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Mitigating Supply Chain Disruptions in Transportation due to Natural Disasters and Climatic Perturbations

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ABSTRACT

Companies have been facing potential devastating impacts from unexpected catastrophic events due to the increasing global supply chain complexity and international outsourced activities. The purpose of the thesis is to discuss and analyze how companies can prepare for the potential disruptions occurring in its supply chain due to the natural disasters and climatic perturbations as well as to present possible strategies for mitigating the impacts from the disruptions. The literature review provides possible proactive and reactive approaches for managing supply chain risks and a final framework of supply chain risk management. A case study of a company is conducted and analyzed under this framework to present first insights into the company's supply chain risk management. The research further identifies practical risk assessment and treatment tools for managing catastrophic supply chain risks. It finally concludes with the possible strategies for companies to mitigate catastrophic risks in supply chain activities. Findings, conclusions and further recommendations are valuable for companies to further build up a robust supply chain in time of increasing trend of natural disasters and weather-relates catastrophes.

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Key Words

Supply Chain, Disruption, Natural Disaster, Supply Chain Risk Management, Strategy

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CHAPTER I

1. INTRODUCTION

The first chapter of the thesis starts with the background of the supply chain risk management in order to highlight the supply chain importance for company's operations. Thereafter, the research problem and its contribution are presented and followed by its research question and sub questions. We conclude the chapter by describing the purpose of this thesis and its limitations.

1.1 Background

Supply chain disruption has been a challenging issue for companies under the globalization and long distance of transportation. If we look back at the natural disasters in the recent decade: the latest earthquake in Japan in March 2011, the Hurricane Katrina in the United States in 2005, tsunami in Oceania, devastating floods in Pakistan, heat waves in Russia, winter storms all over the Europe in 2009 and 2010 and even the volcano eruption in Iceland in 2010 that keep in halt the whole air traffic in Northern Europe for a week, companies' supply chain activities have been put at the edge of high risk due to the uncertainty of the less frequent natural events that yet bring catastrophic impact to industries.

Issues mentioned above can bring devastating impacts on the company's operations and particular on its supply chain. Moreover, such disruptions in the supply chain are not only increasing in frequency, but the severity of their impact is escalating in terms of costs and losses and can bring a company to a partial or complete halt. In line with a growing trend of natural disasters the complex and long supply chain due to increasing pressure to source globally and to exploit lower manufacturing costs made it even more difficult to avoid supply chain risks. The complexity of products and processes are also adding to the probability of disruptions.

A lot of real-world examples of companies' supply chain vulnerabilities can be the evidence of the importance to consider natural disasters as a potential threat to a company supply chain. For example, Ericsson lost 400 million euros when on March 17, 2000, a lightning bolt struck

a Philips semiconductor plant in Albuquerque, New Mexico, created a 10-minute blaze that contaminated millions of chips and subsequently delayed deliveries to its two largest customers: Nokia in Finland and Ericsson in Sweden (Sheffi, Y. (2000); Dole suffered a large revenue declined after the 70% of their banana plantations in Central America were destroyed by Hurricane Mitch in 1998 (Tang C, 2008).; Ford closed five plants for several days after all air traffic was suspended after September 11 in 2001 (Tang C, 2008); and the automotive manufacturer Nissan Motor was forced to shut down three auto assembly lines in Japan because the factories ran out of tire-pressure sensors when a plane carrying a shipment from a supplier in Ireland was grounded due to the cloud of volcanic ash covering Europe after the volcanic eruption in Iceland (Ivy and Donaldson, 2010). In 2005, the fifth largest port in the world, and an important part of the U.S supply chain, was hit by hurricane Katrina, which served many supply chains.

In March 2011, the most powerful earthquake in Japanese history records hit the country, which brought tsunami and the explosion of nuclear plants along the east coastline. Multinational companies' global supply chain activities have been disrupted severely, especially for the automobile manufacturers and electronic manufacturers. Plant closures and production outages among Japan's high-tech companies, combined with port closures brought catastrophic impacts to local and worldwide companies[1]. Japan plays a major role in global supply chains both as a supplier of parts and a producer of final products. Companies including Toyota, Nissan, Honda, Mazda, Sony Corp., Toshiba, Panasonic, Canon and Shin-Etsu Chemical, etc., have suspended several production lines in Japan. The fuel shortages nationwide and power outage in Tokyo area put companies a more difficult position in decision making to mitigate the disruption impact to their production, distribution and the ability of staff to restart to work. The fuel shortages nationwide and power outage in Tokyo area put companies a more difficult position in decision making to mitigate the disruption impact to their production, distribution and the ability of staff to restart to work. Furthermore the shortage of supplying has resulted closing of the production lines in companies in the U.S. who reply on the supplying of critical components from Japan[2]. Airline company Boeing now faces considerable financial risks at the cost of uncertainty in its supply chain as Japan

[1]Japan quake tests supply chain from chips to ships, http://www.reuters.com/article/2011/03/14/us-japan-quake-supplychain-idUSTRE72D1FQ20110314?pageNumber=2, accessed 2011-03-14
[2]U.S. General Services Administration http://gsablogs.gsa.gov/wheelsandwings/2011/03/22/manufacturing-disruption-resulting-from-the-earthquake-in-japan/, accessed 2011-04-10

provides 35% of the 787-related and 20% of the 777-related production[3]. Delta Airline as the largest foreign carriers in Japan is cutting capacity to and through its Tokyo hub by 15% - 20% through May 2011 and expects the crisis of reducing the profit in 2011 in Japan by $250 million to $ 400 million (Nanto, Cooper and Donnelly, 2011). The impact is through more activities in world economy, trade, financial and currency markets. The estimated loss of this devastating earthquake and tsunami could cost up to $309 billion according to the World Bank, which makes it the most expensive natural disaster on record[4].

The issue has grown in importance in light of recent awareness and understanding that the company's failure to plan, measure and mitigate risk factors in its supply chain can negatively affects product quality, customer retention, brand strength and company's profitability. Particular for products that provide high profit margins, risk management has an increasingly important role. In this environment, it is crucial to identify all the possible steps that an organization can take to design their solid supply chain risk management program and to assure continuous product and service availability.

1.2 Research on natural disasters and climatic impact

The environmental concern has been intensifying in recent decades. The amount and force of natural catastrophes since the beginning of the new millennium left significant footprints in history. The existing records ***Figure 1*** on natural disasters can be traced back up to 1900 which shows a significant growing trend in the number of disasters with a sharp increase during last twenty years (EM-DAT[5], 2009).

[3] Supply chain disruption force more delays in Japan, Reuters http://www.reuters.com/article/2011/03/24/us-japan-supplychain-idUSTRE72N18620110324?pageNumber=2 ,accessed 2011-04-10

[4] CNNMoney, Japan earthquake could cost $309 billion http://money.cnn.com/2011/03/23/news/international/japan_earthquake_cost/index.htm, accessed 2011-04-10

[5] EM-DAT: the International Disaster Database a global database on natural and technological disasters that contains essential core data on the occurrence and effects of more than 18,000 disasters in the world from 1900 to present. EM-DAT is maintained by the Centre for Research on the Epidemiology of Disasters (CRED) at the School of Public Health of the Université catholique de Louvain located in Brussels, Belgium. The database is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies.

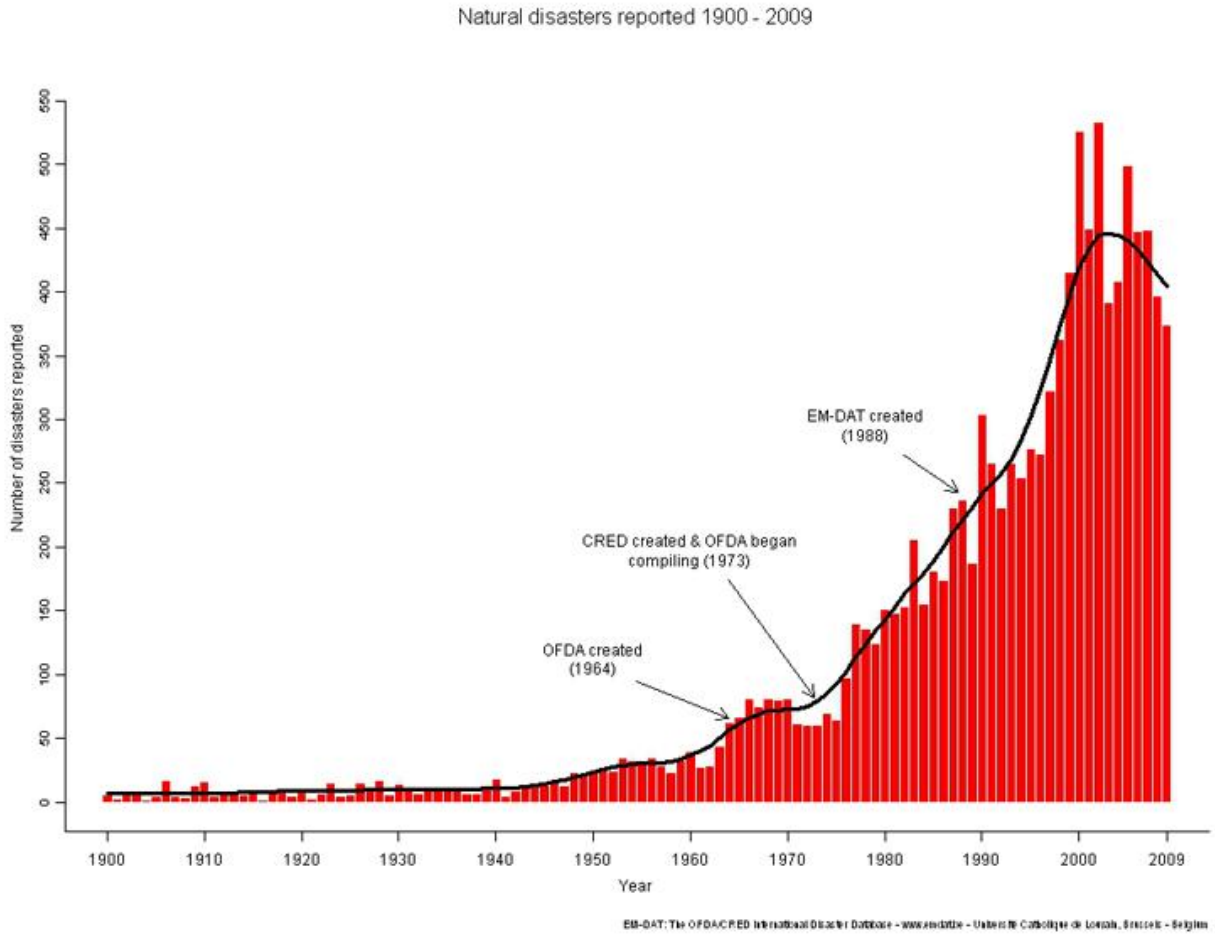

Figure 1 Natural disasters reported 1900-2009

Source: EM-DAT: http://www.emdat.be/natural-disasters-trends

In our thesis we refer to natural disasters and climatic perturbations as a cause of supply chain disruptions. CRED[6] defines a disaster as "a situation or event which overwhelms local capacity, necessitating a request to a national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction and human suffering (CRED, 2010). ***Table 1*** shows the classification of natural disaster subgroups and their main types.

[6] CRED - The Centre for Research on the Epidemiology of Disasters - has been active for more than 30 years in the fields of international disaster and conflict health studies. The Centre promotes research and provides an evidence base to the international community on the burden of disease and related health issues due to disasters and conflicts, in order to improve preparedness and responses to these humanitarian emergencies. CRED trains field managers, students, relief personnel and health professionals in the management of short and long-term humanitarian emergencies and provides Database and information support on Natural disasters, Civil strife and conflict epidemiology and their impacts.

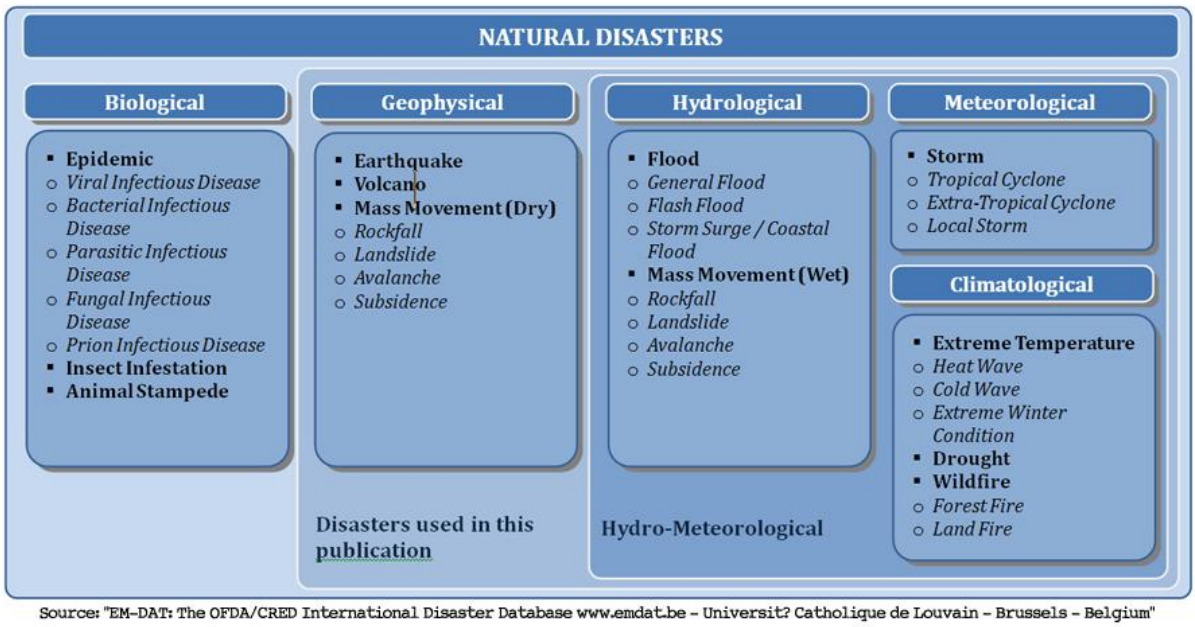

Table 1 Natural disasters classification.

Source: CRED Annual Disaster Statistical Review 2009 – The numbers and trends

Apparently, risks of natural disasters have been increasing simultaneously to the global economic growth. On the other hand, the development paths have been reinforcing the increasing hazard through environmental degradation and contribution to a global climate change (UNDP, 2004). It is widely agreed by the various scientists that climate change is already a reality (The World Bank, 2003). Lecocq and Shalizi (2007) summarized the causal chain linking economic behavior today to economic consequences tomorrow via climate change as:

Economic activities → Emissions → Concentrations → Climate change → Natural disasters →Impacts on physical and ecological systems → Impacts on economy.

Consequently, climate change most probably will have a significant effect on the frequency of extreme weather events and natural disasters occur which lead to a negative effect on economy and businesses (Lecocq and Shalizi, 2007).

In many European countries rising temperatures already lead to a greater incidence of heat waves which in turn increase the risk of wildfires. Climate change is not the sole reason for catastrophes such as these, but is helps create the conditions for them. In some parts of the globe extreme weather events do play out more destructively than ever before. "Looking back we can see that in

the Caribbean the number of particularly large hurricanes has increased. And climate predictions imply that this trend will continue" as Gerd Tetzlaff, professor of meteorology at Leipzig University and head of the advisory board of DKKV (The German Committee on Disaster Prevention) noted[7]. From the business point of view it means that global companies need to prepare their supply chains to be able to respond efficiently and mitigate the effects of these risks.

The previous ***Figure* 1** clearly indicates the sharp increase of natural calamities during last century and particular past 30 years. The next ***Figure 2*** focuses only on those 30 years trend and shows more detailed picture of the catastrophic growth divided by the type of disaster.

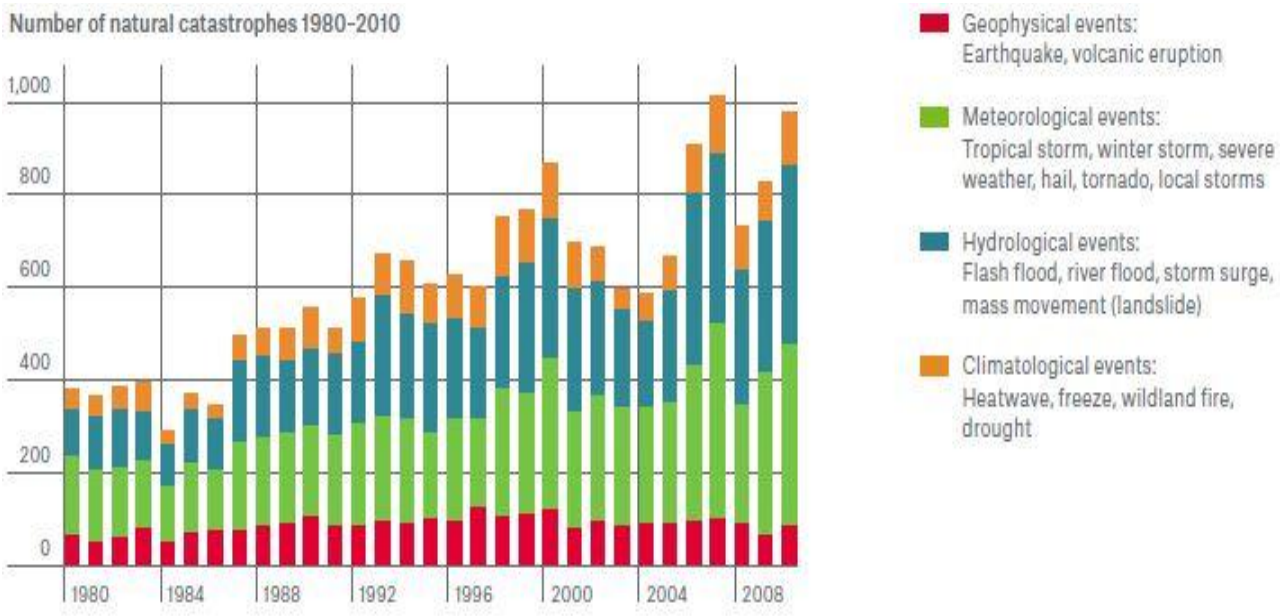

Figure 2 Natural disasters reported 1980-2010

Source: Geo Risk Research NatCat Service, Munich Re, 2010

According to Munich Re[8] the largest reinsurance company the upward trend is obvious with steadily increasing number of winter storms, severe weather, tornadoes and floods over the last three decades and relatively low increment in climatological events. Earthquake and volcanic eruption remain stable; however, they have the highest impact in terms of losses and

[7] Irene Quaile (2009)More natural disasters due to climate change? , http://www.dw-world.de/dw/article/0,,4598063,00.html , accessed 2011-04-20

[8] Munich Re - Munich Reinsurance Company, the largest reinsurance company in a world based in Munich, Germany.

damages. In fact, 2010 was the second worst year in history, after 1980 topped only by year 2007 (Munich Re, 2011). Munich Re noted that 2010 saw one of the most severe hurricane seasons in the past 100 years, but most of the storms luckily were over the open sea. According to another report of Swiss Re[9], which also has a wide database on natural disasters 91% out of all natural catastrophes worldwide in 2010 were caused by atmospheric conditions or climatic perturbations and 9% were attributable to earthquakes and volcanic eruptions or natural disasters (Swiss Re, 2010).

The Annual Disaster Statistical Review provided by CRED stated that of all continents, Asia was most prone to geophysical (56.0%), meteorological (49.4%) and hydrological disasters (40.0%), whereas Europe was the most affected continent by climatological disasters (48.9%) in 2009. In terms of victims, Africa had the most victims from climatological disasters (53.5%), whereas once again Asia had the most victims from meteorological (99.2%), geophysical (91.8%) and hydrological disasters (91.6%). Asia also had the most economic damages from hydrological (66.3%) and geophysical disasters (51.2%) in 2009, but it were the Americas that suffered the most economic damages from meteorological disasters (42.1%) and Oceania from climatological disasters (48.0%) Maps 1, 2, 3 in the Appendix A provide a visualized and more detailed picture of percentage global natural disasters distribution and their impacts in terms of human losses and costs. (CRED, 2010)

There is considerable evidence that economic damages caused by extreme weather events have been increasing noticeably over the last few decades. Munich Re, the world's largest reinsurance firm, compared economic losses in the 1980s with losses in the 2010s and concluded that a significant portion of the increase in losses was due to a change in the frequency of extreme weather events but also due to increased development of urban areas in some parts of the world. According to Munich Re 2010 report overall losses in 2010 were the fifth highest since 1980. ***Figure 3*** shows the increasing trend of overall and insured losses over three decades. 950 natural disasters were recorded last year, compared to an average of 785 over each of the past 10 years.

[9] Swiss Re - Swiss Reinsurance Company, the world's second-largest reinsurer based in Zurich, Switzerland.

