasn't faced a great deal of supplier issues. The parts Beta depends on for the continuity of its supply chain are not so many in number as Alpha's, plus they have many local and U.K. based suppliers that they have been cooperating with for years, so a mutual understanding between them has been developed. Thus, the more suppliers a company has operating all around the world, the more supply disruptions it will incur as compared to having suppliers that are close to a company and can respond quickly to demand and supply variations. This is why Alpha is trying to reduce its supply base and focus on the long term preferred suppliers who provide component parts rather than just parts from many suppliers. However, local suppliers may not be as cost effective as global suppliers. These are trade-offs the companies need to consider.

The transportation network is vulnerable to disruptions because parts need to pass through different borders, traffic and bad weather conditions. Alpha has become very good at managing transportation events due to their experience with these and their understanding of having parts on time. Beta does not face the same challenges as Alpha because the suppliers are relatively near, involving small lead times, except for certain overseas suppliers. Plus, Beta does not worry about the transportation of parts into the warehouse because the suppliers are responsible for it. Moreover, the parts that come from abroad are not only stocked in Beta's warehouse but a U.K. distributor also keeps stocks of these parts.

Both companies have quality standards in place so they can control the quality of parts from suppliers. However, Beta may have problems with water quality, which is a source of disruption it cannot control except by using chemical treatments. In certain instances though, water cannot be treated, so they have to use water in storage and service reservoirs or rezone to supply customers. This becomes very difficult in island zones and they can only use alternative water supplies if the water in the zone reservoirs is inadequate.

Alpha has also been affected by strikes along the network, which may materialize in different countries at varying times. Beta hasn't dealt with strikes because most of the suppliers are in the U.K., though if a prolonged strike were to materialize

across the U.K., then Beta's operations would be affected. This is a scenario Beta needs to consider and develop RM plans for.

There are certain sources of disruptions that may be threatening to a large number of companies from different industries, such as natural hazards and flu pandemics, and depending if there are RM processes or contingency plans in place, the reaction from company to company differs. But based on other companies' disruption experiences, companies may develop appropriate processes which can be applied in their business settings such as solutions to transportation problems, natural hazards and fires.

8.3 Employees' Risk Perception

Examining risk perception between employees is important in order to view their understanding of risk and if there is a common agreement of what risk and disruption are, firstly at a company level and secondly between companies. Further, the perception of these two concepts amongst employees between two different companies helps view how each company approaches each concept for its management practices.

Employees perceive and understand risk based on their daily activities and their experience regarding risk incidents. This is evident by the responses from Alpha's and Beta's interviewees (Table 8.3) who link risk with their daily operations and experience. Beta's employees appear to be more risk aware than Alpha's, due to the RM processes they have in place, where managers and employees from different areas in the company get involved. This risk awareness at Beta helps identify possible sources of risks and then develop appropriate mitigation and contingency plans. At Alpha when managers were asked about risk, they felt uncomfortable with the question and needed time to answer it, whereas at Beta interviewees were already knowledgeable of the risk and disruption concepts.

At Alpha, managers do not consider any disruptions beyond their supply chain such as economic crisis and diseases. At Beta, though, perhaps encouraged by the regulators, managers recognise that they need to deal with external threats to the

network which may impact the stakeholders. There is no formal risk process at Alpha; thus its respondents cannot see beyond their activities of possible potential threats to the company and network in general. At Beta, as the hierarchical meetings progress, the spectrum of potential sources of disruptions to the network gets larger, and the higher the decision makers are, the wider view they have of the sources that may interrupt Beta's operations. Also, the input from the regulators helps them consider risks that have very small chances of materializing but whose impact could be large e.g. flu pandemic.

Table 8.3 : Risk and Disruption Perceptions

Interviewees	Beta		
	Risk Perception	Disruption Perception	Risk + Disruption
<i>Risk Consultant</i>	Anything that could affect the supply of water where no risk processes are in place.	Interruption to supply.	Similar concepts with different time frames.
<i>Business Continuity Consultant</i>	Potential what could happen.	A risk that materializes.	Similar concepts with different time frames.
<i>Operations Manager</i>	Risk has a variety of meanings: mostly related to health and safety + operational risks.	Anything that affects the treatment works and the customers.	Similar concepts with different time frames.
<i>Supply Chain Manager</i>	Risk is the consequence to security or adverse publicity.	A risk that materializes.	Similar Concepts
	Alpha		
<i>Purchase Manager</i>	Risks related to supplier issues: does not supply the parts, poor management and capacity planning, no sufficient capacity	Risk related to supplier issues: does not supply the parts, poor management and capacity planning, no sufficient capacity	Same Concepts

	for extra demand, machine breakdown	for extra demand, machine breakdown	
<i>Manufacturing Engineer Manager</i>	Risks related to: volume loss, quality problems, health and safety, equipment damage	Risks related to: volume loss, quality problems, health and safety, equipment damage	Same Concepts
<i>Materials Planning and Logistics Manager</i>	Risk is anything that stops production and causes building vehicles with parts missing.	Risk is anything that stops production and causes building vehicles with parts missing.	Same Concepts

There are many sources of risk, but the sources that will affect the interruption of company operations can be considered as possible disruption sources. At Beta they consider risk as any source that can have a possible effect on an operation or activity, but disruption is the actual event happening that they haven't developed plans for, and may cause an interruption to water supply. At Alpha risk and disruption are regarded as the same: anything which causes stoppage or damage to the supply chain links. Thus at Alpha there is not a clear distinction between risk and disruption.

Risk and disruption are terms that are understood better when employees are involved in the RM processes and may distinguish between the two concepts. Although risk and disruption may seem to certain people to be the same, there are differences between them. Risk may be anything that can affect the supply chain operations, but disruption is an event that if it materializes will cause supply chain interruption, because there won't be any company processes for handling the disruption.

8.4 Risk Management Process

Beta applies a formal RM process which involves personnel from technicians up to the executive team. Thus, everybody in Beta has the possibility to be involved in the RM process. The risk register is a common way of communicating regarding risk issues. This is very helpful because if anybody in the company

realizes that there is a source of risk which hasn't been looked at, then it can be inserted on the risk register. Thus, sources of risks are being reported and considered which increases the resilience of Beta in the presence of disruptions. Alpha, on the other hand, has no formal RM processes, but mostly deals with risk through experience whereby operational processes are developed to deal with unwanted situations such as bad quality products, transportation problems and supplier capacity problems. At Alpha a risk is usually realized when functions are not performing as expected, or unwanted situations arise due to events, where Alpha recognizes that actions need to be developed to respond to them and also minimize the risk of an event recurring.