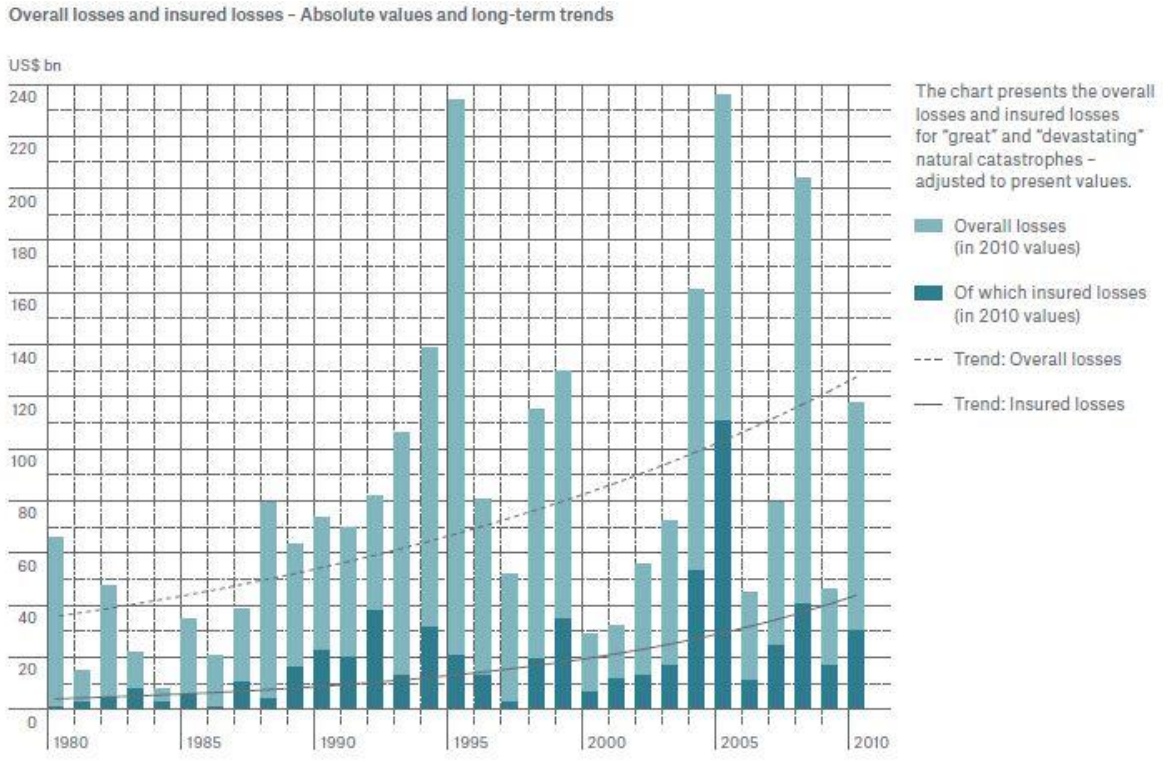

Figure 3 Overall losses and insured losses – Absolute values and long-term trends

Source: Munich Re, 2010

Overall losses amounted to approximately US$ 150bn compared to US$ 50bn in 2009. 2010 a year of four major earthquakes (Haiti, Chile, China and New Zealand) accounting for around one-third of the overall losses. From the figure we can see the increasing trend of both overall and insured losses from natural disasters in recent decades. However, the graph also has an evident of clear difference between overall and insured losses. It can mean that insurance on natural disasters is still not a common fact and individuals or companies simply do not purchase this type of insurance neglecting the impact of consequences from natural catastrophes. Another fact is that natural disasters mostly occur in developing countries, where insurance sometimes do not cover risks on natural disasters or due to the high premiums people cannot afford it leading to huge losses not covered by insurance.

According to Munich Re estimates, European winter storm Xynthia, which swept across Portugal, Spain, France and Germany in February 2010, cost insurers about $3.4 billion, while the earthquake that hit Chile in the same month may have cost the industry $8 billion. That led to an increase in natural disaster claims last year by more than two-thirds to $37 billion, exceeding the annual average of $35 billion over the preceding 10 years. Munich Re also

states and natural catastrophes comprised around 16% of global losses in Australia/Oceania in 2010. The findings conclude that weather-related events have more than tripled in Germany over the past 40 years (GeoRisk[10] research, 2010).

The eruption of the volcano Eyjafjallajökull on Iceland in April was another, quite different natural hazard event in 2010 demonstrated the vulnerability of the tight network of the global economy Munich Re reports. Air traffic over northern Europe remained paralyzed for six days. Fortunately, there was hardly any direct damage, but interruptions in supply of important goods to industrial firms meant that gradually more and more sectors of the economy were affected. The event ended up costing the airlines billions (Munich Re, 2010). Necessary to mention, that Munich Re is a pioneer in insurance solutions for business interruption due to natural hazards.

In addition, Swiss Re argued that insured losses are only the emerging part of the iceberg since there is practically no disaster insurance cover in the developing countries that have been severely affected by devastating natural catastrophes such as, in 2005, the earthquake in Kashmir and landslides and flooding triggered by heavy monsoon rains in India (Swiss Re, 2010 (1).

However, certain factors must be taken into account when considering the significance of economic losses. First, economic losses are expected to increase over time as people move into more vulnerable areas thus more infrastructure, homes and businesses that are susceptible to damage add to insurance losses. Second, inflation also drives up economic losses since buildings and materials increase in price as time goes on. Therefore the perception that the increase in economic losses intuitively means an increase in extreme weather events is misleading (Munich Re, 2010).

As a result, it is impossible to qualify what is worse when it comes to destruction. Whether it is hurricane or earthquake it causes extreme financial devastation and losses. Preventative measures can significantly mitigate damage, decrease the premiums paid on natural disaster insurance and reduce a company's reliance on insurance, which finally may be the safest approach of all.

[10] Geo Risk- Munich Re Research Department on natural disasters.

1.3 Problem discussion

With the increasing number of natural disasters and the growing complexity of supply chain activities, companies are concerned about potential rising risks caused by supply chain disruptions when unexpected natural disaster or climate perturbation occurs. A Natural Disaster Risk Study based on large North America-based companies conducted by FM Global[11] indicates that 96% of large companies have some level of natural catastrophe exposure (FM Global, 2008). Almost one out of three companies has more than 50% of its facilities worldwide located in the areas exposed to natural catastrophes. As a result, companies nowadays are more and more exposed to supply chain disruptions caused by natural disasters which bring companies negative impacts on their business. A report by Hendricks and Singhal (2005) shows that average effect of supply chain disruption in the year leading to the disruption is 107% drop in operation income, 7% lower sales growth and 11% growth in cost.

Although a company cannot prevent the occurrence of natural disasters, it can prevent or reduce the risk of damage from them. There are many tools and measures that an organization can apply in advance such as supply chain risk mapping and risk assessment to identify its characteristics of the supply chain flows. Global companies tend to have more experience in dealing with disruption with more alternative arrangements as their sourcing activities are expanding. Meanwhile it is necessary for companies to redesign a resilient supply chain strategically after the disruption. Tang (2006) suggests nine key features to build a robust supply chain for companies to mitigate the disruption which are discussed later in our paper.

However, if we look at the preparation level of companies for crisis, Monczka and Handfield (2009) based on a survey of *Business Week Global 1000* mention that, "although senior executives now recognize that supply chain disruptions can be devastating to an enterprise's bottom line, strategies to mitigate supply chain disruptions are typically not well developed or even initiated". A troubling statistic is that only between 5 percent and 25 percent of Fortune 500 companies are estimated to be prepared to handle a major supply chain crisis or disruption. In the Natural Disaster Risk Study (FM Global, 2008), it also indicates the

[11] FM Global is a USA-based insurance company that specializes in loss prevention services primarily to large corporations throughout the world in the Highly Protected Risk (HPR) property insurance market sector

preparation level for natural disasters in companies, which show the gap between the level of of natural disaster exposure and the preparedness in companies.

1.4 Purpose of the thesis

The purpose of the thesis is to analyze possible strategies a company can apply to mitigate and minimize the impacts of supply chain disruptions caused by natural disasters and climatic perturbations.

In order to fulfill the purpose we bring up a set of research questions to be answered first:

1. *What are the major factors that amplify the impact of supply chain disruptions due to natural and climatic disasters?*
2. *How can companies prepare for the emergency situations occurring in the supply chain due to natural disasters?*
3. *Which tools and mitigation measures can companies employ to prepare to supply chain disruptions efficiently?*

We hope the results of our research could help companies to refine their future strategies in supply chain risk management especially when facing the risk of natural disaster.

1.5 Delimitations

This research work delimitation concerns the focus specifically on transportation as a part of supply chain management. Furthermore the current study is limited to investigate the disruptions in supply chain caused by natural disasters and extreme weather-related events and do not include perturbations as a result of man-made disasters, such as terrorism, war or armed conflicts as well as oil spills. In addition, the scope of this thesis are the risks only related to supply chain without taking a consideration on other types of risk such as financial, strategic, cultural, transaction risks or operational risk related to IT systems shutdowns, thefts or management problems, etc. Finally, in our thesis we use the example of the supply chain service providing company. Therefore, the results of our study regarding strategies cannot be entirely generalized. The reason is because the strategies for different business activities (i.e. manufacturing, transportation providing etc) might be different.

CHAPTER II

2. RESEARCH METHOD

This chapter is written to present the research method that has been used to achieve the purpose of this thesis. We started with discussion of the qualitative research approach and the methodology of a case study. Further we present the way of our data collection as well as the validity and credibility measurement of the data.

2.1. Research approach

When researchers lack a clear idea of the problems that they will face during research an exploratory study is particularly useful (Blumberg et al, 2005). Our study is exploratory in nature. The lack of documented research on the supply chain disruptions in transportation due to natural disasters led us to conduct an exploratory study. In addition, such research approach can provide much richer and more vivid picture of the phenomena under study (disruptions in transportation due to natural disasters) than other, more analytical methods (Marshall and Rossman, 1999). This further confirms the authors' choice of selecting a qualitative method. Given that the nature of the research is exploratory in nature a qualitative approach was taken. According to Blumberg exploration relies on more qualitative research.

Qualitative research is a method used to increase the understanding of an area about which little is yet known (Strauss & Corbin, 1990). To the best of our knowledge, there has been little investigation analyzing the disruptions in transportation due to natural disasters and climatic perturbations. Qualitative research will provide a valuable means to collect and capture the richness and fullness of the research topic (Saunders et al., 2000).

2.2. Interview guide design

We have designed a question guide for the semi-structured interviews regarding their supply chain risk management to collect our primary data. The questions guide is formulated based on a previous research we found in the topic of risk management in transportation disruption

by Uhlig (2008). In Uhlig (2008), the interview questions have been used for 10 companies to complete the research in managing disruptions in transportation systems of risk management in supply chains. We have studies carefully this research and the process in designing the questions. We formulate our question guide for our research. The question guide is divided into three parts in order to have as much as details in a structured way about the company's risk management in supply chain activities from overviewing to narrowing down the scope. The first part of the questions in to grasp the company's perception toward supply chain risk management and the risk in transportation disruption due to natural disasters, as well as to understand the position of risk management in the organization, the identification of the risk and risk assessment process and tools, and their past experience with specifically weather-related disruptions in supply chain. The second part of the questions is intend to know how the company prepares for the potential risks in supply chain due to the natural disaster, and its strategies to respond to the disruption if it occurs. The third part of the questions is concerned the recovery from the supply chain disruption and the supply chain redesign. Future strategies are proposed at the end of the question guide. The interview guide is presented in ***Appendix C.***

2.3. Case study

Case study method is appropriate when researchers want to define research topics broadly and not narrowly, to cover contextual or complex multivariate conditions and to reply on multiple and not singular sources of evidence (Yin, 2002). The basic case study entails the detailed and intensive analysis of a single case, which can be a single organization, a single location such as a factory or production site, a person or a single event (Bryman and Bell, 2007). Case studies may employ a great variety of techniques including both quantitative and qualitative for the gathering and analysis of evidence (Gerring, 2006). Gerring (2006) argues that the case study approach to research is the most usefully defined as an intensive study of a single case or a small number of cases for the purpose of understanding a larger class of similar cases. We conduct case study with qualitative approach for our thesis to get a better understanding of the risk management in supply chain disruptions and strategies of mitigation in organizations in light of theories and concepts existing at present.

We choose SKF Logistics as a case study for analyzing possible supply chain disruptions in transportation as SKF Logistics is a supply chain service provider offering end-to-end

transportation solutions to its customers and thus dealing with transportation risks on a day by day basis. Also, the company has an over 100 year history of providing logistics services, so the experience in managing risks in its supply chain is another essential factor of our choice. In addition, the supply chain of SKF Logistics has a global coverage and operates in many countries in a world, thus the supply chain is complex and vulnerable which can be easily be disrupted by such events as earthquake or tsunami, volcano or heavy snow storms, so our interest of how they manage these type of disruptions and also how/if they are prepared to them can be satisfied by analyzing it more deeper. Finally, after discovering the basic information about the company we realized that SKF Logistics has a proactive approach of supply chain risk management, with focus on quality improvement and development by applying Six Sigma approach, which can be an invaluable input to answer our research and subsidiary questions of the thesis. SKF Logistics France is the second largest site of SKF group. Willingness of SKF Logistics France and their cooperation toward this project was the main reason for us to select SKF Logistics France as a case study.

2.4. Secondary data

For the literature review in our thesis we used secondary data which related to the data published through public sources such as internal and external reports, scientific articles, newspaper, hand books, websites, magazines and so on. The sources for our secondary data include Internet search engines, articles from library database and academic journal within universities, books and various reports from companies. We also used global natural disaster databases maintained by reinsurance companies, Munich Reinsurance Group NatCat Service[12] - private international level disaster database and Swiss Reinsurance Sigma[13] database as well as EM-DAT: The CRED International Disaster Database, which reports losses associated with large scale and many medium-scale disaster events, but does not include losses associated

[12] NatCat SERVICE – the world's largest database on natural catastrophes maintained by Munich Reinsurance Group, or Munich Re. The database provides the basis for a wide range of information, tools and services related to risk management and research. Originally developed for the insurance industry, NatCatSERVICE is now also used by scientific and institutional facilities and media. Although the entire database is available only to Munich Re clients, the company does allow partial public access. The database includes over 25,000 entries and covers a period from 79 CE to present, recording only "major events" before 1980.

[13] Sigma database, a limited access global natural (excluding drought) and man-made disaster database, developed by Swiss Re. Events are recorded from 1970 to the present. There are approximately 7,000 entries in the database with 300 new entries per year probably due to the more stringent inclusion criteria. The database is not publicly accessible but Sigma does provide a yearly publication of "raw information" listing all disasters for the year available to clients.

with small-scale events or those medium-scale events not reported internationally[14]. While data on human mortality is relatively robust, data on economic losses is generally does not give a clear picture of livelihood losses, particularly due to lack of information and low disaster insurance coverage in developing countries[15]. We select and filter the information of secondary data. We choose those highly relevant information related to this research topic.

2.5. Primary data

In our thesis, we have collected both primary and secondary data. Primary data refers the first hand data collected directly by the researcher for specific purpose or study from personal investigations and questionnaires. The primary data can be collected by using quantitative methods and qualitative methods. We collected our primary data for the analysis by conducting interviews with the employees from different positions at the company. We gathered data and information based on the answers of our interview questions guide from managers who have been directly involved in the activities relating to the interview questions.

We conducted three interviews with three professionals of SKF Logistics, quality control and customer service manager, business development manager, and transport manager. The quality and customer service manager controls the quality of logistics service as well as deals with customer service. Transport manager is running the transportation department and directly responsible for the risks related to disruptions in supply chain during transportation. Both of these two managers are expert and well experienced in their professions. Needless to say, that a quality manager has over 10 years' experience within the organization and now she is in charge of the quality department of the whole French site of SKF Logistics. In addition we interviewed a business development manager in charge of both internal and external customer relations in order to get more clear understanding of the links and collaboration between a company and its customers and to define the strategies which the company might develop to minimize supply chain disruption from the demand side. Detailed contact information will be given in the ***Appendix C***. These experts could provide us with in invaluable insight of supply chain operation in the company and supply with comprehensive knowledge in relation to the purpose and research questions of our thesis.

[14] United Nations Development Programme, *Reducing Disaster Risk: a Challenge for Development*, A Global Report, 2004, www.undp.org/bcpr
[15] See ibid

Each interview lasted from 30 minutes to one hour. The interviews were conducted face-to-face. We recorded the full conversation of the interviews which are exclusive for our thesis. The interviews with the company are recorded electronically and documented on paper. We extract information and primary data for our thesis based on the interviews we conducted. First we noted the answers of the interviews and filter out information which is not related to the research problem. Then we grouped the materials to identify the character of data. We use more headings to category the main points of the answers given during the interviews to help us generate the overall picture and consequences of the interviews for our analysis. We presented the data separately from the secondary data and keep an open mind to new ideas that could arise from the data.

2.6. Quality of the study.

In order to evaluate the quality of this study, this section will examine the quality of research in terms of trustworthiness. We do not adopt the term reliability and validity as we believe that this term is more suited to a quantitative study. Trustworthiness is suggested to be crucial to ensure reliability and validity in a qualitative research (Seale 1999). It is defined as establishing confidence in the findings (Lincoln & Guba, 1985). In order to ensure "trustworthiness" of our study it is necessary to demonstrate credibility, transferability, dependability, and confirmability.

Establishment of the credibility of findings involves ensuring that the theoretical framework developed in the study is understood and fits researcher's observations (Bryman & Bell, 2003). To ensure credibility in our study we used multiple sources for collecting our data that provided us with complementary aspects of the researched phenomenon. The cooperation between the authors in collecting and analyzing the empirical data helped us to reduce the bias and improve confidence in the material gathered. Furthermore, the interview guide used has been based on theories regarding risk management in order to have a match between researchers' observations and theoretical ideas that were developed in our study.

Transferability refers to the extent to which the findings of a study can be "transferred and remain valid for other people, events or settings" (Sekaran, 1992). As we have stated in research approach section, our reason for choosing a qualitative single case study is to collect and capture the richness and fullness of the research topic and particularity of the case rather

then come up with generalizations. One should be careful about generalizing the results of this study, as it was based on the analysis of supply chain risk management of the logistics service providing company which differs in structure and management with the other types of business, such as manufacturing, Third party logistics providers, warehousing, etc.

Other aspects of trustworthiness of the research are dependability and confirmability Dependability in qualitative research is the equivalent of the conventional term “reliability” (Bryman & Bell, 2003). The reliability of this study refers to the findings and results achieved but also reproduced by another researcher at a different time, assuming he or she used the same interview questions and interviewed the same people. We believe that the questions would produce similar results if were asked by another researcher. This is due to the fact that the questions that were asked were based mainly on the respondents’ experience with the focal relationship.

Confirmability is parallel to "objectivity" in a qualitative research, and is concerned with establishing the fact that “the researcher has not overtly allowed personal values or theoretical inclinations manifestly to sway the conduct of the research and findings deriving from it" (Bryman & Bell, 2003). As this study is qualitative in nature, it is important to realize that our own assumptions and interpretations might have affected the results. However the authors secured the consistency of data collection by using tape recorded interviews and written notes from the interviews.

2.7. Source critique

Although interviews are flexible and can give validity by allowing respondents explaining their views, the risk of interviews is that bias from the influence of the interviewers as well as the content of the topic concerned. In our thesis, the risk lies with the primary sources that the company might consciously give us a better view of their business and management. We have received a great deal of information about the company, the concept and the overview of their risk management, yet it is still possible that some information is given unconsciously even if the information is far away from what we want as primary information. The risk lies with the secondary data could be to some extent the outdated information and the results from some articles with the analysis of a particular disaster event in supply chain by applying specific model and stimulation.

CHAPTER III

3. THEORETICAL FRAMEWORK

In this chapter the concepts and theories are presented to enable the reader to get knowledge about the amplifiers or factors that make the supply chain even more vulnerable to disruptions in terms of natural and weather-relates catastrophes. It also considers two possible supply chain risk management frameworks to prepare or respond to disruptions as well as the possible strategies for mitigation of such disruptions. We will conclude with insurance as an essential part of companies risk management. The objective of the theoretical framework is to provide basis to the analysis and to support our findings.

3.1. Factors that amplify the impact of supply chain disruptions

While natural disasters and extreme weather have always been business challenges, their impact becomes more severe and significant as supply chains grow in complexity. Thus, when disasters occur it triggered major business disruptions. Disruptions due to catastrophic events are characterized as those that occur with low probability, but have severe consequences for the supply chain and business continuity (Knemeyer, et al., 2009).

As Riddalls et al. (2002) points out the costly effects of disruptions are followed by increased lead-times, shortages, reductions in customer service levels and increase in costs. From the company financial perspective Hendricks and Singhal (2005) found that companies that experience supply chain disruptions have 33-40% lower stock returns over a 3-year time period in comparison to the industry benchmark. Additionally these disruptions can also mean a loss of reputation for the companies (Sodhi, et al., 2010) Based on Tang (2006) observations most of supply chains break down during major disruptions and many of them cannot recover afterwards. As an example, Lam et al. (2009) investigated the business re-opening rate after Hurricane Katrina. They found that although there was a steady increase in businesses recovering and re-opening over time, ranging from 25 percent four months post-Katrina event to 65 percent two years later, some businesses never did return to the business again. (Lam et al., 2009, Dietch et al, 2011).

As a consequence, the previous studies show that the tendency toward improving the financial performance of supply chains by reducing costs (e.g. reduce supply base, lean production, just-in-time (JIT) inventory system), and reducing assets (e.g. outsourced manufacturing) make them more complex and more vulnerable and thus lead to higher probability of disruptions particular in a time of growing trend of natural disasters. As a result, it brings huge losses in terms of costs, stakeholders' perception and long-term business recovery.

Many academics have been studying the factors that can amplify the possibility of disruptions in supply chain (Ivy and Donaldson, (2010), Sheffi (2007); Elkins et al. (2005). Further down, we will discuss the most prominent ones for the current development phase.

The first is the growing trend of ***globalization and outsourcing of manufacturing***. Bary C. Lynn (2005) points out that outsourcing can increase significantly the potential of supply chain disruptions especially to a particular region. He also underlines that companies in Western Europe and the United States are extremely dependent on China nowadays (Lynn, 2005). However, due to the poor communication in global supply networks, long lead-times, and the complexity of the distribution channels associated with import regulations and security, multiple transfers, and customs requirements these companies are more likely to experience large scale disruptions (Donaldson, 2010). Thus, Sony realized the potential disruption and inflexibility of the long lines from China decided to pull their manufacturing out of China into Japan (Jiang, 2003). However, while doing so they did not consider the probability of catastrophic natural events in that area, as Japan is seen as one of the world most vulnerable zones in terms of earthquakes. Thus, due to the tsunami and earthquake in May 2011 Sony suspended production at eight plants in the affected region and said it was not sure when production would restart (BBC.com, accessed 2011-03-15). As a consequent, due to globalization of supply chain networks, the local catastrophic event has indirect global reflection (Wagner and Bode, 2006).

With the increasing ***product and process complexity*** the number of components and the size of the supply chain are also growing as a number of component suppliers grows accordingly making it more fragile and vulnerable to disruptions (Ivy and Donaldson (2010). In addition, when one of the component in this complex supply chain is sourced from a single supplier (as

in the Ericsson case, where the core product was supplied from a single source located in New Mexico) the disruption in this point of supply is likely to be amplified as it can stop the whole supply chain further down in a flow.

Many researchers conclude that the use of ***lean techniques***, where overall system efficiency is driven by lower inventory levels, reduced buffers and shorter lead time make supply chains more vulnerable to disruptions, since there is a reduced safety stock (Donaldson, 2010; Sheffi, 2007; Elkins et al., 2005). In addition, Donaldson (2010) also points out that lean manufacturing is very effective under the right condition; however, with a higher possibility of nature disasters and climatic perturbations an interruption in only one node of the supply chain can bring the entire system to a complete halt.

And finally, the ***shortened product life cycles*** where products have to recoup their development costs in a shorter time. Consequently, any delays in the supply chain, and thus delay in sales, can adversely affect a company's performance.

The amplifiers listed above but also the additional factors, such as focus on efficiency, central distribution and centralized production were defined in another research done by Thun and Hoenic, 2011. The authors summarized their findings in a picture presented in ***Figure 4*** .

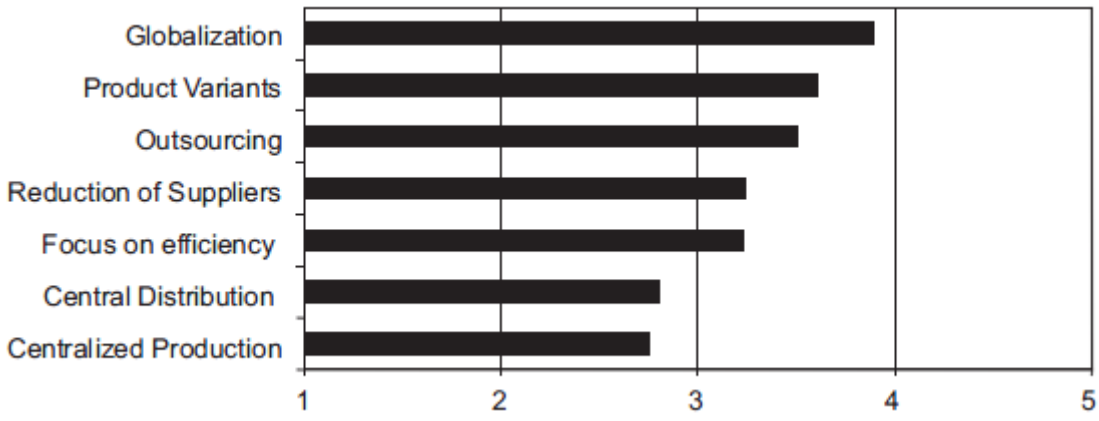

Figure 4 Drivers of supply chain risk

Source: Thun and Hoenic, 2011

From this figure we can see a clear prove that globalization of supply chains and the product complexity or product variants are the main drivers of supply chain risks. It is also possible to conclude that approaches for building up a lean supply chain such as outsourcing, reduction of suppliers and a focus on efficiency are regarded as key drivers for supply chain risks.

Consequently, as Chidambaram et al. noted a supply chain is only as strong as its weakest link. A failure in one of the links could affect many aspects of the supply network (Chidambaram et al, 1999). Thus, for the European company that outsources production or supply from the Far East and when earthquake hit China or tsunami effect Japan European it may also suspend their production for a several days or even weeks losing their customers and profits.

The past events such as hurricane Katrina on the September 11, Island volcanic eruption in 2010, heavy snow falls in December 2009 and 2010 in Western Europe as well as the last earthquake and tsunami in Japan 2011 have increased the emphasis of weather-related disasters for companies over last years. Thus, the CMI, 2010 survey found that extreme weather was the most commonly experienced disruption. ***Table 2*** in Appendix B shows the percentage of disruptions experienced by companies in the period 2002-2010 and how many of them were prepared to these disruptions, by having business continuity plans, which will be discussed in the next paragraph. From the ***Table 2*** we can see that companies put the disruption due to weather-related events as most experienced last years and gave it a top priority surpassing disruption caused by loss of IT. This fast justifies, that disruptions due to the acts of nature have increased in frequency and severity, which may encourage companies to take anticipation measures and develop an effective supply chain risk management.

3.2. Impact of transportation disruption caused by natural disaster

In this thesis we would like to discuss the importance and the impact of natural disaster on transportation disruption are perceived in SKF Logistic. We found previous research related to this topic and present in this section.

Transportation disruption is one of the sources of supply chain management risks (Giunipero & Eltantawy, 2004). A disruption in the transportation service can severely affects the continuity of supply chain operations (Rice and Caniato, 2003). Cavinato (2004) categorizes physical risk as one of the five sub-chains risks for identifying uncertainties in supply chain. Physical risk includes transportation disruption, the damage of goods, and the inaccessibility to inventories as well as manufacturing discontinuity.

Natural disaster is identified as one of the key drivers of disruptions of material flows in supply chain (Chopra & Sodhi, 2004). Wilson (2007) classifies disruptions in general and transportation disruption. Transportation disruption refers as any stoppage in the flow of goods, while other types of disruptions also include an interruption of the production of goods. Significant delay, interruption of the flow of goods, and the destruction and total loss of goods in transit, are considered as transportation disruptions (Cavinato, 2004).

Little is known about how important for companies risk management is in transportation disruption by natural disasters from previous literature (Uhlig, 2008). Tang (2006) points out that transportation disruption risks are often underestimated in companies even though most companies recognize the importance of risk assessment. Tang (2006) also summarizes the reasons of that which rely on the inaccuracy of the supply chain risk assessments and the uncertainty of the return on investment due to the lack of information for measuring potential impact of disruption (Repenning & Sterman, 2001).

However, we found previous studies on the impact of transportation disruption caused by both general disasters and natural disasters. McKinnon (2006) finds that huge national economic losses occur if there is a temporary disruption of road transportation. The impact of transportation disruption for companies can be destructive. Companies that rely on international shipments are more exposed to the risk of transportation disruption (Rice and Caniato, 2003). Wilson (2007) looks at the impact of transportation disruption of supply chain performance by simulating different supply chain settings. The author finds that the impact of a transportation disruption is stronger in a traditional supply chain comparing to a vendor managed inventory supply chain.

An important recent study by Altay and Ramirez (2010) indicates that natural disasters impact all sectors within a supply chain. The impact of different natural disasters varies depending on the company's industry sector and location, as well as different levels of the supply chain activities. However, the authors points out the limitation of the current investigation on the impact of transportation disruption by natural disaster in literature.

3.3. Supply Chain Risk Management framework

Those companies that are prepared are most likely the best able to recover from a supply chain disruption. Executives have put a lot of emphases recently to ensure disruption free performance of their supply chains where the proactive planning and development of Supply Chain Risk Management (SCRM) has become an essential part of a business efficiency and continuity.

Xiaohui et al. (2006) defined Supply Chain Risk Management (SCRM) as an integration of Supply Chain Management (SCM) and Risk management (RM) theory: SCRM = SCM+ RM. Linked to this, Norrman & Lindroth (2002) propose the definition of SCRM as c*ollaboration between partners in a supply chain which apply risk management process tools to deal with risks and uncertainties caused by supply chain related activities*. The focus of SCRM is to understand, and try to avoid the devastating effects that natural disasters and, thus, business disruptions can bring into a supply chain (Norrman & Jansson, 2004).

The previous studies (Wu and Knott, 2006; Peck, 2005, Norrman and Jansson, 2004) point out on three main dimensions which are related to SCRM:

- **risk,**
- **uncertainties** and
- **risk management process**.

Risk refers to a probability of the event and its impact or severity on the business or (**Risk= Probability (of the event) * Impact)** (Wu and Knott, 2006; Peck, 2005). However, while risk in most cases can be calculated, *uncertainties* are genuinely unknown (Norrman and Jansson, 2004). Regarding *risk management* dimension of SCRM, different academic sources label differently the stages of the risk management process although generally they are similar and can vary from risk identification, identification of risk drivers, risk assessment, mitigation strategies and ongoing monitoring, feedback or a learning loop (Norrman and Jansson, 2004). In our thesis we choose four major steps for proactive risk management process and three steps for reactive risk management approach as the most precise and explicit ones. These steps as well as the proactive and reactive approach will be explained later in this chapter.

When considering the area of natural disasters, estimating risks and uncertainties becomes even more difficult or sometimes even impossible. As noted before, risks due to natural disaster have low probability but high and severe impact when they occur, so the uncertainty of their occurrence is really high. Therefore, Kleindorfer (2005) has done an investigation on risk perception of the companies' managers in order to see which role low probability (or high uncertainty) risks due to natural disasters play in the risk management design and planning. The author, therefore, incorporated the risk perception factor into his framework for risk assessment. He asserts that when uncertainty is high, managers will underestimate the importance of an issue (Kleindorfer, 2005). Furthermore, Zsidisin et al., (2005) found that outcomes with very low probabilities seem to be ignored, regardless of their potential significance. In addition, managers are prone to the illusion that less possible risks are in control, which is in reality not always the case (Lovallo and Kahneman, 2003) These findings must be considered when determining an appropriate planning process for risks due to natural disasters and climatic catastrophes, meaning that managers are tent to neglect the low probability events as the potential threat for their supply chain and do not pay enough attention to this in their risk management planning. As the risk potential is quite uncertain regarding frequency and timing of occurrence, special strategies to assess and monitor these risks have to be applied (Chopra and Sodhi, 2004).

While reviewing the previous literature on supply chain risk management we identified that researchers distinguish between proactive and reactive supply chain management approaches (Norrman & Jansson, 2004; Handfield et al, 2010; Hendricks and Singhal, 2003; Tang, 2006). In the following sections we will present both approaches in order to give an overview of the existing ways that companies can apply to prevent and/or react to disruptions in their supply chain.

3.3.1. Proactive Supply Chain Risk Management approach

Norrman and Jansson (2004) state that the primer focus of proactive SCRM approach is to understand all possible risks and minimize their impact by addressing their probability and direct effects. Thus, based on their findings *the proactive risk management* approach includes four major stages:

1) Supply chain risk identification,

2) Risk assessment,

3) Risk treatment,

4) Risk monitoring

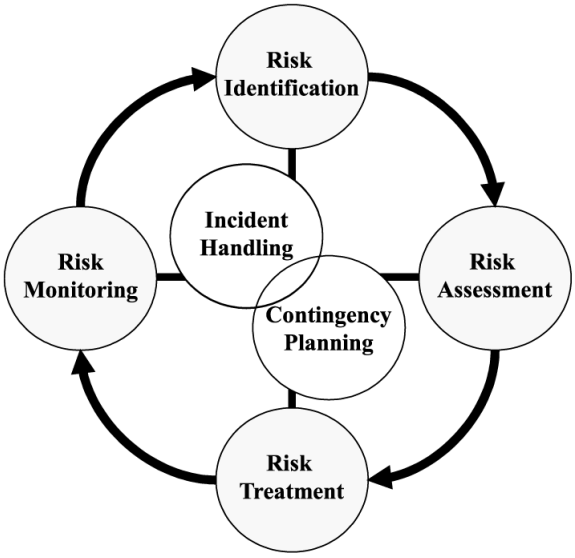

Figure 5 Proactive Supply Chain Risk Management framework

Source: Norrman and Jansson (2004)

In parallel to these steps Business Continuity Management or Contingency Planning and incident handling are also important components of SCRM, which will be described later in this chapter.

1. Supply chain risk identification

By identifying a risk, decision-makers become aware of events that may cause disturbances. To assess supply chain risk exposures, the company must identify not only direct risks to its operations, but also the potential sources and threats of risks at every key location throughout the supply chain (Christopher et al., 2002). In case of natural disasters Knemeyer et al (2009) suggest that the identification and estimation of catastrophic events occurrence could be done in several ways, e.g. by expert opinion combined with historical data, expert opinion combined with decision maker's opinion, game theory as well as catastrophe simulation modeling (Knemeyer et al, 2009)

2. Risk assessment

After the risk identification and analysis, it is important to assess and prioritize risks to be able to choose management actions appropriate to the situation (Norrman and Jansson, 2004). Knemeyer et al (2009) in their work highlight that the risk assessment must be deep and broad and should include not only the evaluation of the suppliers but also the supplier's supplier. On his point of view, a low risk contract manufacturer that uses high risk sources is still a high risk. He also suggests that this broad and deep analysis requires a tool that provides visibility to the whole supply chain including lower tier suppliers. The Risk Map is one the methods to allocate possible supply chain risks regarding their frequency of occurrence and impact on a company's supply chain. Different types of the risk maps exist in theory and practice. However, it is difficult to define which of them is better as it is up to the manager to choose which one s/he prefers (for example 3-to-3 or 4-to4 or 5-to-5, etc). The example of 5-to-5 risk map is presented in ***Figure 6*** where the horizontal axis shows the frequency (or probability) that a given risk will occur and on a vertical axis the impact (severity) of this risk on a supply chain is identified. While assessing risks managers score them from 1-5 for both probability and impact, where 1 representing a low probability (frequency) or impact, and 5 representing a high probability (almost certain) or severe (extreme) risk to the supply chain. Displaying risks in this way makes it easier for the managers to prioritize the risks and indicate the level of concern and attention which should be directed toward each particular risk. Therefore, it can help to define which risks should be treated first (Brindley C., 2004).

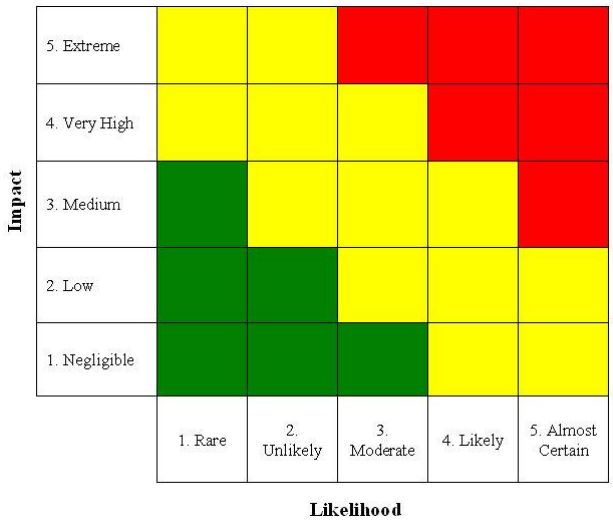

Figure 6 Risk Map.

Source: Brindley C.(2004).

Another way of visualizing risks is to compare the events based upon their probability of occurrence and loss severity probabilities and put them in a risk matrix as shown in the ***Figure 7*** (Knemeyer et al, 2009). The matrix allows managers to visualize risks in relation to the precise losses they could cause to the company, gauge their extent, and plan what type of strategy (i.e. Risk and Loss Mitigation, Loss Mitigation, Risk and Loss Mitigation or Risk Mitigation) should be implemented to overcome these risks. The catastrophic events on a risk management matrix, shown in ***Figure 7*** displays the estimate probability of a catastrophic event (horizontal axis) and the estimated loss exposure for each of the company's key locations (vertical axis).

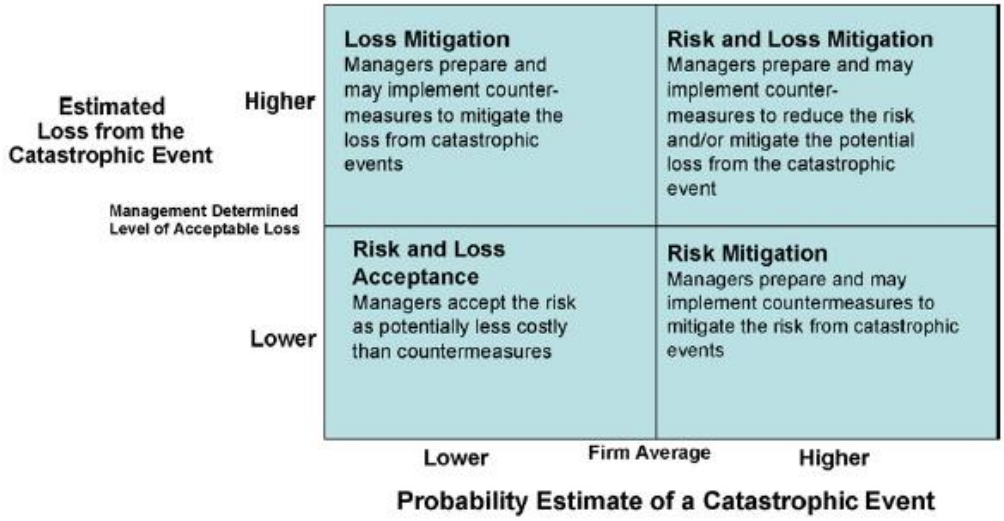

Figure 7 Risk management matrix for catastrophes

Source: Knemeyer et al (2009)

In addition, Kremeyer et al (2009) defines the reason for distinguishing between risks and losses when it comes to evaluation of the possible countermeasures. He points out, that this method helps to assess the financial impact and to see which risks to prioritize and for which supplier or components to take actions. While reducing the risks or estimated loss associated with a catastrophic event impacting a key location is normally considered beneficial, not every risk should be mitigated. Husdal (2005) in his work stressed that in some cases, the costs of mitigation will be greater than the impact of the catastrophic event itself. Countermeasures whose costs exceed the decrease in Potential Loss should therefore be excluded from further analysis.

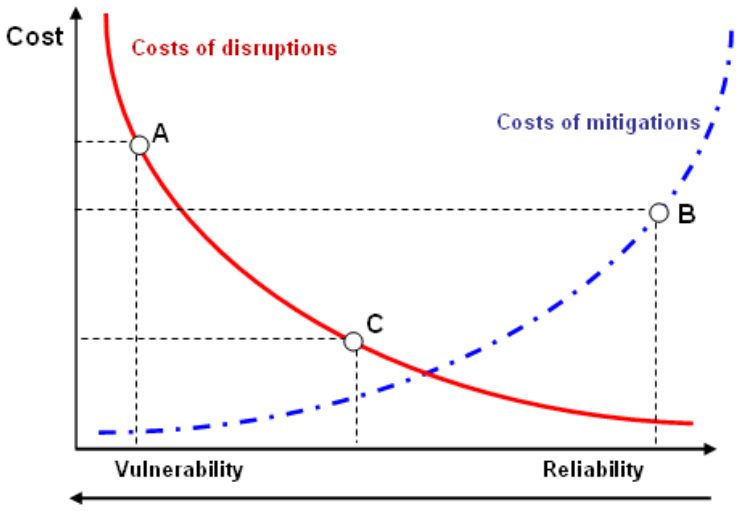

Figure 8 Relationship between vulnerability of disruption and mitigation measures reliability.
Source: Husdal , 2005

In ***Figure 8,*** point A indicates the costs of a supply chain disruption without mitigation. Provided some mitigation, the costs of disruption may be lowered, say, until point C. Too much mitigation may bring the disruption cost down to almost zero at point B, while the mitigation cost is much higher than the potential loss. Neither B nor C are optimal, although C is better than B. The optimum is reached where the cost of disruption intersects with the cost of mitigation (Husdal, 2005)

3. Risk treatment

According to Norrman and Jansson (2004) *risk treatment* is the process whereby decisions are made to accept a known or assessed risk and to take actions to reduce the consequences or probability of occurrence. They identify risk management actions, which are: to avoid, reduce, transfer, share or even take the risk. To avoid risks means to eliminate the types of event that could trigger the risk. To reduce applies both to reduction of probability and consequence. The authors argues that risk could also be transferred from a company's disposal to insurance companies or to its supply chain partners by moving inventory liability, changing delivery times of suppliers (just-in-time deliveries) as well as to customers (make-to-order manufacturing) or by outsourcing activities (Norrman and Jansson, 2004). The development of proactive strategies for coping with all possible disruptions is also included in this stage (Norrman and Jansson, 2004).