In Beta, a RM culture has been developed, which helps adopt a proactive response to situations, whereas at Alpha a reactive response to events is implemented. Beta's risk register procedures which could be adapted according to Alpha's operations, can provide a starting point to Alpha for handling risk to augment their 'fighting fires' approach. The risk register can assist in guiding Alpha in identifying potential threats to its supply chain, classifying them and then developing cost effective RM plans. The categories and scoring at Alpha will be different than at Beta; Alpha will have to define categories that are more suitable to its supply chain operations such as supplier reliability, network disturbance and manufacturing problems.

Both companies collaborate with supply chain partners for lower cost and better quality products, but they do not collaborate based on a formal RM process for identifying and managing risks. Due to disruption events both companies encountered with their suppliers, they are trying to improve certain processes, so the companies won't need to deal with the same events in the future. For example, both companies perform quality checks at their suppliers' and try to improve information sharing with them. At Beta where there is an already established RM process, it is very important to also involve supply chain partners. This can be achieved by promoting RM through seminars, training and exercises. Together, supplier-customer can realize the sources of risks that can affect them and work on developing processes to deal with these risks. This also helps enhance

relationships and communication, tightening up supply chain links. At Alpha, however, they need to first establish a RM process at a company level before expanding it to their supply chain partners.

Table 8.4 lists the risk mitigation strategies Alpha and Beta apply along their supply chain. These plans may be applied by other companies depending on their operations, supplier and customer relationships, supply chain visibility and available budget.

Table 8.4 : Risk Mitigation Strategies

Risk Mitigation	Beta	Alpha
<i>Stock</i>	<ul style="list-style-type: none"> • Storage + Service Reservoirs • Critical Products - at least two other water sites 	<ul style="list-style-type: none"> • Similar Stock with another plant - exchange • Stock higher levels • Secure Place + Regular Counting of pilfered parts
<i>Quality</i>	<ul style="list-style-type: none"> • Water Quality Checks - online monitors • Supplier Checks - visit the plants 	<ul style="list-style-type: none"> • Quality checks at suppliers • Production Quality checks
<i>Water Supplies</i>	Alternative - Rezone, Tankers, Bottled Water, Static Tanks	
<i>Suppliers</i>	<ul style="list-style-type: none"> • Source from Alternative Suppliers • Redundant Suppliers 	<ul style="list-style-type: none"> • Alternative Suppliers for commodity products • Global Suppliers - more than one manufacturing site + same types machines across facilities • Demerit points
<i>Back Up Supplies</i>	Dual feed of Electricity, Power Generator, Stand by Pumps	Dual feed of Electricity + Power Generator
<i>Network Reconfiguration</i>	Rezone, Temporary Connection, Overland Rider	Multi Modal Transportation

Major Equipment Breakdown	<ul style="list-style-type: none"> • Usually recovery within a few hours • Hold Spears • Supplier's turnaround time • Shut Valves, Sensors for Critical Pressure Points 	Technical Assistance
Fires	<ul style="list-style-type: none"> • Operate manually the site • Telemetry • Fire Doors, Fire Sensors, Fire Alarms 	<ul style="list-style-type: none"> • Fire Brigade on site • Fire Alarms
Insurance	Disruptions	Self - Insured
Employees' Flexibility	<ul style="list-style-type: none"> • Event Controller • Multi-skilled people 	<ul style="list-style-type: none"> • 10% Absence Cover • Group Leaders
Hire Office Facilities	Employees redeployed internally or externally (syndicated) to Beta	
Near-Miss	Health and Safety - reported	
Unions	Collaborate with Unions for finding solutions	Collaborate with Unions for finding solutions
Warehouses		<ul style="list-style-type: none"> • Hire a Warehouse • Stock at the ODC + Trailer Parks • If it is run by another company - company responsible
Standardization	Treatment Works	<ul style="list-style-type: none"> • Standard Features for parts across vehicle lines • Customer Packs
Reserved Capacity	<ul style="list-style-type: none"> • Reserve Extra Capacity at supplier's plant (chemicals + strategic products) 	<ul style="list-style-type: none"> • 10% above normal at suppliers • Company provides Extra Tooling • Fixed Cost
Transportation	<ul style="list-style-type: none"> • Do not Expedite • Not involved in the product transportation from suppliers 	<ul style="list-style-type: none"> • Monitoring Problems • Alternative Route • Expedite • Good Communication with Transportation Networks
Bankruptcy		Assistance of the Company to supplier - depending on supplier and reason

Based on the already applied practises of both case studies, risk mitigation strategies identified in the literature (chapter 3) and the case study companies, are proposed in Table 8.5 that will help Alpha and Beta become more robust and resilient to disruptions. The experience of employees regarding disruption events can be used as a guide in developing the appropriate strategies. When risk mitigation strategies are developed, they need to strategically fit each company. Thus, employees need to be aware and knowledgeable of the sources of disruptions, and then develop strategies that comply with the company's operations, philosophy and culture. A key issue here is which risk mitigation strategies are worth investing in. This can be decided based on the company's tolerance level of the risk consequences, the severity of a risk regarding other unmanaged risks, the available funding and the results of a cost benefit analysis.

Following in Table 8.5 is a list of possible additional risk mitigation strategies Alpha and Beta can apply in which the related benefits and drawbacks of these strategies are presented.

Table 8.5 : Possible Additional Risk Mitigation Strategies

Risk Mitigation Strategies	Benefits	Drawbacks
Flexible Sourcing Strategies		
<p>Alpha and Beta</p> <ul style="list-style-type: none"> ▪ can source a significant part from two suppliers: one providing fixed supply volume and the other offering flexible volumes in predetermined min and max limits ▪ with a supplier whose deliveries are not predictable but offers unique products it is best to set a higher reorder point ▪ If a supplier is in a vulnerable geographical area the company may multiple source <p>Beta</p> <ul style="list-style-type: none"> ▪ broaden geographically the supply base ▪ cooperate with internationally 	<ul style="list-style-type: none"> ▪ Flexibility (e.g. contracts) ▪ Necessary back-up ▪ Avoid disabled sites and trade lanes ▪ Continuous supply of materials ▪ Spread risk across two companies and two locations ▪ Shift production elsewhere 	<p><i>Multiple suppliers:</i></p> <ul style="list-style-type: none"> ▪ Transportation costs ▪ Inventory costs ▪ Contracts costs ▪ Product costs