4. Risk monitoring

There are many objectives for risk monitoring. Blackhurst (2008) lists some of the main of them:

- To track systematically the identified risks;
- To identify new risks;
- To manage effectively the contingency reserve;
- To capture lessons learned for future risk assessment and allocation efforts.

Risk monitoring and control is important for supply chain as it helps to ensure that the supply chain operations remain on track. Blackhurst (2008) stress out that risk monitoring must be continues process because risks are dynamic and the list of risks as well as associated risk management strategies will likely change adapting to the changes in the supply chain.

There are two ways of risk monitoring according to Christopher (2011): periodic and regular. Periodic supply chain risk reviews repeat the tasks of risk identification, assessment, analysis, mitigation, risk planning and allocation. Regularly scheduled supply chain risk reviews can be used to ensure that supply chain risks are included in an agenda of company strategy development meetings. If unanticipated risks emerge or a risk's impact is greater than expected, the planned response or risk allocation may not be adequate. At this point, the supply chain team must perform additional response planning to control the risk (Christopher (2011).

Business continuity management (BCM).

In parallel to mentioned above main steps of supply chain risk management Business Continuity Management is an important approach of managing risks in supply chain. ***Business continuity management (BCM)*** is defined as:

. . . *"development of strategies, plans and actions which provide protection of critical business processes; identification of resources required to maintain an acceptable level of business protecting those resources and preparing procedures to ensure the survival of the organization in times of business (supply chain) disruption*" (Hiles and Barnes, 2007).

In other words, it's a way of making sure that unexpected events have as little effect as possible on daily company operations. BCM is usually requires developing action plans or *business continuity plans (BCP).* BCP refers to a planning, including the actions to be taken, resources required, and procedures to be followed in order to ensure continued operations in case of a catastrophic event. According to a study by Chartered Management Institute, CMI (2010), there are was a slight decrease up to 49 percent in the number of organizations which developed specific business continuity plans, from which only 9 percent of the companies require to have a similar BCP from their suppliers. ***Figure 9*** illustrates the percentage of companies with developed BCP. The data shows considerable differences between organizations of different sizes, where larger organizations are more than twice likely to have dedicated BCPs than smaller organizations (65 per cent compared to 29 per cent).

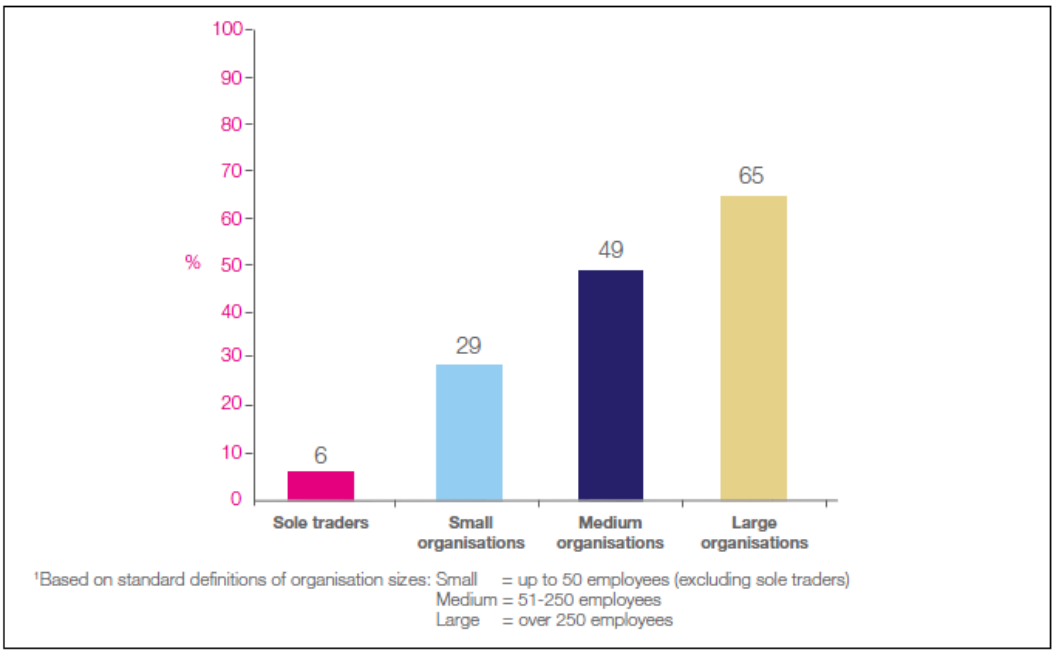

Figure 9 Organization size and BCP level.

Source: Woodman P & Hutchins P (2010)

The study says that the number of small organizations with a BCP increased from 25 per cent in 2009, while there has been little change among medium and large organizations. Sole traders have seen a considerable drop in BCP levels, pulling the overall rate downwards. This data shows that larger organizations are more prepared to the risks then smaller companies and thus can recover from the disruptions with less harmful effects (CMI, 2010). As a consequence, if company cannot manage a risk by eliminating or minimizing the

consequences, it can prepare a contingency plan to know what to do if something happens (Norrman and Jansson, 2004). The steps that are included into contingency plan will be discussed further down and named a reactive SCRM approach.

Seeger et al (1998) point out on the contrast between proactive risk management, which involves assessing potential threats and finding the best ways to avoid those threats and ***crisis management*** which refer to dealing with threats after they have occurred. The authors define it as a discipline within the broader context of management consisting of skills and techniques required to identify, assess, understand, and cope with a crisis situation, especially from the moment it first occurs to the point that recovery procedures start. Seeger et al (1998) identified three elements that are common to most definitions of crisis: (a) a threat to the organization, (b) the element of surprise, and (c) a short decision time. Venette (2003) argues that "crisis is a process of transformation where the old system can no longer be maintained." Therefore the main outcome of crisis management is the need for change. If change is not needed, the event could more accurately be described as a failure or incident.

The letter means, that there is another side to supply chain risk management, the side of actually responding to the risk that occurs. Despite the best planning and the best preparation, sometimes an event happens that was not anticipated, or, the mitigation strategy didn't work as planned. When this happens, companies need to react quickly to the situation; assess the impact, determine the best response(s) and implement these responses in a timely manner. This type of situations is highly related to the natural disaster events. As an example, the Japan quake and tsunami of March 2011 brought a devastating effect even for many highly developed, equipped and prepared businesses. In this case but also for those companies which neglect an impact of natural disasters on their supply chain the following reactive framework is discussed.

3.3.2. Reactive Supply Chain Risk Management approach

Handfield et al, 2010 has developed a reactive approach for addressing supply chain disruptions, which is a part of risk management activities and illustrated in ***Figure 10 and Figure 11.***

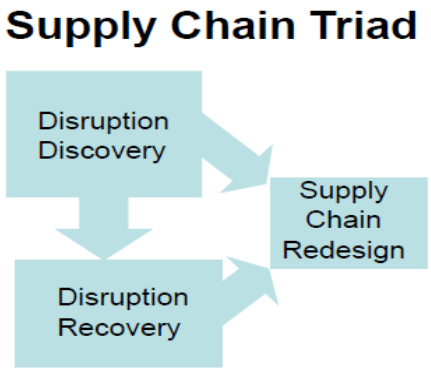

Figure 10 Tree key elements of reactive supply chain risk management

Source: Handfield R, accessed 2011-03-01, http://scm.ncsu.edu/public/risk/risk5.html

The reactive Supply chain risk management approach includes three major steps:

1) The ability to discover the disruption that has happened;

2) The ability to recover effectively from the disruption; and

3) Supply chain redesign.

1. ***Disruption discovery.***

Handfield et al (2010) state that risk managers on this stage must understand the type of disruption that occurred, assess the level of consequences and develop required reaction to an incident in a timely, responsive fashion. In case of disruptions due to natural disasters, the companies need to understand type of natural disaster and evaluate its magnitude and possible impacts as well as consequences it can bring to this particular supply chain disruption.

2. ***Disruption recovery.***

In order to prevent undetected disruptions to be amplified, companies should react immediately and thus to have zero time between occurrence of disruption and its detection (Hendricks and Singhal, 2003). The recovery phase activities should include the actions that are needed to be taken, resources required, and procedures to be followed to resume supply chain in the event of unexpected interruptions.

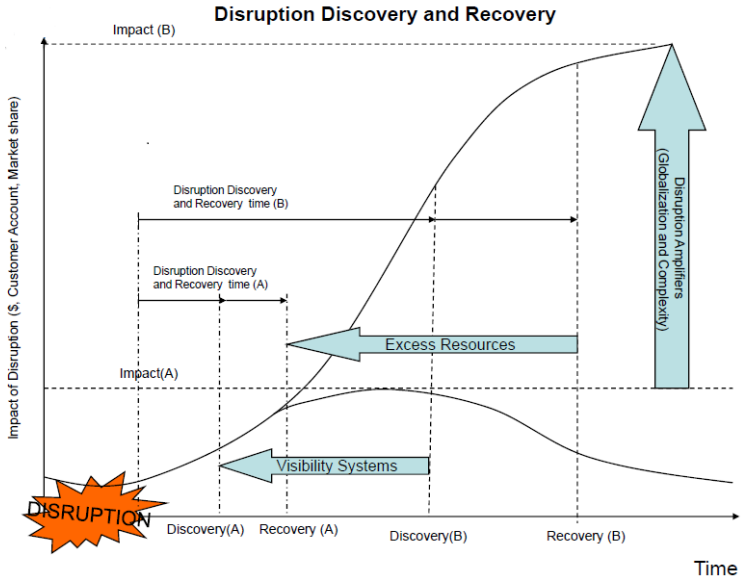

Figure 11 Disruption discovery and recovery framework

Source: Handfield R, accessed 2011-03-01, http://scm.ncsu.edu/public/risk/risk5.html

As shown on ***Figure 11*** the time at which the company discovers and responds to a disruption is critical. Handfield et al. (2010) argues that companies, that already have contingency plans and visibility solutions are able to recover faster and mitigate the impact of a disaster more quickly with lower losses.

3. Supply chain redesign.

Once the company recovered from the disaster, it should take the steps toward redesign its supply chain in order to allow the organization to return back to normal service level. Company might prepare strategies or plans to eliminate the possibility of occurrence such a disruption or at least to minimize the probability that the problem will occur again in a future (Handfield et al, 2010). Possible reactive strategies to redesign a company's supply chain toward more robust or resilient will be discussed in the next chapter of this thesis.

As a consequence, we believe that these two frameworks described above will help us to prepare the consistent guidance for the interviews with the companies and will give a valuable input in order to answer our main and subsidiary research questions of the thesis and thus to see how companies are prepared for the possible risks in their supply chains, which measures they apply while responding to exposed disruptions as well as to list possible mitigation strategies to build a robust supply chain for the future operations. Thus the objective of these frameworks is to provide basis to the analysis and to support our findings.

3.4. Strategies of mitigation supply chain disruptions

In this section we will discuss strategies for companies to mitigate supply chain disruptions from proactive and reactive perspective. Schmitt and Singh (2009) discuss the importance of proactive planning to mitigate and recover from disruptions. To mitigate supply chain disruptions, companies can proactively assess risks and plan actions in advance of the disruptive events or they can discover risks by reactive strategies after disruptions occur and recover quickly from them (Zsidisin et al, 2004).

3.4.1. Proactive strategies

We describe proactive strategies as the plans companies can implement to prepare, reduce or avoid the impact of possible risk from supply chain before disruptions occur. Kathryn and Kumar (2006) points out that proactive risk management strategy enable companies to prepare for mitigating the impact of a disruption if a risk cannot be eliminated.

Initially companies need to recognize their risks by assessing and evaluation tools (Uhlig, 2008). Tang (2005) classified supply chain risks and developed four basic approaches for managing supply chain disruptions: *supply management*, *demand management*, *product management and information managemen*t. These approaches are visually presented on ***Figure 12.*** First, from the *supply management* side, the company can coordinate or collaborate with upstream partners to ensure efficient supply of materials along the supply chain. Second, *demand management* refers to the fact that the company can coordinate or collaborate with downstream partners to influence demand in a beneficial manner. Third, *product management* means that the company can modify the product or process design that will make it easier to make supply meet demand. Fourth, according to the *information management*, the supply chain partners can improve their coordinated or collaborative effort if they can access various types of private information that is available to individual supply chain partners. Based on Tang's (2005) model, we discuss proactive strategies to mitigate risks of disruptions from supply management, demand management, product management and information management.

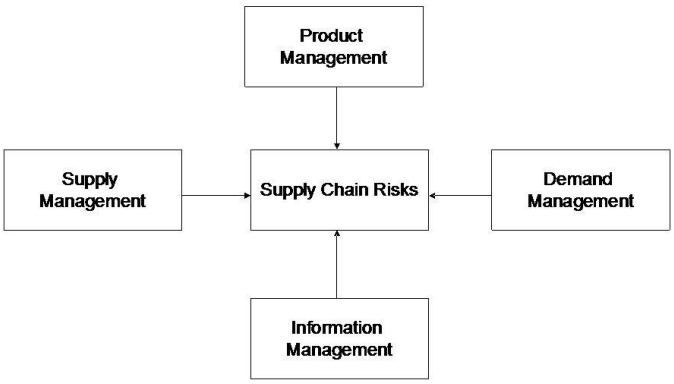

Figure 12 Four Basic Approaches for Managing Supply Chain Risks

Source: Tang, 2005

Mitigation strategies for risks related to supply management.

The strategies related to the supply management can be developed into the three following categories:

Contingency Suppliers

Giuniper and Eltantawy (2004) argue that supplier is an important factor that affects the level of investment in risk management for companies. Cooperation with a well-prepared supplier can reduce the vulnerability of the entire chain (Kathryn and Kumar, 2006). Companies can mitigate risks when a disruption comes from a supplier side by creating a flexible supply base with reasonable number of back up suppliers instead of relying on single supplier. Companies can invest more to adopt closer relationships in collaborating with upstream suppliers to ensure efficient supply of materials in supply chain, while suppliers should have enough capacity, efficient technology and risk management to reduce risks from disruptions (Tang, 2005; Giuniper and Eltantawy, 2004).

Flexible Transportation

Tang (2006) suggests flexible transportation can be applied as a proactive approach. When a disruption occurs, multi-modal transportation, multi-carrier transportation and multiple routes can ensure the smooth material flow in supply chain and reduce the risks. Kathryn and Kumar

(2006) also argue that it is important to select a transport company that has the ability to handle disruptions which can provide stability to companies during catastrophes.

Although it is unlikely to prevent transportation disruption such as high way and airport closing caused by natural disaster, there are still several approaches of mitigating transportation disruptions can allow companies to prepare supply chain in a better way to minimize losses from disruptions (Tang, 2006; Kathryn & Kumar, 2006). Multi-modal transportation can prevent the supply chain operations being disturbed when disruptions occur in the sea, in the air or on the road. Alternate mode of transportation can reduce or prevent the loss from delaying and to ensure smooth flow of materials in supply chain.

Mitigation strategies for risks related to demand and product management:

Safe inventory

Carrying additional safety stock can mitigate the negative impact from disruptions (Tang, 2005; Kathryn & Kumar, 2006). It can ensure that supply chain continue to function smoothly when companies facing a disruption in supply chain. Shortage of supplies can be avoided and customer demand can be met . Locations of both facilities and suppliers also play important role in safety (Kathryn & Kumar, 2006; Tang 2005). Companies should consider the potential risk when selecting business locations and plants as some geographical regions are more likely to have high frequency of hurricanes and earthquakes and other natural disasters.

Demand shaping

Companies can coordinate and collaborate with downstream buyers to influence demand in a beneficial way (Tang, 2005). Products can be modified or designed to meet the demand easier. A study by Chong et al. (2001) shows that customer's demand for products can be changed due to the reconfiguration of products on display in retailing shops. Hendricks and Singhal (2005) suggests that problems in supply demand mismatches can be avoided by better coordinating and integrating planning and execution.

Mitigation strategies for risks related to information management include:

Risk information transparency

Christopher and Lee (2004) suggest that the key element in any strategy to mitigate supply chain risk is to improve 'end-to-end' visibility. They argue that total end-to-end visibility will enable supply chains to be transparent. By sharing information among supply chain members, uncertainty can be reduced and supply chain visibility can be improved. The right member in supply chain will get the right information at the right time. It also points out the importance of the accuracy and accessibility of information in supply chain, such as inventory, demand, forecasts, production and shipment plans, capacities, backlogs, etc. This information should be managed tightly and should be easily accessed by members in supply chain. In Hendricks and Singhal (2005), it indicates that inaccurate forecasts result in demand-supply mismatches. Companies should look more carefully at the forecast of the assuming static lead times, transit time, capacity and transportation distribution routes when planning. It also presents several steps for companies in developing visibility to reduce disruptions.

Investment in technology can also make supply chain visibility more transparent therefore reduce the chance of supply chain disruption. Tang (2005) suggests that by implementing Collaborative Planning Forecasting and Replenishment (CPFR) it is possible to mitigate risks among supply chain partners. Hendricks and Singhal (2005) argue that supply chain management systems have the ability to track and trace unexpected events and send out alerts so that companies can respond correctly. One example is the RFID technology which improves the accuracy of real time information of the physical flow of products.

Advanced warning

Sarathy (2006) points out that early warning tool can identify sources of vulnerability which triggers company's awareness of potential and actual disruptions. Kathryn and Kumar (2006) suggest that advanced forecast of a catastrophe can help company better prepared and minimize the disruption effects. It is necessary to implement constant monitoring of the geographical environment. Monitoring weather conditions has been used by Toyota and Ford in the past and data was shared within their suppliers to reduce the impact of potential disruption.

3.4.2. Reactive Strategies

When disruptions had happened companies can respond to an unanticipated supply disruption by applying reactive mitigation strategies in order to recover quickly from the event and mitigate the business impact from such events.

Event detection

Chritopher and Lee (2004) suggest it is important to have alerts for out of control condition. The appropriate parties in the supply chain have to be alerted when deviations from the prepared contingency have occurred. It needs intelligent controls to examine if the deviations are normal or random events, or if they represented unexpected changes that need attention. Chritopher and Lee (2004) point out that in such case, a statistical process control chart should be sensitive enough to detect out of control condition but not to cause unnecessary changes and corrections in supply chain.

Contingency Plans for Recovery

Christopher and Lee (2004) suggest contingency plans are tools to make corrective actions for members of supply chain when out of control conditions have been detected. For example, if the shipment schedules have deviated from plan due to the traffic conditions, there should be clearly defined contingency plans for the logistics carrier to take appropriate action such as alternative supply source and alternative prepared shipments. Tang (2006) argues that postponement strategy can be a cost-effective and time-efficient contingency plan in the context of disruption recovery. Postponement strategy aims at delaying activities until the exact attributes of demand can be identified (Robert 2002, p79). It allows a supply chain to reconfigure the product quickly in supply disruption (Tang, 2006). Hendricks and Singhal (2005) also discuss that by implementing the strategy of postponement or delayed differentiation, supply chain disruption and demand-supply mismatches can be reduced.

Supply Chain Collaboration

Guinipero and Eltantawy (2004) argue that supply chain risk can be mitigated by coordinating the relationship in the supply chain and increasing the flow of information and communication efforts. It points out that hiring and developing employees is the key to managing risks in supply chain. Hendricks and Singhal (2005) also suggest that it is necessary

to achieve collaboration and cooperation with supply chain partners by sharing information. This helps reduce information distortion and lack of synchronization in supply chains.

Supply Chain Redesign

Companies must build more flexible and resilient supply chain to enhance responsiveness after responding to the disruption and recovering from it (Hendricks and Singhal, 2005; Tang, 2006). Hendricks and Singhal (2005) discuss three dimensions for companies to build flexibility into their supply chain: (1) building flexibility on the product design side by standardization, postponement, and mass customization to offer the capability to react sudden shift in demand and disruptions in delivery parts (Kathryn & Kumar, 2006); (2) building sourcing flexibility by contracting flexibly with suppliers when demand is fluctuating. Multiple sourcing strategies are more effective when suppliers have flexible facilities (Kathryn & Kumar, 2006); (3) building manufacturing flexibility by acquiring flexible capacity to produce various products under volatile demand. Standardizing various processes of production makes it easier for facilities to coordinate their efforts (Kathryn & Kumar, 2006).

Wassenhove (2006) discusses the idea that understanding the core capability of humanitarian logistics can help private sector logistics improve the performance of disaster logistics in their supply chain activity. It presents that the core business and competence of humanitarian organization is to deal with the small probability but big impact event which private sector logistics in companies are poor in dealing with. Agile, adaptable and capable of setting up and changing supply chains quickly in difficult conditions are the characteristics in humanitarian logistics. Private sector logistics can learn from humanitarian logistics about vulnerability assessment when working with uncertainty and risk, preparation and response to disasters, as well as effective coordination during response to operate better their global supply chain under the same condition.

3.5. Insurance is an essential actor in risk management.

While preparing strategies for business disaster recovery a company might think about how it will finance its recovery from a disaster when it happens (Paradine, 1995). Many evidences shows that supply chain disruptions through catastrophes have a tremendous impact on companies' performance. Thus, Ericsson lost over €400 million after a fire on one of their sub-supplier's plant. Similarly, a fire at Toyota's break supplier forced Toyota to stop its production and caused an estimated damage of $40 million per day (Norrman & Jansson, 2004). Topper (2011) concludes the obvious solution of financing business recovery is to transfer some risk of loss through insurance. Thus, insurance provides a risk transfer mechanism and allows organizations to enhance their disaster management capabilities and avoid huge financial losses arising out of natural disasters (Arnold, 2008).

In addition to risk transfer, Paradine (1995) mentions that insurance can also assist businesses with incentives for risk prevention and mitigation activities from natural hazards. Thus, insurers can help to assess company's risks and provide information on company's risk exposure. In terms of natural disaster insurance and particular reinsurance companies put a lot of forces and investments to carry out an advanced database on natural disasters, i.e. Sigma or Nat Cat service, to forecast future catastrophes and simulate possible consequences in order to evaluate the losses and define a proper premium rate on natural disaster events (SwissRe, 2010, MunichRe,2011)

Thus, insurance can also convey incentives for risk prevention through charging risk-adjusted insurance premiums for business interruptions (Topper, 2011). Hence, right after the hurricane Katrina disaster in 2005 the premiums on business disruption due to hurricanes rose up to 600% in that area (Topper, 2011). In addition to high insurance premiums, Arnold et al (2008) point out that, high deductibles, limited coverage of the insurance on natural hazards which might also encourage companies to develop a continuous risk management planning and pre-disaster mitigation activities especially in area with high exposure to natural disasters as such measured can results in reduction of the company's insurance premiums.

Furthermore, Paradine (1995) refers insurance to a reactive approach of dealing with risks. In itself insurance does nothing to prevent losses rather it protects a company from the financial

consequences of loss in contrast to risk management activities which it is about being proactive and taking steps to prevent incidents.

On the other hand, many companies only limit their risk management activities toward insurance company responsibility and may consider that they are fully protected from the unexpected events, which means that the necessity of risk management activities are not developed and, moreover, neglected by managers (Norrman and Jansson, 2004).

Finally, Topper (2011) stressed on the importance to understand that there is no insurance policy that can cover all the problems. In contrast, companies need to accept that some of the supply chain risk became uninsurable. In the longer-term, climate change brings an additional challenge for insurance industry as the magnitude of damages continues to increase. UNEP's Finance Initiative reports that by 2025, insurers may withdraw from some markets as the risks become too high for the pool of premium available (Arnold et al, 2008) In this connection, it would be beneficial to explore further risk transfer possibilities and risk mitigation scenarios as well as employ risk management strategy.

Consequently, Pickard (2008) suggest while it is essential to have a disaster recovery plan, and while business interruption insurance is vital to the company's financial recovery from natural disasters, the best protection which will help the company to prevent losses comes from a total robust disaster risk management program. However, insurance combined with a risk management strategy is the best combination for ensuring business continuity and business risks mitigation related to extreme weather and natural disasters.

3.6. Summary of literature review and analytical framework proposal.

Managing risk in supply chains is an essential topic in supply chain management nowadays. Growing trend of outsourcing, globalization, just-in-time delivery, lean manufacturing, single-sourcing and offshore purchasing can save money for a company but they also make its supply chain more fragile and vulnerable. In addition, observations show the increasing trend of natural disasters and particular great and devastating catastrophes during last three decades with much stronger impact and severe effects than in the past. Such events can lead to a partial or complete halt of a company's global supply chain with all the following negative effects, i.e. financial instability, operational time losses, market share reduction, customer disloyalty and long recovering period.

Furthermore, in our thesis we are focusing on transportation disruption as one of the sources of supply chain risks. While companies that rely on international shipments are more exposed to the risk of transportation disruption little is known about how important for companies is risk management in transportation disruption especially from natural disasters and severe weather events. Thus, in this thesis, we would like to point out the importance of not only understanding and managing risks internally within a company but also trying to better analyze, assess and manage risk along the supply chain and transportation particularly and to take immediate action when incidents are indicated.

After investigating the previous academic works we defined two main approaches the company can apply to manage and mitigate its risks in the supply chain. The first is Proactive Supply Chain Risk Management, which involves mapping the entire supply chain and its dependencies, identifying, assessing and understanding the various threats and risks, and implementing strategies to remove or reduce them. It is a continual process and is normally should be monitored, constantly updated and adjusted to a current company's operations. Moreover, at the risk assessment stage we also included a behavioral aspect, namely risk perception of the managers who are responsible for risk identification and evaluation. This aspect was investigated by Kleindorfer (2005) and incorporated into his framework for risk assessment. The importance of risk perception is obvious, as risks due to natural disasters has a low probability and therefore often neglected by the managers when considering the impact of different risks on the company's operation. Thus, by underestimating the possible crucial impact of this type of risks managers usually do not pay enough attention to them while developing strategies for mitigation such risks. It means that they do not develop the action to respond

immediately, do not purchase insurance on natural disasters and thus not covered financially from such risks and do not consider them as potential threat while choosing a supplier from a disaster prone area.

The second approach is Reactive Supply Chain Risk Management applied when the catastrophic even already happened and the response actions required. This approach divided into three steps: disruption discovery, recovery and supply chain redesign. Researchers state that the better a company has prepared, the broader and consistent business continuity plan it developed the faster company can switch to a recovery stage without wasting as much time on a problem discovery and risk identification step (Handfield et al, 2010). But, there is always a possibility that an "unthinkable" will occur, like with eruption of the Icelandic Eyjafjallajökull volcano, when many companies basically where not prepared to such event. In this case, the approach to manage the risks that has happened but are not covered by a contingency plan, namely crisis management, will include the same three steps, but the time between disruption discovery and actual recovery phase will be much longer. The longer this time period the more losses company will face as time is a crucial factor when it comes to supply chain operations, especially in just-in-time process.

The additional component of an effective supply chain risk management is insurance. However, insurance is more a reactive way of dealing with disruptions. It can help to protect a company from the financial consequences of loss after an event, but it never replaces the loss of employees, management time, reputation and customers that impatiently turn to another supplier. Consequently, insurance combined with risk management strategies is the best combination for ensuring business continuity and business risks mitigation related to extreme weather and natural disasters.

After analyzing the previous literature on supply chain risk management we can see that it is important for the companies to be proactively prepared to the risk exposures. It helps to minimize the probability that risks will affect the company's supply chain (Norrman and Jansson, 2004). Researchers state that this approach also helps companies respond to the event much faster and thus save time and resources when the crisis event occurs. On another hand, it is difficult to predict all possible risks that a company's supply chain is exposed to. Therefore, the reactive approach is available to cope with incidents that already happened in

supply chain (Handfield et al, 2010). Consequently, we come to the conclusion that the combination of both approaches would allow a company to cope with supply chain risks in the most effective way.

Description of SCRM framework.

For the more clear and consistent overview we built a visual framework that combines two possible approaches to effectively manage and mitigate company's supply chain risks. In the figure 13 there are four steps (Risk identification, Risk assessment, Risk treatment, Risk monitoring) that are related to the ***proactive supply chain risk management approach. The reactive SCRM approach*** is also incorporated in the model and consists of three main steps (Disruption discovery, disruption recovery and supply chain redesign). It means that before the accident has happened a company takes a proactive approach and only when an accident occurs a company turns to reactive approach of dealing with risks.

Risk perception that was studied by the Kleindorfer (2005) is also incorporated into our framework in the second step of proactive approach, as it is an important factor during assessment risks due to natural disasters. Research has shown that such risks are usually neglected during risk assessment and thus risk planning process by a company's managers. This leads to the fact that this type of the risks is not anticipated in a company (Kleindorfer, 2005).

Additional factor which included in the framework is insurance. The previous literature (Paradine, 1995; Norrman and Jansson, 2004; Topper, 2011) defines it as a reactive way of dealing with risks. However the decision of insuring from the business interruption caused by natural disasters is taken always ***before*** the accident happened. Therefore we included insurance into the risk treatment step of the proactive approach where decisions on how to deal with risks in a company's supply chain are taken.

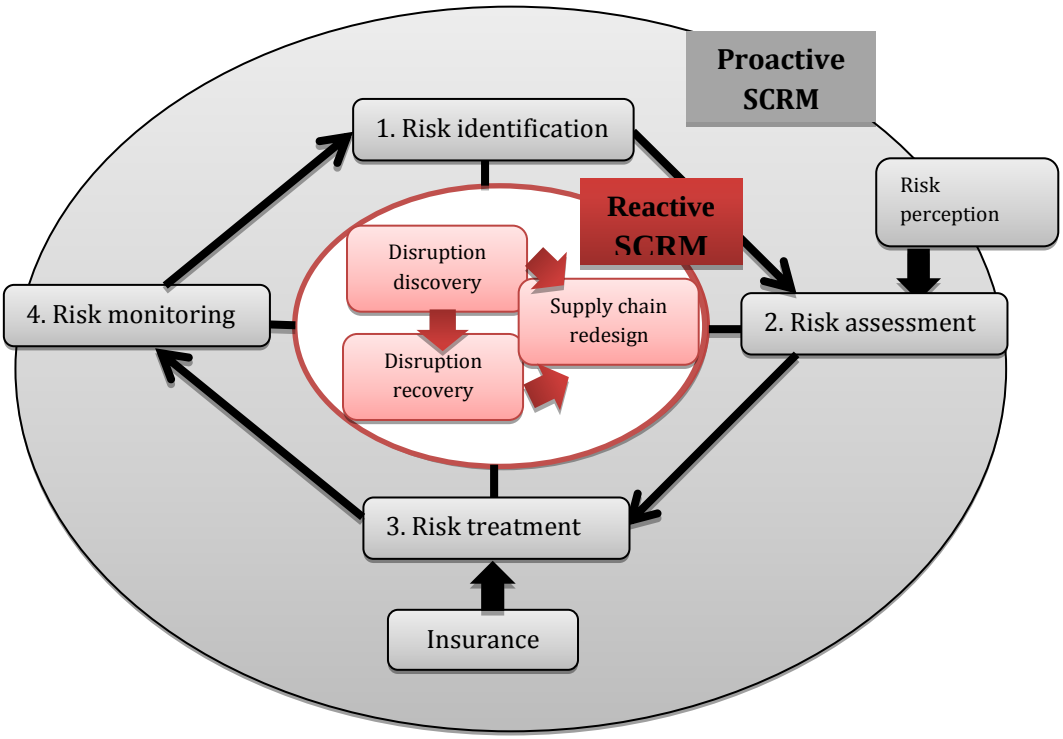

Figure 13 Supply Chain Risk Management framework

Source: own illustration elaborated from Normann and Jansson (2004) and Handfield et al (2010)

Consequently, this conceptual framework integrates proactive supply chain risk management approach with reactive supply chain risk management approach as well as insurance and managerial risk perception factor.

Moving from approaches of SCRM (reactive and proactive) to strategies.

As a part of the supply chain risk management, we also present a framework based on Tang (2005) for possible mitigating strategies of supply chain risks (***Figure 14***). This framework shows that a company can coordinate or collaborate with upstream suppliers from supply management, downstream partners to ensure supply and demand along the supply chain from demand management. From product management, product or process design can be modified to make supply meet demand. Information sharing should be available through all supply chain activities from information management. When unexpected disruption happens, reactive strategies are triggered. If proactive strategies are well planned and prepared, they are applied to mitigate the impact from the risks to supply chain activities.

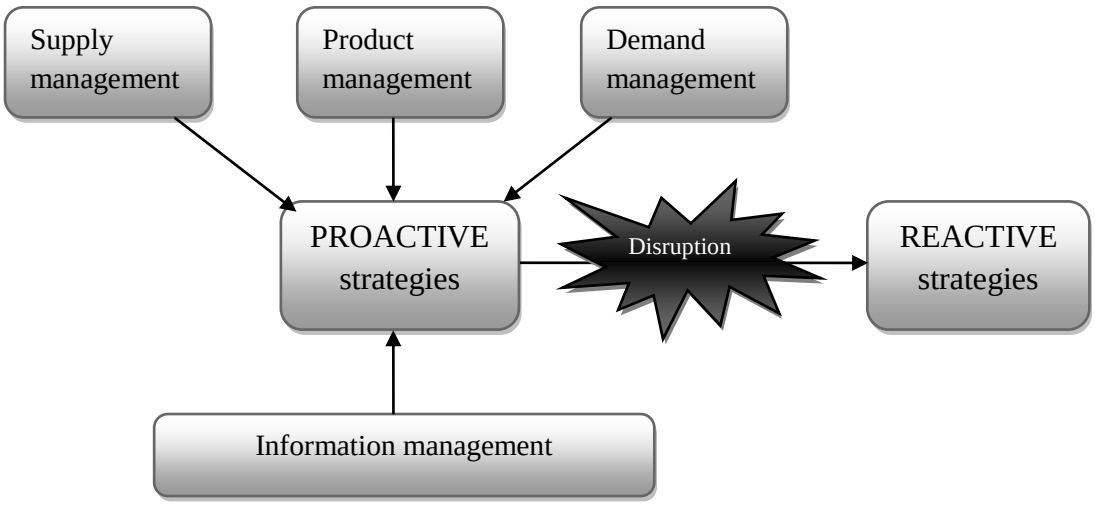

Figure 14 Framework for mitigating strategies of supply chain risks

Source: own illustration elaborated from Tang (2005)

These two frameworks will be used in the following chapters for analyzing our results from a case study. We expect to see whether the theory on supply chain risk management reflects the real world situation. We also would like to see which aspects of theoretical framework are highlighted by the company and if there are any which are less emphasized.

PART II. RESULTS

CHAPTER VI

4. RESULTS FROM THE CASE STUDY

In the following chapter we will analyze the case company SKF Logistics. We will first present the overview of the organization and its business activities. Then we provide detailed information on SKF's Logistics risk management and the strategies the company applies to mitigate supply chain disruption due to natural disasters. The information is provided by the SKF Logistics supply chain professionals during the interviews and the structure of the analysis is based on supply chain risk management framework taken from the chapter 3.

4.1. The organization of SKF Logistics

SKF Logistics is a global logistics service provider with more than 100 years of industrial logistics expertise and managing risks in its supply chain. The company belongs to SKF Group, based in Sweden, with its second largest site worldwide located in France. The focus of SKF Logistics operations is to create a seamless global network of capability, while assuring exceptional quality, reliability and service (www.skf.com, accessed 2011-04-10)

4.1.1. SKF Group

SKF Group is a leading company in supplying products, solutions and services within rolling bearings, seals, mechatronics, services and lubrication systems in the world. SKF was founded in 1907 with its headquarter in Gothenburg, Sweden. The company was established in Europe, North and Latin America, Asia and Africa in 1920. Today SKF is represented in more than 130 countries, with more than 100 manufacturing sites and sales companies supported by around 15000 distribution locations (www.skf.com, accessed 2011-04-10)

There are three divisions of business in SKF Group, each focusing on specific customers groups: Industry division which serves industrial Original Equipment Manufacturer (OEM) customers in 30 global industry customer segments; Service Division, which serves OEMs

and aftermarket customers providing products and knowledge-based service; Automotive Division which serves automotive OEMs and aftermarket customers supporting in bringing innovative solutions. Six Sigma technics play an important role in SKF's continuous improvement of its global business process. Six-Sigma mainly helps SKF to reduce the inventories, increase availability and reduce errors in sales and distribution as well as to assure the high quality of the products and services (www.skf.com, accessed 2011-04-10)

4.1.2. SKF Logistics

SKF Logistics support SKF Group global business by its logistics processes and systems, which involve all parts of the logistics need in supply chain. It creates its own integrated supply chain and worldwide logistics centers to provide reliable and cost-effective logistics services to the customers. With 15 logistics centers and the capacities in more than 170 countries globally, SKF Logistics provides services in four areas listed below (www.skflogisticsservice.com, accessed 2011-04-10).

In *Transportation Management,* SKF Logistics operates transportation network of air, sea, road and express program to provide manufacturing companies shipping finished products and industrial goods. Through its global network of transportation partners, the organization creates a transport system by combining all modes of transportation and alternative options. Single contract simplifies the process of administration. With the global tracking and tracing support, the security of products is ensured.

In *Warehousing*, SKF Logistics has 15 international distribution centers supplemented by local warehouses. The operations are designed to optimize resource utilization, cycle times, productivity, cost efficiency and information management while reducing errors and waste. SKF Logistics manage warehouse operations by implementing warehouse management systems and updated technologies including RFID, which allow the organization to better control the information flow and quality control checks.

Product Information and Packaging is another business area of SKF Logistics, which aims to minimize the handling, picking and repacking operations from production to the final customers by using the standardized product and transport packaging materials. Used empty pack materials are returnable to SKF Logistics which helps to achieve cost efficiency.

In *IT Systems and Business Consultancy*, all SKF Logistics processes operation through integrated IT systems. The IT systems operate on an EDI platform of Global Application Integration Architecture which ensures the global network connectivity and enable the effective communication. This makes supply chain more visible and cost controlling.

SKF Logistics operates based on the business concept that to integrate deliveries of long-distance-sourced components and semi-finished products from different suppliers to manufacturers. Combining with the factories' material handling solutions, it provides supply of components to channels inside the factories. With all the systems in the organization, it provides consistent delivery performance with short lead-times in the supply chain. The organization has more than 50 customers using the logistics service now. SKF Logistics Services build up their global logistics network and operate through regions of Belgium, Brazil, China, France, Germany, India, Italy, Mexico, North America, Singapore and Sweden (www.skflogisticsservices.com, accessed 2011-04-10)

4.1.3. SKF Logistics France

For the purpose of this thesis, we choose SKF Logistics France and second-largest after Sweden SKF' site and the one with the longest 100 years operation period. SKF Logistics France business includes offering of raw materials, components, finished products, bonded storage, as well as preparation of remote control, stock management and EDI interface. It provides service in transportation with their global transportation network for shipment to more than 170 countries by delivering to over 50000 customers. Transportation services include control of the product and information flow, door-to-door transportation, and on-line tracking service under the monitoring operations. The organization has warehouses and distributions for SKF products from France and Spain. It also provides storage and distribution of products for external customers. More value added services are provided such as development of packaging, customs and operation in import and export, project management and customer account management, as well as activity measurement including quality control. There are approximately 1300 employees working on site, and 60 people working within SKF Logistics (www.skflogisticsservices.com, accessed 2011-04-10).

Figure 15 shows the organizational structure. The organization is centrally managed by General Manager, and includes the divisions of Quality, Controlling and Customs, Packaging, Transportation, Warehousing, Customer Service, which has the same manager as Quality division; Internal Business Development and Projects, External Business Development and Communication, and finally for each SKF Logistics customer a customer service representative is assigned .

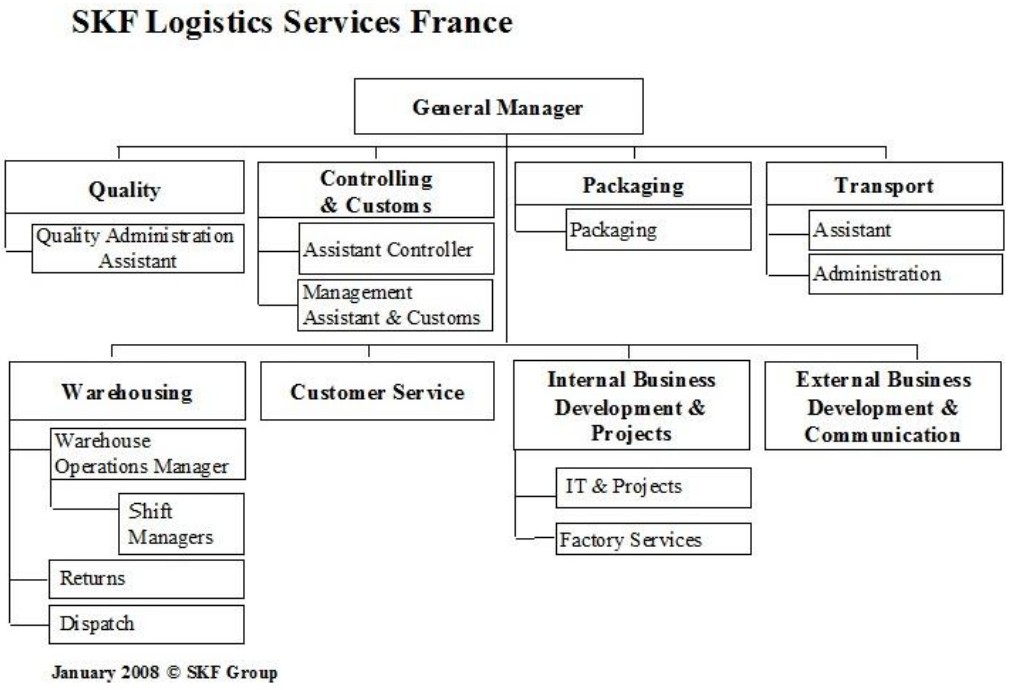

Figure 15 Organizational structure of SKF Logistics Services France

Source: SKF Logistics France, (interview with Quality manager, 2011-04-24)

SKF Logistics France has close relationship with Product Division in SKF Logistics referred as internal business. On one hand Product Division is the supplier of SKF Logistics France by stocking products in their warehouse and documenting information. On the other hand, Product Division turns into their customer as SKF Logistics France reship the products after receiving the products to other divisions within SKF Logistics. External business refers to commercial business, which provides services outside SKF Logistics business. SKF Logistics France develops services both internally (70%) and externally (30%) in product ordering and shipment, logistics services as well as providing logistics solutions for customer (www.skflogisticsservices.com, accessed 2011-04-10).