known suppliers where they can switch production between plants		
Back-up supply contracts		
Alpha and Beta: contract a specific order quantity with the supplier in advance whereby the supplier delivers a pre-specified fraction of this contracted quantity before the beginning of the selling season and reserves the capacity for producing and delivering the remaining units	<ul style="list-style-type: none"> ▪ Order up to the back-up units by paying the original purchase cost ▪ Quick delivery ▪ Reducing inventory cost and size 	<ul style="list-style-type: none"> ▪ Penalty cost for any of the back-up units that are not purchased ▪ No flexibility to order more items than the agreement which may result in unsatisfied demand
Quantity flexibility contract		
Alpha and Beta <ul style="list-style-type: none"> ▪ customer is committed to order a certain quantity in advance, but the supplier has the flexibility to change this quantity upward or downward up to a certain amount at a specified time frame ▪ fixed supply contract with a supplier that specializes in cost efficiency to provide guaranteed quantities plus a flexible contract with upper and lower volume limits is provided to a supplier that specializes in flexibility 	<ul style="list-style-type: none"> ▪ Order amount that suits better a company's requirements in predetermined levels ▪ Reducing inventory cost and size 	<ul style="list-style-type: none"> ▪ Time frame not as close to real demand as the backup contract ▪ Costs more per unit than traditional contracts
Supply Chain Visibility		
Alpha: can enhance its information sharing network by sharing information with their second and third tier suppliers, thus having better visibility of the supply chain processes and awareness of any shortfalls Beta: be updated for any shortfalls along the supply chain from their first tier suppliers	<ul style="list-style-type: none"> ▪ Coordination, better visibility, agility and effective response ▪ Real time information ▪ Reduce inventories ▪ Increase customer service ▪ Reduced production/ logistics/ transportation cost ▪ Enables reroute goods, revise 	<ul style="list-style-type: none"> ▪ Investments needed ▪ Access sensitive information ▪ Distorted information

	production plans, redeploy production resources and adjust capacities	
Flexible Transportation		
Alpha: is very efficient in flexible transportation, it can also reserve extra capacity in carriers' agreements in order to be able to change automatically from one mode of transportation to another	<ul style="list-style-type: none"> ▪ Prevent supply chain operations from stopping ▪ Flexible logistics strategy ▪ Switch carriers quickly ▪ Promote competitive bidding 	<ul style="list-style-type: none"> ▪ Extra agreement costs
Postponement Strategy		
Alpha: this will be possible after the assembly line process is simplified in order to offer the customer packs. Currently, due to the huge variety of products produced postponement strategy cannot be applied	<ul style="list-style-type: none"> ▪ Meet demand ▪ Cost-effective and time-efficient ▪ Reconfigure the product quickly 	<ul style="list-style-type: none"> ▪ Assembly reconfiguration costs ▪ Supplier contracts costs
Demand management		
Alpha <ul style="list-style-type: none"> ▪ offer vehicles with different features at better prices if they remain unsold ▪ a commodity product can be replaced by another supplier which is easily substitutable in the manufacturing process 	<ul style="list-style-type: none"> ▪ Promote what is available ▪ Switch components between suppliers due to commonality of products offered 	<ul style="list-style-type: none"> ▪ Customer dissatisfaction ▪ Lower profits ▪ Logistics redesign
Stockpiling		
Alpha and Beta <ul style="list-style-type: none"> ▪ stockpile the significant parts that are sole sourced ▪ parts with low holding stock and low risk of obsolescence ▪ parts that can only be used in an emergency situation 	<ul style="list-style-type: none"> ▪ Quick Response ▪ Resilience ▪ Economies of scale 	<ul style="list-style-type: none"> ▪ Higher Inventory costs
Standardization		
Alpha: <i>Standard manufacturing processes:</i> This can be achieved across the Company's manufacturing plants so they can shift workforce and production	<ul style="list-style-type: none"> ▪ Shift production from one disrupted facility to an alternative ▪ Flexibility, 	<ul style="list-style-type: none"> ▪ Investments needed for platform redesign ▪ Redesign inbound and outbound network

<p>across plants, near-identical plants to be able to change a platform, car models when demand is different</p> <p><i>Components:</i> excess parts of one product in one plant can be used to build vehicles in another plant, if the component is standard between suppliers the Company will have the opportunity to procure it from many sources</p>	<p>interchange-ability</p> <ul style="list-style-type: none"> ▪ Move personnel around, work across plants ▪ Same component for different vehicles ▪ Inventory costs decrease ▪ Larger stock levels from current suppliers 	
Employees' Flexibility		
<p>Beta: appoint team leaders that can perform all the jobs in their team.</p>	<ul style="list-style-type: none"> ▪ Absence cover ▪ Rotate capable personnel to jobs requiring extra workforce 	<ul style="list-style-type: none"> ▪ Depends on team leader who may leave the company ▪ Not enough time to provide the additional help needed

8.5 Conclusions

RM is emphasized differently between the two case study companies. Although both companies have processes in dealing with risk, only Beta follows a formal SCDM approach. Although Alpha does not follow a formalized procedure, its experience and good knowledge of SCM practices has helped the company develop useful SCM processes to deal with supply chain uncertainty. Beta's employees though, due to their involvement in the RM process, help the company with their expertise in dealing both proactively and reactively with disruptions. Alpha does not take advantage of such expertise in terms of writing down RM processes and plans, which also affects the effectiveness and efficiency of the decisions regarding uncertainty of supply chain operations' performance. Thus, a formalized approach helps develop a RM culture in the company and deal proactively with possible sources of disruptions by developing risk efficient responses.

The form of the SCDM processes adopted will depend on the nature of a company's supply chain operations, the regulations it must obey to, investments available, the reactive or proactive culture in a company environment, the

company's risk appetite, and the willingness of management to invest time and money resources for the implementation of such a process. Depending on the SCDM methods (e.g. qualitative or quantitative), processes (e.g. assessment) and people (e.g. departmental level, supply chain partners) a company chooses, formal processes can differ between company settings.

SCDM is helpful for all company settings in order to reduce their supply chain vulnerability and improve company supply chain operations, but it is mostly helpful for companies that operate in global supply chains, in an unpredictable environment, where competition is high or where there are health and safety issues directly linked to the company's services or products provided. Thus, the more prone the company's supply chain operations are to disruptions and affecting stakeholders the more useful a SCDM process is. This is because it helps a company recognize the areas of vulnerability for which risk efficient action plans can be developed, and also may increase the robustness and resilience of a company in the presence of supply chain disruptions.