4.2. SKF Logistics' Supply Chain Risk Management

As mentioned above SKF Logistics operates as a supply chain service provider for over hundred years and thus the history of dealing with supply chain risks is also quite long. The main objective of the company to cope with such risks is to minimize the possibility of occurrence supply chain risks in order to have a superior supply chain service performance and uninterrupted supply process by applying risk management and Sig Sigma[16] approach in their daily activities. In the interview with quality manager, Sig Sigma is not any more an advantage from a customer point of view, it is a must that company should fulfill in order to remain and be competitive on a market. Thus SKF Logistics applies Six Sigma as a tool of excellence in order to organize their lean internal procedures, and be able to measure precision and quality and thus to save costs by making fewer errors (Quality Manager, 2011-03-24).

SKF Logistics does not have a separate organization for supply chain risk management, however, these type of company's risks are managed with a cross functional team, where professional from different departments and functions are involved into identification, evaluation and managing risks as well as designing strategies for risk mitigation. This team is an integral part of all organizational processes. It is believed, that the functional managers of each specific task (warehousing, packaging, transport, customer support) have a deeper insight and more broad experience dealing with supply chain risks thus they know better which risks their division can be exposed to and how to treat them. Thus their contribution in the supply chain risk management is invaluable, giving more precise, deep and broad overview of the supply chain risks (Quality Manager, 2011-03-24)

On a centralized/ headquarter level, corporate function for supply chain risk management is executed by the Global manager of SKF Logistics service division as well as the head of each department within supply chain division e.g. transport, warehousing, quality, customer service and controlling, customs, external and internal business development. The headquarter risk management team located in Sweden, Gothenburg and responsible for the supply chain risks on a strategic level related to first level supplies. They are working together in a matrix-

[16] Six Sigma- is a business management strategy to improve the quality of the process results by identifying and removing the causes of defects and minimizing variability in business processes and operations.

oriented way, which means working together with a management team consisting of representatives from the different units (Quality Manager, 2011-03-24)

The roles of the main functions involved are:

- ***Quality and controlling management*** has the overall responsibility of quality control and control of organizational reliability, thus keeping an uninterrupted logistics service level in SKF Logistics;
- ***Customs manager*** decides on insurance and has contact with the insurance companies as well as co-ordinates risk management activities in relation to customs and legislations in different countries;
- ***Transport manager*** is responsible for the operative work and daily interface with transportation companies as well as securing the reliability of supply chains and their ability to deliver;
- ***Warehousing manager*** is responsible for handling risk regarding packaging and overall logistics activities while providing storage service;
- ***External and internal business development managers*** are responsible for the commercial interfaces with the external/internal (SKF Group) clients and therefore involved in the evaluation of their clients and communication with them when disruption occurs.

Quality manager has stated that the same approach is taken on each local operational level, in our case at the French site. The managers of different functions from logistics service division are working closely with each other and with their assign corporate manager at headquarter. Supply chain managers should use the tools and processes developed by the centralized management team to analyze, assess and manage risk in supply chain as well as follow the ISO standards for risk management and business continuity. On the other hand, the supply chain managers have full responsibility to support risk management issues of SKF Logistics on a local operational level.

From the interviews with several professionals (Quality manager, Transport manager and Business development manager, 2011-03-24) of SKF Logistics we could see that the company takes a proactive approach to deal with supply chain risks and design their risk management activities according to the following steps.

4.2.1. Proactive Supply Chain Management in SKF Logistics

The transport manager provided us with the complete overview of Proactive SCRM approach in SKF Logistics, which includes four following steps:

1. Risk identification

In order to identify all the possible risk in the company's supply chain the SKF Logistics team build a structure of various participants/stakeholders in supply chain. They also identify relationships between different stakeholders, key measures and cargo ownership thus building a complete picture of a company's supply network. After that, they evaluate whether significant risks exist within the supply network, and whether existing risk management practices can manage them. In order to make it structured and more clearly defined all the risks are visualized on a supply chain risks map.

The SKF Logistics cross functional team defines supply chain risks as following: the risk of supply failure (disruptions at supply side, cargo damage), strategic risks (business interruption risks), the risk of natural disasters, the risk of geopolitical events (e.g. strikes) and regulatory risks (legislation of different countries). Natural disasters and geopolitical events are assigned to the catastrophic supply chain risks. In addition, risks related to the major transportation providers, namely first-tier transportation suppliers, which provide their transportation service for the whole SKF Group globally serve are identified and handled centrally in SKF Logistics in Sweden, local transportation and supply chain risks are monitored by its locally responsible site (Transport manager, 2011-03-24)

Finally, from the interview with the quality manger we identified that the SCRM process for catastrophic events of SKF Logistics is strongly based on ISO norms, namely the ISO 25999 for crisis management and business continuity planning which will be replaced by an international standard ISO 22301 by the end of 2011. The company also applies ISO 31000 "Risk management -- Principles and guidelines on implementation" standard to regulate its risk management activities (Quality manager, 2011-03-24)

2. Risk assessment

For the risk assessment step the workshops attended by different functional and business specialists are facilitated where events which could lead to disruptions are discussed. The

evaluation of potential supply chain risks begins with identification of key supply chain locations and developing a list of potential threats to these key locations. As a result, management will have a developed list of key supply chain nodes/locations with a specification of catastrophes that should be considered for each of those locations. For each event causes are identified, so that preventive actions can be developed (Transport manager, 2011-03-24).

The next step is to assess probabilities of occurrence of catastrophic risks and the impact of certain events on the supply chain in each of supply chain location. Therefore, the main questions that are answered in the risk assessment stage are: (1) How probable is it that a certain event occurs? and (2) what is the significance of the consequences and losses?

Risk perception in SKF Logistics.

When assessing the risk of catastrophic supply chain events, transport manager mentioned two main difficulties that exist. First, for assessing Low Probable but High Impact risks conventional tools are only applicable in a limited way. Extreme events cannot be treated with the same expected value decision making tools as high-probability, low consequence risks. They are also most likely to be perceived different by most decision makers. Therefore, in our interviews we included a question of how do the managers at SKF Logistics perceive risks caused by natural disasters and catastrophic weather conditions. As a result, in most answers, managers perceive the consequences of those events as considerable but not dramatic for the company's supply chain operation. Mostly, due to a very mature risk management process, including the assessment and mitigation plans of catastrophic risks, with integration of Six Sigma approach in all the companies activities, as well as cultivated risk culture, so that most of employees informed and aware on possible risks and trained on mitigating them. In addition, the weather related crises (snow storms, volcano eruption, floods) that happened in the past did not affect business continuity significantly, and had no severe impact on a service level. Thus those managers that were involved into the interviews perceive risks due to natural disasters and weather related event as daily operational problems, and not defined as critical or crisis.

Tools and methods for risk assessment in SKF Logistics.

The risk management team of SKF Logistics uses several tools to assess catastrophic supply chain risks. Due to the high complexity of assessing this type of risks, there are not many structured quantitative tools to evaluate this type of risks. Simulation technique is one of the tools that the company uses to assign probabilities to certain events in certain areas. Thus, group discussions guided by a simulated disaster are designed to test the ability of the group to respond to a situation and to test the theoretical ability of a group to respond to a situation. It allows people to test a hypothetical situation, evaluate the potential losses and consequences. Thereby not only a theoretical planning process is performed but people also have to exercise against a plan. Consequently, for instance, the probability of French site to be affected by the heavy snow or port strikes is explicitly assessed during such meetings.

In addition, company's management also applies a qualitative approach in order to define probability and impact of supply chain risks. Therefore, "What – if analysis" is used to analyze and visualize the potential catastrophic supply chain risks. The managers brainstorm WHAT activities to apply IF an extreme event happens and evaluate which consequences it can cause. After this analysis assessed risks are visualized on a risk map with different colors regarding the impact intensity and its hazard. The most harmful related to a red color, less harmful to a green one. In addition, in the context of catastrophic supply chain risks expert opinions as well as available historical data on such events is applicable by the company's management while assessing supply chain risks due to natural disasters.

3. Risk treatment

The next step is risk treatment, which includes both developing risk mitigation strategies and deciding on those. Risk management basically is penetrated throughout the whole organization from central to local. Thus, risk treatment is a line responsibility, and who is doing it depends on which tier the risk source is part of: for higher tier, central transport manager is responsible, while for lower tier, the local cross-functional team is assigned for and for internal plants it is production manager (Transport manager, 2011-03-24)

In addition the problem of high investments into supply chain risks mitigating measures was raised. The quality manager, who commented on this, was very clear and explicit that the

company sees it more than reasonable and vital to invest into contingency and security, risk planning, risk analysis even though the payoff cannot be seen at once it pays back later. When the disaster happen the losses in terms of money, time and customer perception is much lower if mitigation measures have been employed. It is crucial for the SKF logistics service to meet customer expectations in the best possible way and they never failed so far (Quality manager, 2011-03-24). Therefore, the main philosophy of SKF Logistics is to build trustful relationships and continuous communication with supply chain partners to assure the risks are transparent throughout the entire supply chain and can be prevented or mitigated at the very beginning (Business development manager, 2011-03-24)

However, it is also crucial for the company to ensure its financial losses from supply chain disruptions by purchasing insurance on business interruption (including due to natural disasters, such as heavy snow falls) and cargo damage during transportation activities.

4. Risk monitoring

Risk monitoring is required to all the potential supply chain risks previously identified as it has a dynamic character, and should be regular analyzed and updated. Especially if the risk level is very high, or high and not mitigated, the more frequent and rigorous risk monitoring is required (Transport manager, Quality manager 2011-03-24).

During the interview, the quality manager admitted that there is still a high level of trust between company's departments and partners in the supply chain from daily operation perspective. "We need more daily control to be integrated" as quality manager noted. There is not enough daily control. With regards to long relationships between supply chains partners the daily checking points is still neglected, i.e. who is checking out, who is receiving on a daily basis. Thus she pointed out that the more frequent and structured monitoring process in order to have updated information of a supplier/client side should be developed and employed (Quality manager, 2011-03-24).

Risk assessment and treatment templates are used to monitor who is responsible internally and how different supply chain partners/clients are developing compared to their commitments. For the transportation suppliers, the requirement of having business continuous plan is explicitly specified in a written form in the contact as well as special attention is given to how their risk management processes are developing (Transport Manager, 2011-03-24)

4.2.2. Reactive Supply Chain Risk Management in SKF Logistics

The interviews show that SKF Logistics did not face a lot of crucial incidents which could stop the production for a long time or had devastating impacts on business and customers. However some issues are always in place but they are normally handled on a day-by-day basis. For the risk handling SKF Logistics has developed the procedures and business continuity plan in order to decrease the consequences of an accident.

When the incident occurs on a way of transporting goods from manufacture location to the SKF Logistics customers the customer service representative which is assigned to each customer should inform immediately the customer and discuss the possible action suitable for the customer. The incident should then be communicated to other line function managers, e.g. transport manager for sourcing a backup transport solution, according to the situation and to required forces to solve the problem. The incident is also should be reported to the Head of Logistics services in France and then to a manager in charge for SKF Logistics services in Sweden (Business development Manager, 2011-03-24)

For each risk source the customer service representative is appointed and knows exactly what to do when the incident occurs, based on the prescribed actions in a contingency plan. The cross function team for risk management is trained on different scenarios, for example a disruption in the supply chain due to a strike at the port or if ship sinks in the ocean on a way from North America to France. When an incident occurs, the cross functional team should work closely together, if necessary (Quality Manager, 2011-03-24)

On the other hand if SKF Logistics cannot manage a risk by eliminating or minimizing the consequences, the company makes a contingency plan to know what to do if something happens. SKF Logistics has divided contingency planning into three main steps:

1. Disruption discovery.

Once the incident has happen its cause, possible eliminating activities and measures as well as consequences should be defined on this stage. The contingency plan is a useful and helpful tool at SKF Logistics which includes the information of who is responsible for which actions and whom report to in case of emergency. The response actions are also important in order to assess the level of damage from the incident and in order to control activity. The response

actions can include communicating the involved into an accident parties to identify the cause of disruption as well as to study the contingency plan for incident mitigating actions and define all necessary activities. If contingency plan does not have enough mitigation measures the cross function team of risk management should facilitate the meeting in order to brainstorm all possible solutions and decide on the most appropriate ones (Transport Manager, 2011-03-24).

2. Disruption recovery.

The recovery phase includes the actions and measures to quickly recover from the disruption and prevent it from impacting their operations and especially to avoid any negative impacts on their customers. SKF Logistics recovery activities can include shifting to another transport operator, schedule another delivering time if the cargo is not urgent for the customer, etc. (Transport Manager, 2011-03-24). However, SKF Logistics always consider the customer wish and act according to the requirements of the customer (Business development manager, 2011-03-24)

3. Supply chain redesign.

Once the incident was solved the restoration plan is needed to allow supply chain activities to return to normal service level. SKF Logistics managers used the knowledge from the event and take steps if it is needed to redesign their supply chain and minimize the possibility that this incident will happen again. This includes the development of the appropriate tools for optimization a dynamic supply chain operations (Transport and Quality manager,2011-03-24).

Tools and methods for disruption mitigation in supply chain.

Over the years of providing supply chain service, a lot of tools for improvement have been implemented by SKF Group and SKF Logistics. Some of the examples are: the "track and trace" system has developed for a better control, visibility and traceability of supply chain activities on a real time basis and thus to respond to the occurring issues much faster and precisely. They also established a throughout risk management assessment for each of its major transport suppliers and created contingency plans for disaster planning at each location. In addition, risk culture is cultivating within a company managers, so everyone is encouraged to communicate and report about the risk that occurred, the risk information is shared between the employees through the meetings, briefings, job prescriptions.

4.3. SKF Logistics' strategies for mitigation supply chain disruption in transportation due to natural disasters and climatic perturbations.

In this paragraph we analyzed strategies for risk management in supply chain that SKF Logistics applies for disruptions mitigation. These strategies are defined during the cross functional meetings and discussions on risk treatment activities. We distinguish them between proactive and reactive strategies based on the theories in the literature review.

4.3.1. Proactive strategies

In this paragraph we identify the SKF Logistics' procedure in a pre-disruption setting by discussing their proactive risk management strategies. We categorize the strategies based on the model we proposed in Chapter 3 in ***Figure 14***. Different strategies are distinguished and categorized following the interviews with SKF Logistics professionals. First we summarize the proactive strategies applied by SKF Logistics shown ***in Figure 16*** .

Figure 16 shows the proactive strategies applied by SKF to mitigate the supply chain risks. It includes contingency supplier, flexible transportation, flexible decision making, transparent information sharing, advanced warning, controlling and documenting, as well as supply chain collaboration. We explain the details of each strategy in this section.

Proactive strategies:

- Contingency suppliers;
- Flexible transportation;
- Flexible decision making;
- Transparent information sharing;
- Advanced warning systems, controlling, and documenting;
- Supply chain collaboration

Figure 16 Summary of proactive strategies to mitigate supply chain risks in SKF Logistics

Source: own illustration

Mitigation strategies for risks related to supply management.

Contingency suppliers

Suppliers here are referred to transportation companies as SKF Logistics Service is a logistics service provider. As SKF Logistics has different shipping units and global business network, they differentiate their suppliers with different levels of class. The large transportation companies, which take care of the global transportation such as Geodis Wilson, are defined as first-class level of suppliers. The second-class level suppliers are smaller companies those who mainly operate local transportation service. First-class level suppliers is generally required to be prepared with their contingency plan to mitigate the potential risks that could happen in transportation due to either natural disaster and weather related condition or human intervention. While second-class level suppliers could be the contingency suppliers locally if any emergency event occurs. The details of the actions for different level of suppliers are implemented into the contract conditions between SKF Logistics and those suppliers. An example of a recent strike at the port of Le Havre in France is given by the manager. The contingency plan of supplier has mitigated the risk and the impact from the event (Transport Manager, 2011-03-24).

Flexible transportation

Transportation in SKF Logistics is outsourced to transportation companies, as we mentioned in *Contingency Suppliers*. The contingency plans of first-class level suppliers are handled centrally by the key account management team in Sweden. SKF requires their suppliers to have the same level of risk management and contingency plan as SKF, as well as having the abilities in arranging flexible transportation (Transport Manager, 2011-03-24)

Mitigation strategies for risks related to information management.

Flexible decision making

SKF Logistics is flexible decision making to achieve their high level of services. In the case of the shortage of products from SKF's Logistics suppliers, for example due to the delay of shipment from America because of the weather conditions, SKF Logistics managed to receive shipment from other product suppliers in the basis of the decision taken by the Product Division. It happened one or two times also in occasion of the container transportation when strike occurred. Depending on the flexibility and the request from Product Division, SKF

Logistics is able to mitigate the potential risk from customer demand side (Transport Manager, 2011-03-24)

Quality of the service is essential for SKF Logistics as a supply chain service provider. The company implements Six Sigma vertically and horizontally in the whole organization for shaping its strategies. The Six Sigma method helps the organization to measure, analyze, reduce waste and improve the service level overall. By this SKF Logistics reduces the risk to their customers in the demand chain that can be caused by quality issues in the whole supply chain (Quality Manager, 2011-03-24)

Transparent information sharing

The organization has built up a global network of information including the risk information sharing. Track and trace and RFID are widely used both externally and internally in the organization. For example, at the production site of the organization, track and trace system is on small truck going to the product for delivery within companies. Track and trace and RFID ensure the security of the product flow and recognize the location of the products during transportation. The organization will be informed the activities and incidents of trucks and containers on-line with the system. Information is shared within the organization and with the customers so they can know where the problem is immediately when incident occurs (Transport Manager, 2011-03-24).

Advanced warning systems, controlling and documenting

Track and trace and RFID have been an important part of the advanced warning system for the organization to get in touch with both suppliers and customers. Meanwhile Controlling & Customs Division is monitoring and ensuring all the supply chain activities are on the right track. For the first-class level suppliers, they are covered and managed centrally by monitors. Second-class level suppliers are monitored locally. Reports on the monitoring monthly based and documenting and auditing are implemented and discussed at meetings in the organization both before the incident happens and after. (Transport Manager, 2011-03-24). The examples of the strike and the delay given above are documented.

One concern of the controlling is pointed out that the organization needs more frequent checking in the confirmation of the information and reporting on a daily base. For example,

who is responsible in doing and what is he/she doing. As the complexity of the business in the organization, such daily base controlling could reduce more risks not only caused by human errors but also the further impact from these risks (Quality Manager, 2011-03-24)

Mitigation strategy for risks related to supply and demand management.

Supply Chain Collaboration

One important concept we find from the interviews is integration. For example, first-class level of transportation suppliers, those that coordinated centrally from the headquarter in Sweden, is integrated into SKF Logistics first-class supplier plan and their contingency plan. The perception toward both potential risks from natural disasters and weather related conditions, and other types of risks is integrated into the operation level and penetrated into the organization. It needs to be integrated more into a daily base as well as the controlling activity we mentioned. In order to smooth the integration, supply chain collaboration is carried out effectively between SKF Logistics and their suppliers. SKF Logistics also collaborates with their customers by sharing information to minimize the potential risks. Risks in supply chain activities thus can be reduced.

Good relationship and good communication with both suppliers and customers are important for mitigating the potential risks. The organization has more cooperation relationship than just simple supplier-customer relationship with their transportation suppliers. Same level of risk management and contingency plan are conducted under the cooperation. The organization's role changes depending on the situation which requests more collaboration and flexibility. As we mentioned in the overview of the organization, the organization plays both supplier and customer for Product Division. Having the both relationships, it is necessary for the organization to have various plans to proactively prepare for the potential disruptions in supply chain management (Business development manager, 2011-03-24)

4.3.2. Reactive strategies

As soon as the organization has considered as many as the potential risks, it can response rapidly when unexpected event happens. If emergency and incidents happen globally or locally, as the example of strike and delay mentioned, the accidents would be detected first by the monitor and by the assigned customer service representative. For the first-class level suppliers, if something happens, it will be monitored, reported and handled centrally. As the contingency plan is well prepared, it is not difficult to find out the disruption if the transportation service is provided by first-class suppliers, and the risk will be minimized as possible as they can. Contingency plan and the actions assigned to each possible risks listed in this contingency plan are activated when the accident has occurred in order to mitigate the disruptions and to ensure the service level for the customers. Documentation, record and report are completed to help further redesign the supply chain in the organization (Transport Manager, 2011-03-24)

CHAPTER V

5. ANALYSIS AND DISCUSSION

In this chapter we analyze the case study of SKF Logistics and provide the findings of the thesis. We combine the theoretical framework and our findings to further discuss the similarities and differences of supply chain risk management in theory and in practice. We present the aspects of the theoretical framework that are highlighted in SKF supply chain risk management activities as well as the less emphasized factors for SKF. We conclude with the discussion of the research importance.

5.1. Analysis of the Case Study

In this part of the chapter we will present the analysis of the results achieved during the interviews with SKF Logistics professionals. First, we will analyze the SKF Logistics supply chain management from two perspectives (proactive and reactive). Then, we will analyze the strategies which the company apply to mitigate their supply chain disruptions. The second part of this chapter will turn to the discussion on the findings.