9 Conclusions

SCDM combines the areas of SCM and RM and tries to minimize the impact a disruption may cause along a supply chain. The application of formal RM processes to supply chain risks is not a widely used practice as is evident from both the literature and the Alpha case study finding. Thus, it can be derived that in most company settings, supply chain risks are managed but without following a formalized procedure, but mostly based on experience, past incidents and the need for the development of best practices related to SCM processes and activities. Thus, RM is inherent in SCM, because risk is constantly handled in order to develop more profitable and operationally healthy supply chain operations.

There are numerous applications of formal RM processes in finance, accounting and project management, but formal SCDM has been very limited applied across companies. Literature regarding SCDM is limited (e.g. Ericsson) and usually refers to particular SCM strategies which can be implemented by an organization to minimize the impact of a disruption by being more robust and resilient. Such strategies are not typically proposed as the output of formal processes which help first identify the possible sources of risks, assess the impact of these risks and then develop strategies to manage risks defined as important. This is mostly evident from the Alpha case study, which although does not apply any formal SCDM processes, has processes and strategies in place to deal with uncertainty and reduce the possibility of a disruption materializing such as supplier technical assistance and flexible transportation.

Companies though by trying to develop supply chain strategies in order to optimize their supply chain operations may not be aware of the possible range of supply chain risks they are facing. Deciding on supply chain strategies without also considering the most risky supply chain operations, controls and procedures for which strategies need to be developed before the sources of risk lead to supply chain disruptions, may not be considered best practice. This is because companies although try to improve their operations, they neglect possible risks that may cause great negative impact such as loss of production and negative company

reputation. A formalized SCDM approach will help the company evaluate which supply chain risks the company needs to develop action plans for before developing to serious disruptions, thus, not only protecting the company from possible supply chain disruptions but also developing robust and flexible SCM strategies.

9.1 SCDM Formal Procedure

Supply chain disruptions can be handled by adopting a number of strategies such as multiple suppliers, employee flexibility and flexible transportation. Although these strategies may provide a good solution in case of a disruption, they do not help the company identify and realize important potential risks it may face along its supply chain. Thus, although it may be preparing for a potential strike at a port, a fire at a supplier's plant may cause a disruption to the production of the company. A formal SCDM process can help identify all potential important sources of disruptions, guide decision makers through the different steps, and also help take informed and revised risk-efficient decisions for handling possible sources of disruptions.

Formality is about providing a framework that guides and encourages the development of best practice by providing structure and discipline to the process (Chapman and Ward, 2003). By following a formal RM process, decision makers can take informed decisions rather than ad hoc ones based solely on their working experience. Additionally, the SCDM process is an iterative process in which continuous improvements can be achieved. The phases of the SCDM process are firstly analyzed at a generic level and then analysis of each phase becomes more detailed as analysis is progressively refined. In this way, first a general understanding of the possible risks and action plans is achieved, and then as the process is repeated, the decision makers become more familiar with the best actions and solutions needed for managing the important risks.

SCDM consists of a set of processes for developing proactive and reactive responses to both risk sources and risk events respectively. Although SCDM is mostly related to the proactive handling of risk, there are risks that arise which

need to be handled reactively by having contingency plans in place because not all risks (e.g. flu pandemic) can be handled in a proactive manner. Based on the literature and the auto – manufacturing case study, it can be demonstrated that usually companies react to disruption events rather than follow a proactive SCDM process which includes pre-determined contingency plans and business continuity procedures. The water utilities case study company though, due to the vital service it provides to customers, must follow procedures set by regulators. In such an instance, more formal procedures need to be developed across the company and with supply chain partners regarding contingency plans, ones which will ensure the minimum disruption to the company's operations in the event a risk materializes.

Company formal procedures are best to be recorded and followed by company personnel, so the company can ensure that the pre-agreed and developed procedures are followed and adhered to. Thus, in order for a company to have formal processes in place, it also requires to be proactive in terms of the parties involved, the strategies, methods and techniques to be followed. RM tools, techniques and models can provide guidance to decision makers in order to choose the best suitable strategies and activities for SCDM. The RM model first helps develop a SCDM formal process which can guide the involved SCDM project parties through the defined phases. At each phase there are RM tools and techniques which can be applied with the most widely applied and known being probability/impact matrix, heat map, and risk register. Also, tools and techniques used for the analysis of specific steps during RM when following a quantitative approach are based on the disciplines of mathematics and statistics such as decision trees, statistical control charts, simulation and fault and event trees diagrams. Thus, although the SCDM strategies that will be identified and developed depend on the area of SCM, the RM models, techniques and tools which derive from different business disciplines provide the guidance for identifying risk efficient SCDM strategies.

The dynamic nature of formal SCDM processes also promotes organizational learning. By having formalized processes in place, procedures are not only known

verbally and executed but are documented with the necessary descriptions and analysis so are not forgotten when an employee leaves, but expertise knowledge is passed on to company employees and supply chain partners in a tangible form. This transfer of knowledge helps the organization implement formalized procedures, techniques and tools that are executed and are not removed with the departure of an employee. Beta's case study risk register highlights how effective a formal process is, because not only does it capture employee knowledge and expertise but also employees are knowledgeable of the processes they need to follow. Thus, a formal iterative process is a continuous learning cycle, which through employees' involvement with the process, is constantly revised and developed, and the employees become more familiar and knowledgeable of the processes, techniques and tools needed to be developed and implemented.

Adopting formal SCDM processes require top level management commitment who also understands the organisational changes necessary to support such processes. Convincing employees to implement a new process is challenging because they are unfamiliar with it and in order to successfully implement it, there is a need to comprehend the different activities related to SCDM. It is advisable that if a SCDM process is applied for the first time, to seek the advice of consultants that specialize in the application of SCDM processes to overview the training of the employees and the application of the new process. Also advisable is that the SCDM process is not firstly applied at an organization-wide level but at a departmental level. This will help the company realize the changes and improvements that need to be made related to the process which will then be integrated into the company's decision making SCDM process. Further, Ward (2005) proposes targeting areas of the organisation where the benefits from RM will be greatest, and then using this experience as a learning process before attempting more widespread deployment.

Relationships between supply chain parties are very important in order to develop common SCDM reporting systems and integration processes. If one link in a supply chain breaks, then the rest of the supply chain parties may also be disrupted. Because of this, it is beneficial for a company to promote the formal

SCDM process to its first tier suppliers so that the link between the two companies is stronger. The implementation of SCDM depends on a company's power to influence suppliers to develop similar processes. Supply chain reliability as highlighted in the supply chain literature, is also important because collaborating with suppliers that can exchange credible information and deliver quality products in a timely manner is very important for the smooth operation of the supply chain.

9.2 Revised Risk Management Iterative Process

There are many variations of the RM framework but most frameworks support similar processes, others emphasizing more detailed descriptions and others just describing the basic RM steps. The different RM frameworks have similar objectives which are to identify and manage possible sources of risks.

The RM iterative process in figure 4.1 was based on the RM processes proposed in the literature, and was developed in order to help the researcher during the literature search, design and development of the case studies, by providing a structure of the basic issues to be researched and discussed. Based on the Beta case study, the RM iterative process in figure 4.1 can include another two steps. These steps are presented in figure 9.1 The first added step relates to the *hierarchical risk reporting* process which could be placed after the define context step. After the define context where the strategic plan and the operational level processes are defined, it is very important for the company to define the hierarchical reporting process (e.g. parties involved, timing, risk reporting between different business areas) of the SCDM process. Also, another step that can be added to figure 4.1 after the implementation and management step is the *residual risk management process*, where risk management plans that didn't produce the expected targeted results, will need to be redesigned. This is an important step because SCDM action plans may not go according to schedule, and based on the assessment regarding the progress of the SCDM processes, in the light of new information or internal/external to the company changes, new or revised action plans may need to be developed.

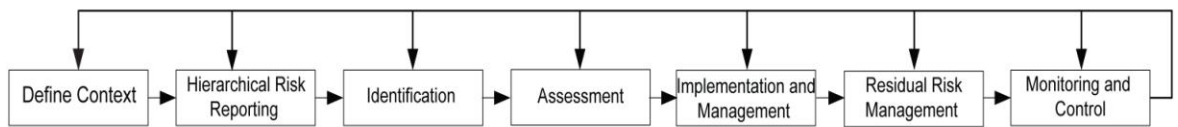


Figure 9.1 : Revised Risk Management Iterative Process

Achieving SCDM efficiency and effectiveness heavily relies on the SCM practices and strategies the company has in place and also shares with its supply chain partners (e.g. EDI). By having a formalized process which guides the decision makers along the SCDM process, helps them identify effective and efficient action plans for the sources of risk they are mostly concerned of. Firstly, efficiency is tried to be achieved by implementing the iterative process, which helps the involved parties familiarize with the SCDM process so solutions are detected with the least possible waste of time and effort, because as the process is repeated the involved parties perform better in respect of cost and time. Effectiveness which is linked with efficiency is realized by trying to find the best possible RM processes through identification and assessment which help the company develop robust and resilient strategies in the presence of supply chain disruptions. The monitoring and the residual risk management processes help increase the effectiveness because if the action plans don't develop as planned or don't provide the intended results, they can be detected against targeted outcomes, thus alter the SCDM action plans accordingly in order to respond to the expected results.

9.3 Distinction between Risk and Disruption

Risk and disruption are similar concepts which some people, such as in the Alpha case study, perceive them as the same. But in practice these two concepts denote different timeframes and impact; from when it is a possible risk until it becomes a disruption. People who have worked in RM teams distinguish the difference between risk and disruption. Based on the answers from case study interviewees and the SCDM literature, it can be distinguished that risk is anything that may have a possible effect on performance which may relate for example to a company's operations. On the other hand, disruption is the actual risk source

materializing, which may cause the stoppage of goods or services running through a supply chain for which the company does not have processes to deal with and is above the company's tolerance level. A company's tolerance levels are the acceptable levels set by the company based on: specified time frames until recovery to normal operations is established and the disruption's impact on the company. It may be a small disruption (stoppage of a machine on the production line for one hour) up to a mega event disruption with a huge impact e.g. destroyed warehouse facilities by a natural hazard. How big and important a disruption is depends on the company's tolerance level in accepting the disruption and how the parties rank a possible source of disruption if it materializes. Disruptions though, are usually regarded as low likelihood events with a high impact on operations, because organizations usually develop processes to deal proactively or reactively to reoccurring events as part of their daily operations.

9.4 Barriers to the development of formal SCDM Processes

Although formal SCDM can provide guidance through its process, if the usefulness of this process is not appreciated, then it is very difficult for SCDM to be applied to its full potential. Based on the literature and the case studies, companies usually avoid spending resources on preparing for disruptions that may never materialize, and companies that do apply RM do so either because of regulations or disruptions in the past that had an adverse impact on their companies' operations. The basic reasons for not applying SCDM are time and cost. Time, because risks are not just identified and then solved, but need to run through iterative analysis where changes and monitoring need to be followed until the degree of risk is placed at an acceptable level. Cost relates to the training of employees regarding the implementation of formal SCDM processes but also the cost of employees for looking into and overseeing SCDM processes. As employees become familiar with the formal SCDM processes, the effectiveness of the processes will provide better results and the cost and time needed will diminish as time progresses. This is evident in the Beta case study where employees are familiar with the process which has resulted in a routine process; risks are entered, reviewed and monitored regularly, team risk meetings help

enhance discussion and organizational learning related to RM methods, tools and techniques used. There is the possibility though, that SCDM will not be successfully applied and the usefulness of the processes not realized. Such difficulties need to be recognised and handled at an early stage where changes are more easily applied and accepted by the company.

9.5 Research Limitations

The research topic is a fairly new one, for which real-life examples of formal SCDM processes are hard to find. Although supply chain and RM literature provides a number of literature sources and theories, literature relating to SCDM processes is limited. Finding the related bibliography and journals to the study, required a significant amount of time and searching. Finding case study companies that suited the research and agreeing in participating, was both difficult and challenging. The results derived from the two case studies were very helpful in addressing the research questions, but may not be generalizable because the sample of companies is very limited and does not cover most types of organizations and supply chains. As a result, there could be variations on how employees perceive risk and disruption, the phases of a SCDM process, techniques and tools a company may adopt, and the SCDM strategies which could be implemented. Having results from additional case study companies would enhance comparisons between the SCDM processes and strategies companies are adopting, in order to derive propositions of what SCDM activities, controls and formal SCDM processes best apply to different supply chain settings.