5.1.1. SKF Logistics Supply Chain Risk Management

We apply our theoretical framework to analyze the case study with SKF Logistics. The framework is a combination of proactive approach and reactive approach for supply chain risk management while incorporating the perception and insurance plan. We found that the supply chain risk management in SKF Logistics and their strategies are fitting the theoretical model in most aspects, however, some differences in theory and in practice are also exist. The framework of SKF Logistics' supply chain risk management activities is presented into two parts of ***Figure 16*** Proactive Supply Chain Risk Management framework in SKF Logistics and ***Figure 17*** Reactive Supply Chain Risk Management framework in SKF Logistics

Analysis of Proactive SCRM approach in SKF Logistics.

Figure 16 Proactive Supply Chain Risk Management framework in SKF Logistics shows how the findings from the interviews with SKF Logistics professionals are analyzed from the proactive approach using our theoretical model. We found that the four steps: risk

identification, risk assessment, risk treatment and risk monitoring of supply chain risk management are also applied by SKF Logistics. SKF Logistics identifies the potential catastrophic events that may cause disruptions to their supply chain network by building up supply chain teams which includes cross functional management team together with external supply chain partners as well as risk mapping. Significant risks are evaluated and current functional management practices are examined in the network. SKF Logistics priorities risks to be able to choose management actions to the situation in risk assessment. By identifying key supply locations and assessing the probabilities of the occurrence of potential disruptions, specific actions are designed to mitigate those risks that can happen in the SKF Logistics' supply chain.

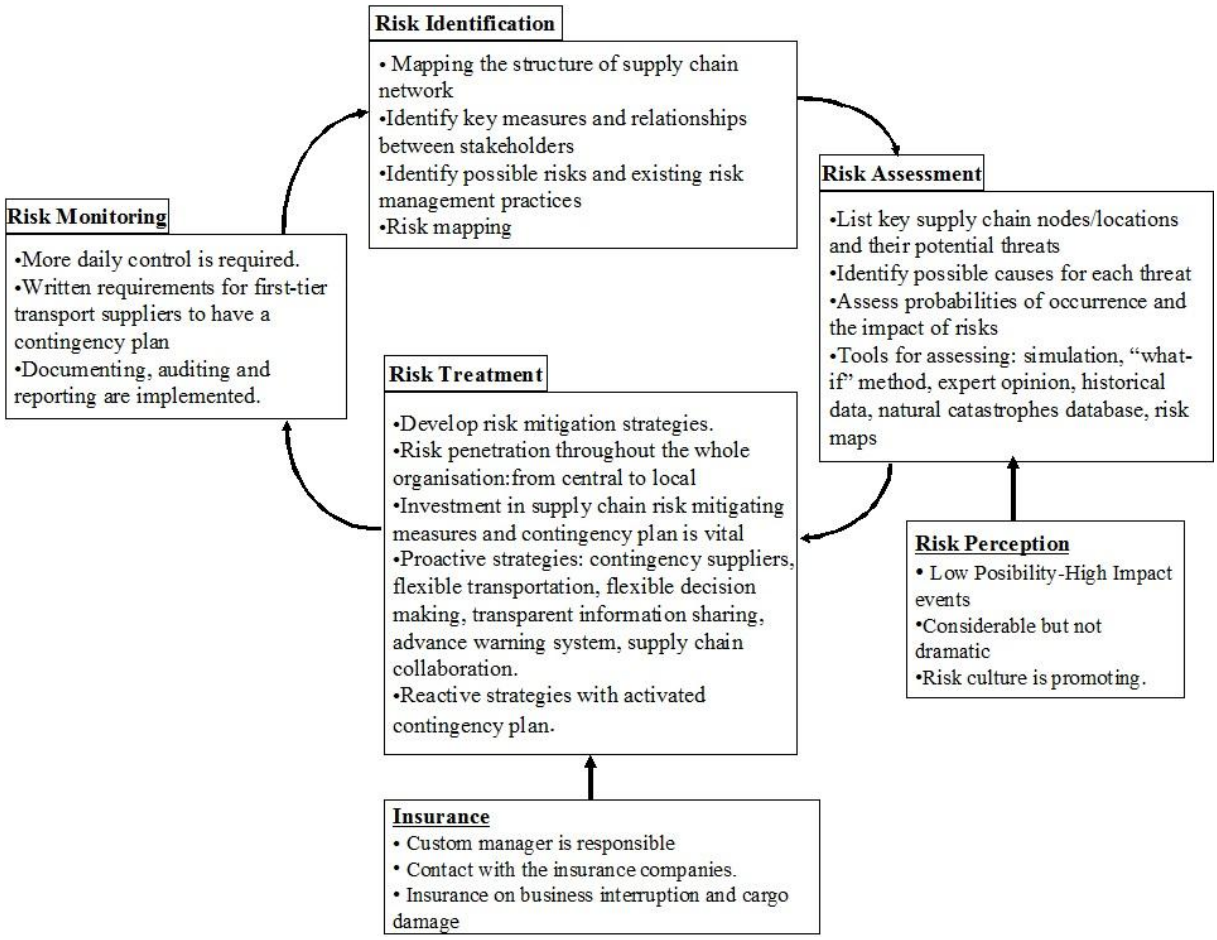

Figure 16 Proactive Supply Chain Risk Management framework in SKF Logistics

Source: own illustration

SKF Logistics applies a proactive attitude of investment into supply chain risk management and a proactive action of implementing supply chain risk management. It contributes and

evaluates the risk assessment process from various perspectives which avoid or prevent the damage in supply chain from potential risk as much as possible. Risk culture is cultivating in SKF Logistics for the less frequency of the daily control of the supply chain activities. Improvement is expected to make the risk perception reach a higher level to ensure their high quality service. Risk treatment process is where SKF Logistics enforces their supply chain risk management activities. By developing risk mitigation strategies and investing in contingency plan, proactive strategies are implemented to reduce the consequences and probability of occurrence of the assessed potential risks. Proactive strategies include contingency suppliers, flexible transportations, flexible decision making, transparent information sharing, advance warning system and supply chain collaboration.

Although insurance is considered as a part of reactive strategy, it is an additional yet important component during the operation of the risk treatment process. It is executed by custom manager by contacting with the insurance companies and coordinating risk management activities. The company constantly renews its insurance on business interruption and cargo damage during transportation process.

Risk monitoring is operated by Controlling Division in SKF Logistics while first-class level suppliers are monitored centrally. Daily report of monitoring are made combining with the activities of documenting and auditing.

We can see that the supply chain risk management activities in SKF Logistics follow our theoretical proactive framework. Potential risks that can occur in the supply chain network are carefully identified and examined under the proactive attitude toward risk perception. By implementing the tools of track and trace system, what-if method, and contingency plan, potential risks and the mitigation plans are treated precisely with specific strategies. A risk monitoring system controls the whole supply chain flow to help tracking the identified risks, managing the contingency reserve as well as capturing lessons learned for the further improvement within supply chain. The whole approach is covered by insurance.

Analysis of Reactive SCRM approach in SKF Logistics.

The following ***Figure 17*** presents the reactive approach of supply chain risk management in SKF Logistics based on the reactive framework. The reactive approach is used when the crisis

situation already had happened and the mitigation actions need to be applied immediately. Three steps of reactive approach in SKF Logistics are identified. On a disruption discovery phase the disruption location and its cause are reported immediately to SKF Logistics, which triggers the contingency plan activities and measures for eliminating potential risks. Recovery actions including shifting transport operators and flexible scheduling of delivery can be applied. Supply chain restoration is essential after the crisis event as more appropriate tools can be developed for further optimization of the SKF Logistics supply chain operation.

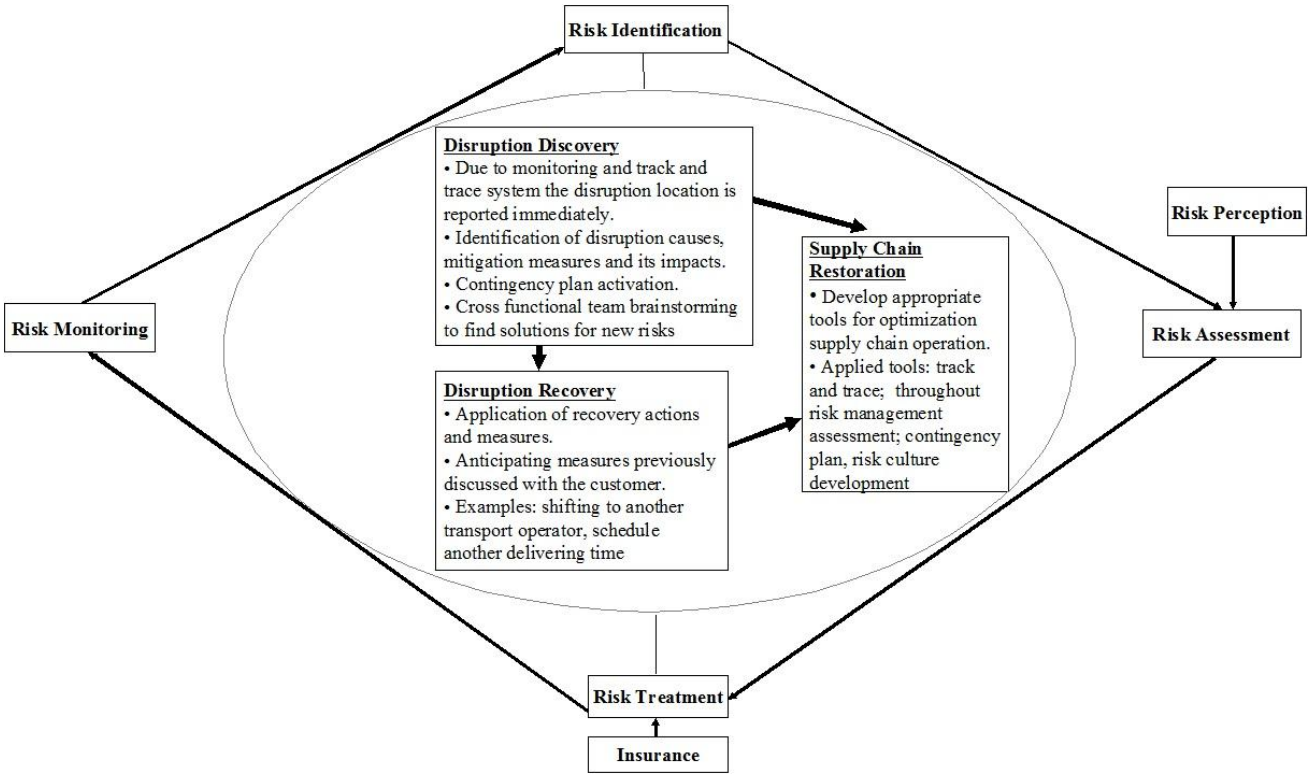

Figure 17 Reactive Supply Chain Risk Management framework in SKF Logistics

Source: own illustration

From the ***Figure 17*** above we can see that reactive approach for SKF Logistics supply chain risk management also can be analyzed with the reactive theoretical framework at the step of disruption discovery and disruption recovery. However the supply chain redesigns process in not clearly defined by SKF Logistics. This step is rather continuous in the company than just a follow up action after the catastrophic event. Thus, the company improves their supply chain activities on a constant basis by integrating high quality level in all the supply chain activities based on Six Sigma approach but also learning from the previous crisis situations how the optimization of supply chain daily operations can be done. On the other hand, it can be

explained that SKF Logistics mainly executes proactive strategies for the risk mitigation. Even if the disruption occurs in the supply chain, managers can immediately identify its location and apply the proactive plans and strategies, thus the damage from the risks for their supply chain can be minimized. We think that supply chain restoration stage of SKF Logistics corresponds to the supply chain redesign step as it allows SKF Logistics managers to further re-examine and develop more efficient tools for their supply chain operation.

5.1.2. SKF Logistics strategies for mitigating supply chain disruptions.

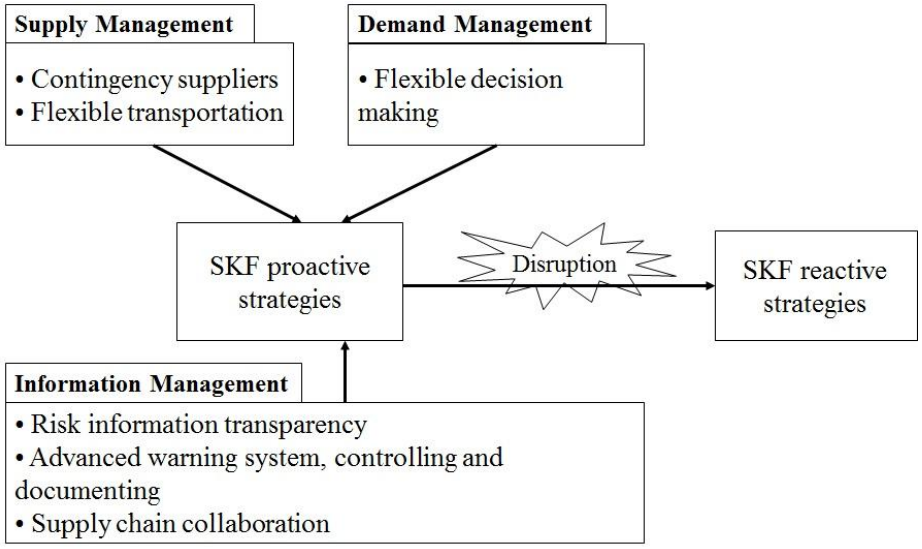

Figure 18 Mitigating strategies of supply chain risks in SKF Logistics

Source: own illustration

Figure 18 shows how the supply chain risk mitigation strategies in SKF Logistics correspond to our theoretical framework of strategies for mitigating the supply chain risks. Three approaches of mitigation strategies have been found as a proactive way. From supply management, contingency suppliers and flexible transportations are provided. From demand management, SKF Logistics applies flexible decision making in order to satisfy the company's customers and achieve a high level of service. From information management, information transparency, information system implementation and supply chain collaboration based on the information network are essential through the whole supply chain risk management activities. SKF Logistics emphasizes its strategies at information management by investing and implementing information system such as track and trace system. When an

unexpected disruption occurs in the supply chain, reactive strategies and contingency plan are triggered and proactive preparation is ready to mitigate the impact from the disruption. For example if a strike happens at the port, flexible transportation is applied to ensure the on-time delivery or if the road is blocked due to the heavy snow storms in winter time the contingency supplier or flexible transportation can be applied. Proactive strategies therefore cooperate with reactive strategies to minimize any damage and risk from the disruption in the supply chain.

However, we found that strategies of product management in SKF Logistics are not applied in our framework. This can be explained as SKF Logistics is a service provider and not a manufacturer. The original model proposed by Tang (2005) includes manufacturing enterprises where the production line is another key point in the supply chain activities. As presented in the case study, SKF Logistics is both a service supplier and a receiver as it has their internal client the manufacturer SKF and external partners such as transportation providers and customers demanding their logistics. From this perspective SKF logistics need even better prepared risk planning and comprehensive supply chain risk management as it affects company's supplier's and customer's sides.

The framework of SKF Logistics strategies for mitigating supply chain risks presented on ***Figure 18*** Mitigating strategies of supply chain risks in SKF Logistics is a part of the supply chain risk management framework shown in ***Figure 16*** Proactive Supply Chain Risk Management framework in SKF Logistics. After the steps of risk identification and risk assessment, the proactive strategies are applied specifically at the step of risk treatment. As one step of the risk management, risk monitoring is also a fundamental part of the strategies and a thorough base for the whole supply chain activities.

5.1.3. Impact and importance of transportation disruptions caused by natural disasters

SKF Logistics managers think that the impact of transportation disruptions make weaker not only supply chain operations, but also bring damages into the relationships with customers and the negative image and reputation of the company. Therefore SKF Logistics considers the importance to invest into mitigation measures and contingency planning and acts proactively

toward the risks mitigation in transportation. Flexible transportation, alternative transportation mode and alternative shipment and route can be applied when disruptions occur.

However specific risks from transportation disruptions caused by natural disaster or weather related conditions are not clearly defined because of the less frequency of the occurrence of natural disaster and weather related conditions. The importance of risk management in these specific risks is not at the top level in the whole supply chain risk management framework in the company. It is included in the general framework in supply chain risk management. As SKF Logistics is well prepared for the potential disruptions so far, the company's transportation operation has not suffer and did not face huge losses due to the natural disasters and weather related catastrophes. For example, recent earthquake in Japan also did not interrupt the operational activity of SKF Logistics in Japan as their distribution sites were located far from the distracted area more on the western and central parts of Japan. However, some of the SKF Logistics customers in automotive industry were forced to close down their production due to destruction of their plants, no electricity supply or in most cases due to demolished transportation infrastructure and closed ports after the earthquake and tsunami in March 2011.

5.2. Discussion of case findings

We presented above the findings from the case study. The activities of supply chain risk management in SKF Logistics fit our model at the proactive approach. They fit the reactive approach of disruption discovery and disruption recovery, instead of supply chain redesign, SKF Logistics achieves supply chain restoration after the disruption. Strategies in practice at SKF Logistics fit our model from supply base, demand base and information base. Product base is not available as SKF Logistics is a service providing organization.

Aspects of theoretical framework that are highlighted at the SKF Logistics.

Under the general framework SKF Logistics ***highlights*** proactive risk management approach in operating supply chain instead of reactive management approach, which is about dealing with threats after they have occurred. SKF Logistics considers it is necessary and important to invest into proactive risk management measures and contingency plans to reduce the damage from potential supply chain risks from a long term prospective. It is essential for SKF

Logistics to implement education and penetration of supply chain risk management knowledge in order to develop risk culture within the organization as it is people who operate the supply chain daily activities. Therefore SKF Logistics has focused on risk identification and risk assessment and developed contingency plans and also requires its suppliers to achieve the same level of risk management. SKF Logistics has not in fact suffered any crisis or huge losses from the supply chain disruptions so far. This can be explained that the potential risks and the measures for the risks are well evaluated and assessed, the contingency plan including the strategies is detailed and the company is well prepared for most cases. Precise documenting and auditing help the organization review and learn from the past to keep improving their skills in dealing with the uncertainty in the supply chain operation. Information system of monitoring plays vital role in reporting and responding the real situation of the flow in supply chain. At the end insurance is a must for the organization to ensure both to suppliers and customers as well as the organization itself.

Aspects of theoretical framework that are less emphasized at the SKF Logistics.

In this research, we have discovered that there are some issues that are ***less emphasized*** by SKF Logistics practices in comparison with the theoretical framework. First, the reactive approach to risk management is less elaborated then the proactive approach. If something outside the contingency plan is happened the company will bear the risks and the impact of these risks is unknown. Second, we have obtained the general strategies applied in SKF Logistics during the interviews. However, specific strategies for specific events and from which perspective (e.g. suppliers or customers) in the contingency plan are not indicated during the interviews. Therefore we are not able to know the detailed perspective of the contingency plan in SKF Logistics but in general. Natural disaster and weather conditions are not treated as top risks that could cause severe supply chain disruptions and bring the huge impact to the organization and their clients. They are included into the general consideration during the risk identification and risk assessment, however, the importance of weather related factors is less emphasized during the whole risk management operation. Risk culture exists in the company. SKF Logistics has the attitude in putting efforts into controlling of supply chain; however their actions are less satisfying so that the organization need to improve from now on.

CHAPTER VI

6. CONCLUSIONS

In this chapter we present the answers to the purpose of our thesis and the research questions, based on the theoretical framework, case study findings and analysis. These answers are given for a company's utilization of the results.

6.1. Strategies for mitigating supply chain disruptions due to natural disasters.

The purpose of this study is to propose possible strategies that a company can apply to mitigate the impacts of supply chain disruptions caused by natural disasters and climatic perturbations. For the easier overview, we summarize them in ***Figure 19*** Possible Mitigating Strategies for Companies to apply

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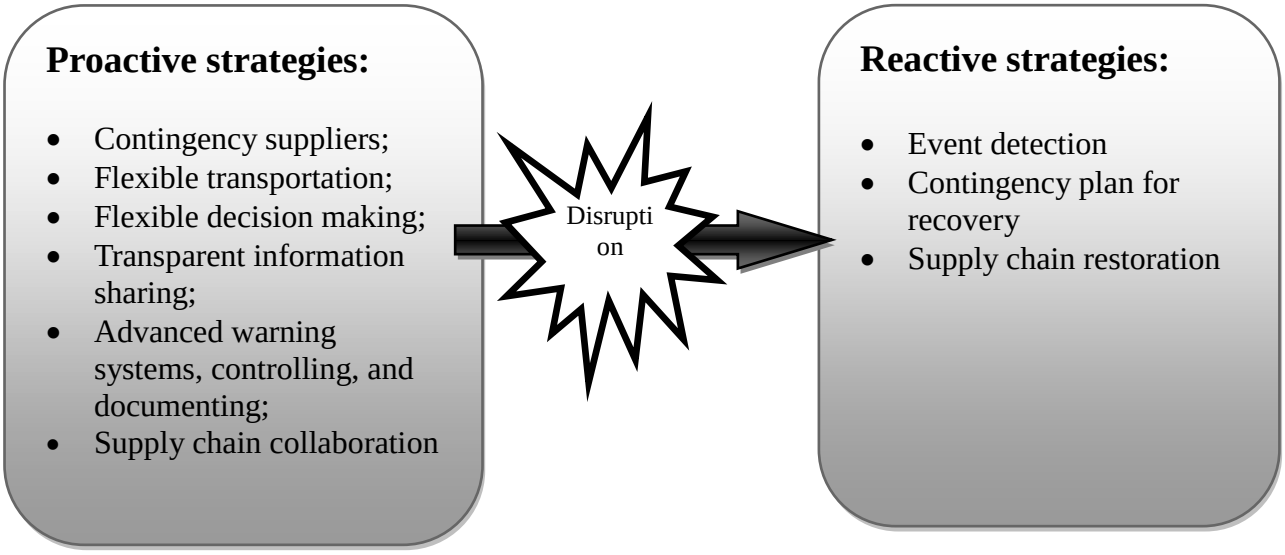

Figure 19 Possible Mitigating Strategies for Companies to apply

Source: own illustration

We propose that companies consider possible strategies from proactive approach and reactive approach based on the model we proposed (***Figure 14***). Companies can apply our model for strategies to further help them shape and refine their own strategies from different perspective. In the proactive strategies, companies can apply contingency suppliers, flexible transportation, flexible decision making, transparent information sharing, advanced warning systems, controlling and documenting, and supply chain collaboration. In the reactive strategies, companies can apply event detection, contingency plan for recovery and supply chain restoration. In order to prepare a company's supply chain to any possible disruptions that can occur in the supply chain proactive strategies are applied to mitigate the potential risks. In the case, when unexpected events happened, reactive strategies are applied; however, proactive strategies can be still activated to minimize the risks. Companies thus could improve their supply chain after experiencing in dealing with unexpected events.