9.6 Suggestions for Future Work

This study focuses on formal SCDM processes as presented in Chapters 4 and 7, which are derived from the literature and the case study findings. The study, however, didn't examine the applicability of the SCDM processes in other company settings in order to understand which activities, tools and techniques in each phase best apply to a specific company type and its supply chain setting. These will highly depend on a company's and supply chain's structure, the data

availability, the processes and controls followed by the companies and the relationship types a company maintains with its suppliers.

Additionally, although the water utilities case study demonstrates the effectiveness of a formal SCDM process, it would be informative to assess the effectiveness of the formal SCDM process proposed in figure 9.1 in other company settings in different business sectors. This would then help inform figure 9.1 for any additional phases or alterations that maybe needed and any other techniques and tools that could be applied in each phase.

Moreover, possible research that may be performed will relate to visits to different company settings to examine their SCDM strategies, processes and practices. This will help gain a more general idea why companies are reluctant in applying RM processes, the extent they are willing to apply them and what are the current RM or SCDM processes (formal or informal) currently in place. As a result, a more comprehensive picture of the SCM strategies, formal RM or SCDM processes applied and the issues that top management or employees are considering will be registered and analysed. This will help improve the current SCDM processes because the issues concerning top management may be addressed which may help in more acceptable and widely applied SCDM processes.

SCDM is an interesting subject because it combines two broad areas, SCM and RM, and tries to develop processes based on these two areas. This study approached SCDM from a formal RM qualitative approach which can help formalize the SCDM process in different company settings:

- Companies that are already applying RM at a company level could expand their process by also incorporating SCDM
- Companies dealing with possible sources of disruptions by only developing supply chain strategies instead of following a formal process can formalize their SCDM processes, and
- Companies that are in the process of developing formal SCDM, could augment activities and strategies that may be helpful for a company's specific disruption management requirements.

If the area of SCDM is further developed so that each phase includes helpful guidelines for different types of companies, then it may be applicable to a variety of companies. If more companies are applying formal SCDM processes, then the uncertainty along a supply chain may decrease and tighter supply chain relations can be developed, contributing to more effective and efficient supply chains.

Appendices

Appendix I : Vendor Managed Inventory

Important information sharing between supplier and customer through vendor managed inventory (VMI) can help decrease supply and demand variations of the materials and product orders. Following VMI descriptions are presented:

- In VMI the customer shares information with the vendor such as actual sales of their product, current on-hand inventory and details of any additional marketing activity such as promotions. The vendor having this information available takes responsibility for replenishing the customer's inventory. As a result, no orders are received, but instead the customer defines the upper and lower limits of inventory that it wishes to have on site. Thus, it is the supplier's responsibility to maintain the customer's inventory within specified stock bands (Christopher, 1998).
- VMI is a protocol positioned between two organizations (buyer – vendor) in the supply chain that gives the necessary inventory and sales information, authority and responsibility to the supplier in order to manage the customer's inventory (New and Westbrook, 2004).
- With VMI the seller needs to have access to the buyer's inventory balances and must have the responsibility of sustaining the buyer's inventory balances within arranged limits (Walker, 2005). Walker (2005) further explains that when the inventory level has dropped below the reorder point, the supplier is authorised to replenish inventory from the minimum up to the arranged maximum level, therefore no purchase orders are received from the buyer.
- In VMI the retailers hand over the ordering and replenishment planning decisions to the manufacturer who in turn, achieves direct information access regarding customer demand and retailers' inventory positions (Tang, 2006a).

Vendor and buyer, by exchanging information and forecasts on customer demand, actual sales, retailers inventory levels, marketing and sales promotions, come into an agreement where the buyer provides the responsibility to the vendor to manage

and replenish inventory based on agreed-upon upper and lower limits. All these steps of the VMI process, plus the dependence of the vendor on the buyer, require trust to be the basis of their interactions. Furthermore, the buyer may not only provide the necessary information such as inventory levels and sales data, but also inform the vendor of its strategies, such as expansion and marketing plans. This will help develop a common understanding between the two parties so mutual goals are developed.

VMI provides to the vendor actual data of sales and demand levels, thus decreasing risk of forecasting error but also help in planning production and distribution at more accurate levels and with lower operating costs. Both parties benefit from VMI mostly related to inventory and processing costs. More specifically, benefits VMI can offer to the buyer include (Christopher, 1998; Walker, 2005; Tang, 2006a; Sheffi, 2007):

- reduction of inventory levels whilst the risk of stock-out diminishes
- decrease of overhead and operating costs related with replenishment planning while taking advantage of certain guaranteed service levels, and
- elimination of the need to forecast and order, by reducing the possibility of order amplification and removing an entire echelon of inventory.

A vendor benefits from VMI (Christopher, 1998; Tang, 2006a; Sheffi, 2007) by:

- having direct access to real demand information
- having a much better plan and schedule for production and distribution
- reducing safety stock requirements, by decreasing the bullwhip effect due to direct access of information regarding customer demands, and
- reducing production / logistics / transportation costs due to coordinated production and replenishment plans.

A decision that is sometimes difficult in the VMI agreement concerns which party and over which activities it will have inventory ownership. Ownership is determined when the supplier either owns the inventory at the retailer's warehouse subject to a minimum and maximum inventory level or issues promises that the

inventory at the retailer's warehouse will stay within certain pre-determined levels (Tang, 2006a). Thus, the vendor under VMI has more responsibility and costs related to inventory (e.g. replenishment of part or product, holding costs, transportation and on time delivery), but on the other hand takes control of the inventory and accesses the buyer's order and inventory information, which helps schedule production more efficiently.

Appendix II : Collaborative Planning, Forecasting and Replenishment

Another type of agreement similar to VMI where vendor and buyer cooperate in order to determine the required inventory levels and replenishments plans is collaborative planning, forecasting and replenishment (CPFR). Specifically, Tang (2006a) describes the CPFR process between the manufacturer and the customer in which both parties develop mutually agreeable demand forecasts. First, the manufacturer produces an initial demand forecast based on his market intelligence on products and the customer generates his own initial demand forecast based on his customer's response to pricing and promotion decisions. Then, both parties will share their initial demand forecasts and resolve the differences in their forecast to obtain a common forecast. Finally, when both parties agree on the common demand forecasts, the customer will develop a replenishment plan and the manufacturer will develop a production plan independently. CPFR is a mutual agreement amongst interested parties (e.g. supplier, customer) on demand forecasts, where both parties use each others' information for production and stock levels. This is beneficial for both parties because it helps reduce inventory levels and safety stocks.

Sheffi (2007) refers to a CPFR pilot process between several Johnson and Johnson products and Superdrug Plc, which began in August 2000 and ran until the end of 2000. Every week, the two parties would exchange their sales and orders forecasts. Then, a special CPFR software engine would process the data and return any inconsistencies between the data sets. After the data process, a joint group decided which forecast was correct and who should adjust. Thus, the data were adjusted and the process repeated the following week. As a result, CPFR helped in a 13 percent reduction of Superdrug's inventory levels, whilst improving in-store availability by 1.6 percent. This was achieved because CPFR provides the chance for exchanging necessary and important information which facilitates in better planning of the different operational activities such as production scheduling, lead times and inventory levels, required for the minimization of cost and maximization of customer satisfaction.

The difference of VMI with CPFR is that with VMI, after the information is exchanged between the buyer and the supplier, the supplier is in charge of the inventory and replenishment levels of parts or products in predefined upper and lower limits. In CPFR the buyer still places the orders to the supplier but the supplier has a better idea of the requested orders and reorder times than if he didn't have access to the buyer's information. Thus, CPFR and VMI help better estimate inventory levels and reduce supply and demand uncertainty, which assist in reducing product unavailability and unneeded stock.

Appendix III : Information Technology

Nowadays, companies heavily depend on technology for the transmission of data and real time information that is necessary for the planning and handling of inter – organizational activities. In supply chains, IT systems have the potential to facilitate closer inter-firm links through facilitating increased information sharing (New and Westbrook, 2004). The implementation and development of IT has helped supply chain entities improve their level of collaboration and coordination in different areas such as purchasing, logistics and forecasting. The information flows help in the coordination among the supply chain members and have a direct impact on production scheduling, inventory control and delivery plans of the supply chain entities (Lee et al., 1997).

Information-enriched supply chains perform much better than companies that do not have access to information further than their corporate boundaries (Mason-Jones and Towill, 1997). Companies invest in IT because they benefit from the real-time collaboration and integration between supply chain partners and better visibility along the supply chain which have resulted in improvements in production planning, inventory management and distribution. Therefore IT, which processes the necessary information for synchronous decision making between companies, can be seen as the backbone of the supply chain business structure (Sanders, 2005).

Although IT offers the above advantages, it also has certain disadvantages which can affect both a company and its supply chain. Increased dependence on IT makes companies' operations more vulnerable to computer viruses, software problems and other technology outages. For example, SQL Slammer was a computer worm that spread directly to vulnerable computers on the Internet in January 2003. As a result, Slammer infected 90 percent of vulnerable hosts within only 10 minutes of its first appearance. Hardest hit were Internet service providers in South Korea. Slammer also affected the operations of Seattle's 911 call centre, American Express's customer service and Continental Airline's online ticketing system. Generally, Slammer caused an estimated \$750 million to \$1.2 billion in damage (Sheffi, 2007). A virus attack can cause millions of pounds loss for a

company and if a virus spreads to other supply chain companies the loss might be even greater. Thus, the IT infrastructure of the company and the companies it cooperates electronically with needs to be updated and robust in the presence of disruptions.

Due to its high importance in exchanging information quickly and bringing companies closer around the globe, IT is becoming a prerequisite between supply chain partners. For companies that do not implement IT or implement it but do not comply with the IT infrastructure of the other supply chain members, there is the possibility of losing its supply chain partners. Weele (2005) argues that suppliers' electronic capabilities will determine if they will be able to continue in a customer relationship, because it is expected that the focus business will exclude suppliers from business who do not offer electronic linkages or who have incompatible information systems. Customers preferably choose suppliers with updated IT systems for faster and more secure interactions.

IT is a powerful resource for the company and its supply chain and if not developed to levels that enhance its robustness, an IT shortfall can cause a disruption along the supply chain in a speedy manner, leaving no chance for immediate reaction. This is why companies and their supply chain partners need to ensure that IT systems are updated regularly, so supply chain resilience is increased.

Appendix IV : Types of Outsourcing

Weele (2005) describes two major types of outsourcing, turnkey and partial outsourcing. Turnkey outsourcing applies when the responsibility for the execution and coordination of all the activities lies with an external provider. Partial outsourcing applies when only a part of a function is outsourced and the coordination of the activities still lies with the outsourcer. A major problem with partial outsourcing is how to distinguish the responsibility for the final performance of the outsourced activity between the parties involved (Weele, 2005). This can be clarified by identifying who is responsible for what and based on the performance that is expected by each party.

In turnkey outsourcing, the buyer heavily depends on the provider for the agreed-upon services which, if not provided to these standards, will affect the effectiveness of the buyers' product or service. The advantage is that the buyer has more time and resources to concentrate on the in-house activities and leave the responsibility of delivering the product or service to the provider.

Partial outsourcing is usually implemented when the buyer wants to have more influence and control over the outsourced function. This, however, means more time, cost and required knowledge from the company, so it can collaborate with the provider of the outsourced function. Therefore, a company when deciding to outsource a function needs to develop very clear guidelines and understanding with its providers, so no confusion is caused about who is responsible for what at each stage. Additionally, they must set similar strategies for the outsourced function, so they can achieve better coordination and collaboration between them.

Allen and Chandrashekar (2000) provide a different categorization of outsourcing types than Weele (2005) which are; labour, mixed and complete outsourcing. In *labour outsourcing* the contractor provides some employees and the host firm provides some employees, materials, process and systems, technology and equipment, facilities and management / supervision. In *mixed outsourcing* both parties provide the same services, which include employees, materials, process and systems, technology and equipment, facilities and management / supervision.

Mixed outsourcing needs to be carefully planned and duties clearly defined and assigned, because a function is performed by two companies which need to coordinate for its effectiveness. Finally, in *complete outsourcing* the contractor provides employees, materials, process and systems, technology and equipment, facilities and management / supervision, and the host firm provides program management. Thus, the host firm tries to have in control in all three categories the management and supervision of the outsourced activity. Outsourced activities are best to be managed more closely than if they were performed in-house. Thus, it is more favourable to outsource the execution of a process but never the control of that process (New and Westbrook, 2004). The host firm, by having the control of a function, can monitor the outcome, detect any undesirable results and act in a timely manner.

We can conclude that complete outsourcing is similar to turnkey outsourcing and that labour and mixed outsourcing share the same characteristics as partial outsourcing. Allen and Chandrashekar (2000) provide a more detailed description of the people and services provided for each type of outsourcing, and Weele (2005) stresses the advantages and disadvantages of outsourcing related to influence, control, and knowledge. The type of outsourcing depends on the company's requirements and the level of control it would prefer to have on the processes of a function.

Appendix V : Letter to Possible Case Study Companies

Risk Management Processes for Managing Disruptions in Supply Chains

A research proposal from Maria Tsiakkouri, PhD student
School of Management, University of Southampton, SO17 1BJ

I am a PhD student researching Supply Chain Disruption Management supervised by Stephen Ward, Professor of Risk Management and Douglas Macbeth, Professor of Supply Chains. My study involves developing processes that will guide managers in dealing proactively with possible sources of supply chain disruption.

Globalization, global competition, increasing complexity and uncertainty in business operations increase the exposure of supply chains to disruptions. Terrorist attacks, natural hazards, diseases, computer virus attacks and economic crises are certain kinds of disruptions that can have a significant impact on the performance of a supply chain. Such disruptions can affect the viability and competitive advantage of a company: for example, goodwill of customers and the reputation of a company can be damaged if the organization is not able to respond effectively.

Disruptions are rare but often quite damaging. The success of the company in dealing with such threats heavily depends on the organization's level of preparedness. Thus, formal approaches are required by the company in order to manage disruptions caused in the supply chain. Moreover, companies should not only focus on their own risks but also focus on risks associated with other links in their supply chain.

Proposed Approach

My work to date has involved an in-depth study of the existing literature on supply chains and risk management process frameworks. As a next step, empirical work will be undertaken to develop a deeper understanding of the range of disruption issues facing different types of organisations, and to identify possible approaches to disruption management that may or may not involve formalised risk management processes. Areas I would particularly like to enquire about are:

- i. Key problems and issues for management in implementing formal risk management processes;
- ii. Managers' perceptions of risk and the kinds of disruptions they are mostly concerned with;
- iii. Current disruption management processes, and experience with these.

I am particularly interested in any methods your company uses due to the fact that your company operates in a rapidly changing environment and faces global competition. Your experience would help me develop a formal process that can be used to handle possible sources of disruptions.

A report summarising the analysis and results of my work will be given to participating companies. All interview answers will be treated confidentially. If requested by the company, anonymity will be applied.

Yours Sincerely,

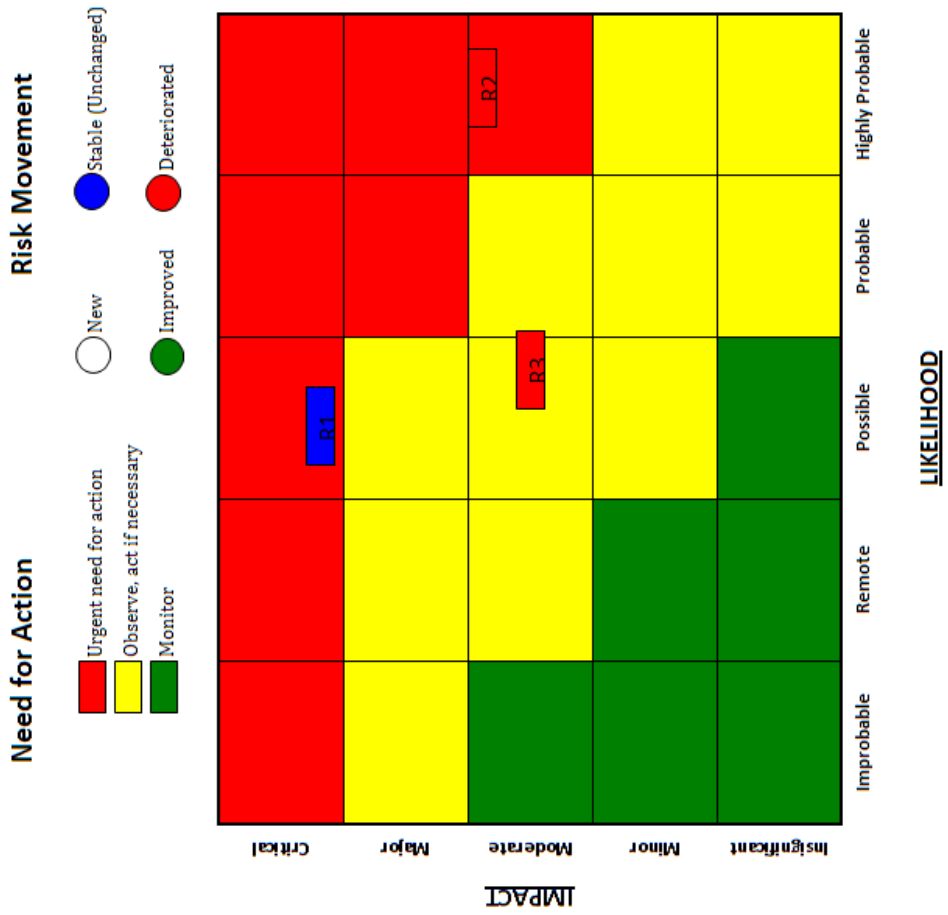
Maria Tsiakkouri

Appendix VI : Example of Interview Questions

1. Brief description of what your job entails
2. Could you please describe the water supply chain
3. Do you prefer to single or multiple source
4. Do you dual source, and if yes for which parts, and the reasons that you choose dual sourcing
5. Do you have a list of alternative suppliers you can refer to in case a supplier becomes idle
6. Do you reserve extra capacity or redundancy in certain suppliers plants so you can handle demand variations
7. How to you distinguish a critical from a non critical part
8. Transportation used from suppliers to the company; Transportation providers
9. How many warehouses are there; Reasons for this
10. What types of disruptions your company is mostly concerned with
11. If a warehouse catches on fire, or it is destroyed partly by a storm or flooding, what are the contingency plans
12. During the summer flooding which areas were affected and how did you respond Was it a reactive response, or you already had proactive plans in place
13. When a disruption occurs, how do you normally act and difficulties dealing with it
14. Which are the critical capacity constraints in the supply chain and how do you deal with them
15. Do you implement stockpiling (maintain inventory of critical parts and equipment) in order to succeed quick response if a disruption happens.
16. How do you conceptualize risk and if you perceive any distinctions between risk and disruption
17. What types of disruptions your company is mostly concerned with
18. Do you categorize risks? If yes, what type of categorization and why
19. What approaches do you use in identifying, assessing (cost-benefit, risk-map matrix), managing and monitoring risks
20. Which are the key problems and issues for management in implementing formal risk management processes

Appendix VII : Heat Map

RISK KEY	
Label	Risk Title
R1	
R2	
R3	



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