6.2. Research question 1.

What are the major factors that amplify the impact of supply chain disruptions due to natural and climatic disasters?

To understand better the causes of supply chain disruptions we address the major factors that amplify or intensify the impacts of supply chain disruptions due to natural and climatic disasters in our thesis. Nowadays almost every company relies on ***global supply chains network, outsourcing, just-in-time delivery, shortened product life cycles lean manufacturing and single-sourcing*** which from one side save money for a company but from another make its supply chain much more fragile and vulnerable. The ***complexity of products and processes*** is also adding to the probability of disruptions. As a result, supply chain disruptions lead to huge financial losses, reduction of market share, threatening production and distribution, as well as damage of company's reputation. The recent catastrophe in Japan in March 2011 is an explicit example where the natural disaster as a key driver for disruption in line with all the mentioned above amplifiers made a lot of companies from various countries be involved and negatively affected by a disaster. However, more deep and throughout analysis of amplifiers of supply chain disruptions has been given in the chapter 3.1. of this thesis.

6.3. Research question 2.

How can companies prepare for the emergency situations occurring in the supply chain due to natural disasters?

The second research question is how companies can prepare for the emergency situations occurring in the supply chain due to natural disasters. Although transportation disruptions can affects supply chain operations severely, and natural disaster is a key driver of the disruption in supply chain, transportation disruptions caused by natural disasters is still not treated as priority when it comes to the importance of supply chain risk management.

Companies can prepare for the emergency situations from two approaches: proactive supply chain risk management approach and reactive supply chain risk management approach. From a proactive approach, companies can go through the four steps of risk identification, risk assessment, risk treatment and risk monitoring. Risk perception regarding the attitude toward risks due to natural disasters in a company's supply chain should be considered by the managers at the risk assessment stage. Companies can define and map the risks more clearly and more accurately when they have a correct risk perception. Although insurance is treated as a reactive way of dealing with disruptions, it is an important component of risk management that can ensure the financial losses from supply chain disruptions caused by natural disasters.

6.4. Research question 3.

Which mitigation measures and tools can companies employ to prepare and respond to supply chain disruptions efficiently?

Results of the previous studies and our findings provide us with a broad and structured picture of tools and methods that companies can apply in order to prepare and respond to supply

chain disruptions due to natural disasters. The figure 20 presents the findings on tools and methods to assess and manage risks in supply chain.

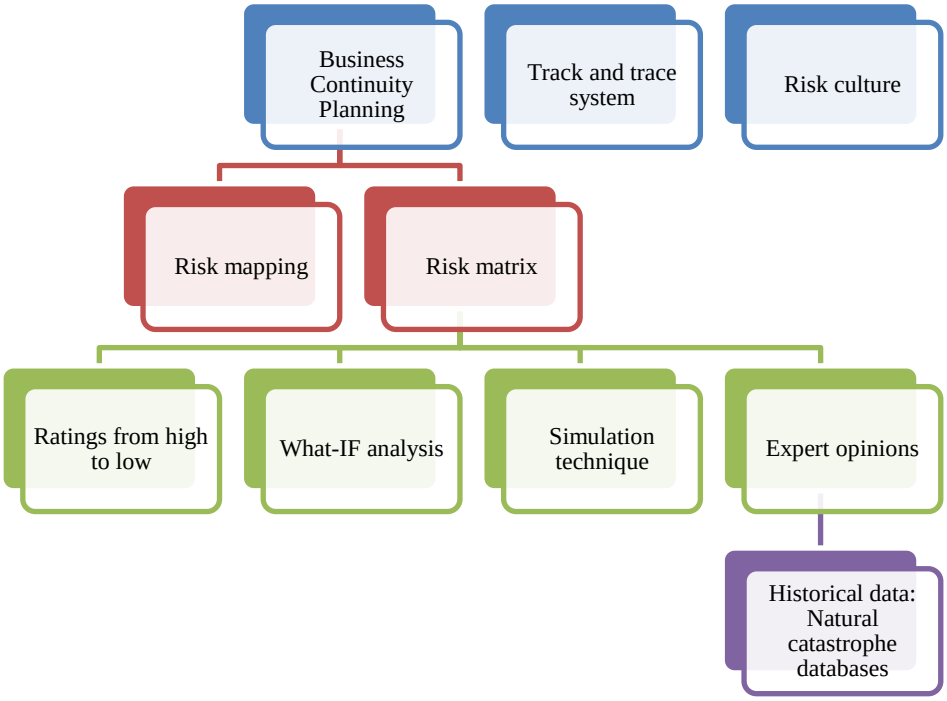

Figure 20 Tools and measures to prepare to supply chain disruptions.

Source: own illustration

From the ***Figure 20*** it can be seen that ***historical data on natural disasters*** can be used by the company's managers in order to know the possible effects, frequency and the areas which are prone to a particular disaster, such as hurricane, earthquake, flood or heavy snow falls. Several natural catastrophe databases are available, such as Sigma, NatCat or EM-DAT, which was mentioned in our thesis previously, provide with broad and detailed information on natural catastrophes and climatic perturbations. This information can be used by experts and companies' risk managers in order to design their opinion on how the risks in supply chain can be treated. When talking about experts, we refer to the reinsurance or insurance companies' professionals, researchers that investigate risk exposure due to natural disasters and the ways of their treatment. All of them can be used by a company to get a good insight on how to deal with risks due to "acts of God" in their supply chain.

Simulation technique refers to a group discussions guided by a simulated disaster in order to test the ability of the group to respond to a situation and to test the theoretical ability of a

group to respond to a situation. It allows people to test a hypothetical situation, evaluate the potential losses and consequences.

"**What – If analysis"** can be also used to analyze and assess the potential catastrophic supply chain risks. The managers define WHAT activities to apply IF an extreme event happens and evaluate which consequences it can cause. This method can, therefore, help to prioritize risks and define their impacts according to the **range from high to low**.

Consequently, these two methods can facilitate the visualization of risks on a **risk map** and/or risk matrix, where all the possible supply chain risks spread out regarding their impact and probability of occurrence. For the better distinguishing of risk intensity different colors used to be applied for the risk maps. ***Figure 6*** in chapter 3.3.1 illustrates the example of a risk map where also a more detailed explanation of a risk map application is given.

The **risk matrix**, on another hand, allows managers to visualize risks in relation to the precise losses they could cause to the company's operations, gauge their extent, and plan what type of strategy (i.e. Risk and Loss Mitigation, Loss Mitigation, Risk and Loss Mitigation or Risk Mitigation) should be implemented to overcome those risks.

In addition to the mentioned above tools and methods **"track and trace" system** is an efficient and effective way to improve traceability and visibility of supply chain operations. As a result, it helps to define any disruptions in a supply chain at a very early stage and respond to the disruption as fast as possible.

Risk culture is a fundamental element of risk management. Risk culture in the organization can help employees to understand better a company's risk exposure and how to manage risks when they occur, as it requires a constant training and risk-related education to ensure consistent risk behavior in the company. Developed risk culture also encourage individual responsibility toward risk mitigation and influence the management decisions while assessing and prioritizing risks and when considering risk mitigation strategies. Therefore, development of risk culture in a company can be a tool of risk management to ensure that employees aware of risks and have enough knowledge to prevent, minimize or mitigate those risks during daily operations.

CHAPTER VII

7. SUMMARY, CONTRIBUTION AND FURTER RECOMENDATIONS

In the final chapter first we will summarize the research study. We conclude the contribution of this research. We also provide suggestions in supply chain risk management for transportation disruption caused by natural disaster for further research as well as for companies in a practical way.

7.1. Summary of the research

The overall goal of this master thesis was to determine the possible strategies a company can apply to mitigate the negative effects from supply chain disruptions caused by extreme weather events and natural disasters. This intention was sought after the observations that show the increasing trend of natural disasters and particular great and devastating catastrophes during last three decades with much stronger impact and severe effects than in the past. We also found that almost one out of three companies has more than 50% of its facilities worldwide located in the areas exposed to natural catastrophes.

The main analysis of this thesis is based on SCRM literature review together with empirical data from the case study of SKF Logistics. After investigating the previous academic works and comparing it to the real world application at SKF Logistics supply chain we defined two main approaches the company can apply to manage and mitigate its risks in the supply chain. The first is Proactive Supply Chain Risk Management, which involves mapping the entire supply chain and its relationships, identifying, assessing and understanding the various threats and risks, and implementing strategies to remove or reduce them. It is a continual process and is normally should be monitored, constantly updated and adjusted to a current company's operations as the risks in supply chain are dynamic and changing over the time. The second

approach is a Reactive Risk Management, which includes three steps: disruption discovery, recovery and supply chain restoration. This approach is facilitated by supply chain business continuity plan, where all possible supply chain risks and the strategies to eliminate them are listed in a special file. SKF Logistics has developed a broad and consistent supply chain business continuity plan which means that the company is well prepared for the accidences in its supply chain and thus can switch faster to a recovery stage without wasting much time on problem discovery and identification step. However, there is always a possibility that unpredictable event out of contingency plan will occur. In this case, the approach to manage the risks that had happened namely crisis management will include the same three steps, but the time between discovering, analyzing and actual recovery phase will be much longer and the longer this time period the more losses the company will face.

These findings suggest that in general there are two approaches for the mitigating strategies that company can undertake to mitigate its supply chain disruptions. First, proactive strategies refer to plans a company can develop in order to prepare, reduce or avoid the impact of possible risk in supply chain before disruptions occur. Second, the reactive strategies applied when the disruption has already happened and a company needs to react fast to minimize the negative effects and to return to the normal operations.

In addition, several tools and methods to respond to supply chain disruptions were discussed in the literature and during interviews with SKF Logistics. We defined that a useful approach might be to use several qualitative SCRM tools to narrow down and visualize the risks in certain nodes of the supply chain. Therefore, risk ratings from high to low or risk mapping, which also applied by SKF Logistics, can serve as a useful and clear way to identify and visualize supply chain risks. Once the key locations are identified, more elaborate risk assessment tools can be applied to assign probabilities to certain events. Due to the high complexity, simulation technique is one tool that can serve for this purpose. Also expert opinions seem to be well applicable in the context of catastrophic supply chain risks. Track and trace system is an effective and efficient method to mitigate disruptions is supply chain. Finally developed risk culture is an additional way of effective addressing risks in the organization, which can influence the decisions of management even if they are not consciously weighing risks, which is crucial when we talk about risks due to natural disasters. However risk culture cannot exist without risk perception

The empirical research has shown that the SCRM of many companies is still in its infancy status. Therefore, a general awareness for SCRM and the risk types in the supply chain are a prerequisite before more advanced tools and methods can be applied. An attractive alternative, in case there is a lack of knowledge and resources to assess the risk type catastrophe in the supply chain, is the external sourcing of relevant data. The natural catastrophe database provided by reinsurance companies can provide a useful insight for managers to evaluate the probability of risks from weather related events.

For companies that have a less mature SCRM it might be beneficial to have a closer look on the discussed tools and methods for the assessment of catastrophic supply chain risks and to also build up resources for the assessment process.

We also considered a behavioral aspect, namely risk perception of the managers who are responsible for risk management. The results show that risk perception of risks from natural disasters is comparably low and is less highlighted by the SKF Logistics, as a company sees itself as proactive and well prepared for different types of risks. It is also the fact that the company did not experience devastating events in the past so that the awareness that such events will happen is low. Thus, managers underestimate the possible crucial impact of this type of risks and do not pay enough attention to develop specific strategies for mitigation risk from the "unpredictable". However, if we look at some companies' that have neglected the importance of the catastrophic events, and was hardly disrupted by them, like in case of Ericsson in 2001 or Sony in 2011 after the recent Japan quack, the conclusion is obvious, before taking any strategic decisions the managers should investigate and take into consideration low possible evens as they can cause a great devastating effect on a company's operation in future.

Finally, in our study we mentioned insurance as an additional component of an effective supply chain risk management. We conclude that insurance is more a reactive way of dealing with disruptions. It provides a risk transfer mechanism and allows organizations to enhance their disaster management capabilities and avoid huge financial losses arising out of natural disasters. In a case of SKF Logistics insurance is used to protect a company from the financial losses of business interruption or damage of goods. But, insurance can never replace the loss of employees, management time and company's reputation. Consequently, insurance

combined with risk management strategies is the best combination for ensuring business continuity and business risks mitigation related to extreme weather and natural disasters.

7.2. Contribution of the research

Based on the results of the research the companies may develop a number of important implications for future practice. First of all, from the findings companies may see the importance of being prepared to the catastrophic events particular in a recent development path as the findings clearly identifies the growing trend of natural disasters. It also gives the clear view of how devastating can natural disasters be for a company's supply chain and its operation in general.

They also may get ideas regarding how to organize their SCRM and which strategies and risk management approaches to apply in case of disruptions in the supply chain. The detailed steps of SCRM approaches as well as possible tools and mitigating measures might help the companies to understand the process of risk management and help to integrate it into their own supply chain.

In practice for companies like SKF Logistics implementing the supply chain risk management from proactive approach, our model can be applied to help companies to build up clear steps of the supply chain risk management. We emphasize the risk perception into the risk assessment process in the model as it is important for companies to recognize and evaluate the potential risks from natural disasters. The strategy model in risk treatment process can advise companies to consider and set up their proactive strategies from various relations with their partners according to their industry. Under the collaboration and communication of today's business, the supply chain risk management is also beneficial for the companies participating in the chain in order to share the risk and improve together. After developing proactive contingency plan and strategies, companies can follow up the situation by monitoring and reporting on a daily base.

7.3. Recommendations for further research

The analysis of this master thesis is based on a single case study of the logistics service providing company thus the findings and conclusions cannot be generalized and used for companies in operating in other business areas without adjusting. However the results of this thesis can provide the following insights for future research. Our suggestions would be to investigate more case studies from different business perspectives, i.e. manufacturing, inventory management etc and various industries to be able to compare the supply chain risk management approaches from different business angles.

Furthermore, the future research can be done for the companies which operate in more vulnerable in terms of natural disasters areas of the world. As our research shows that globally the most active zones in terms of natural disasters are Asia, America and Oceania, thus it would be useful to explore how companies prepare their supply chains to disruptions and which strategies are more appropriate for them to apply in order to mitigate the impact of catastrophic events in those areas.

From a literature review we can conclude that there is only a limited number of studies addressed to the disruptions in transportation due to natural disasters, so our recommendation would be to explore and develop this issue in a further research as transportation is an essential part of supply chain and lack of knowledge of possible risks and its anticipating measures can lead to severe negative impact on effective company's operation.

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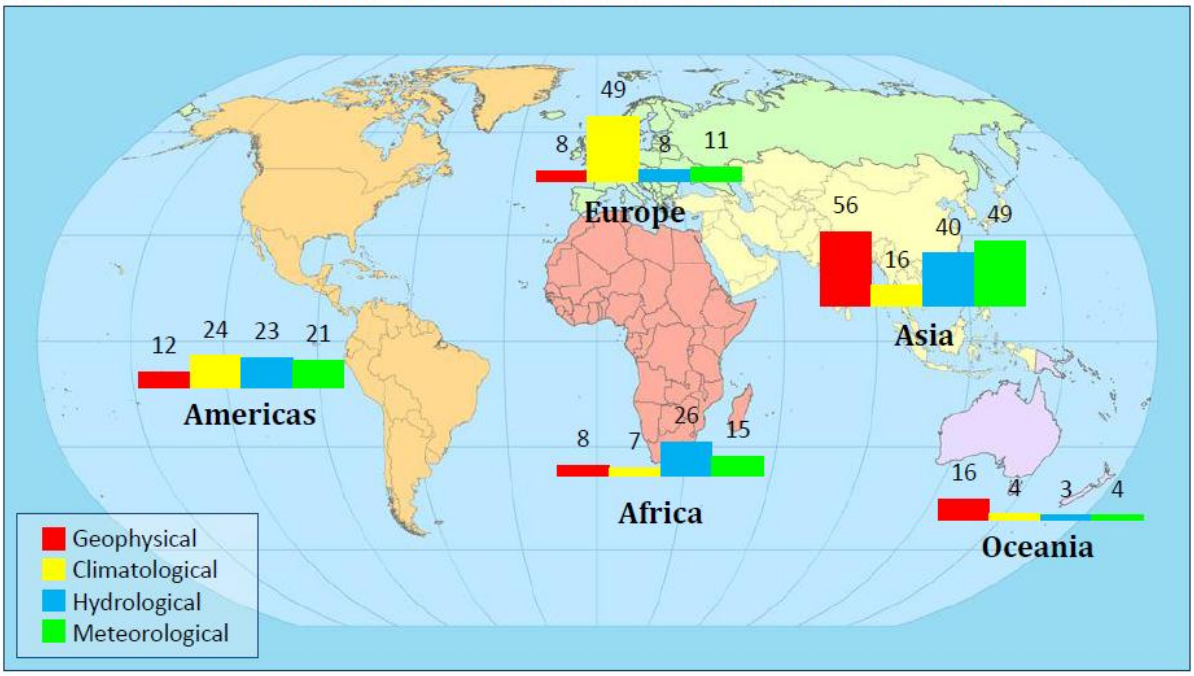
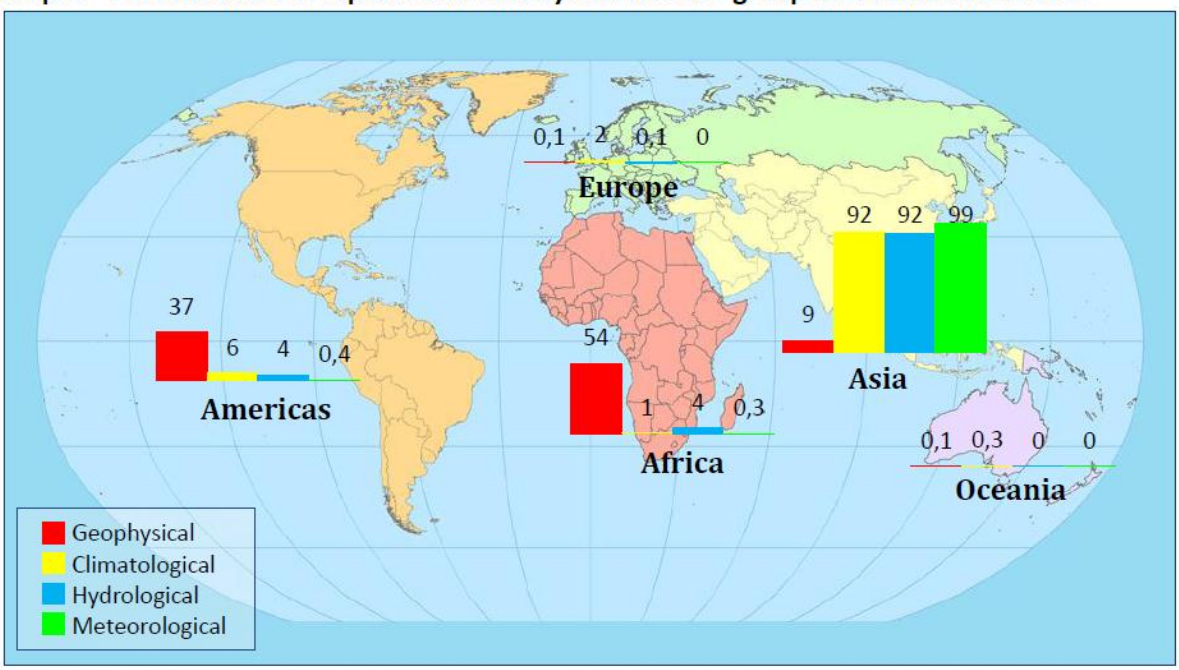
Appendix A

Map 1 – Percent share of reported occurrence by disaster sub-group and continent in 2009

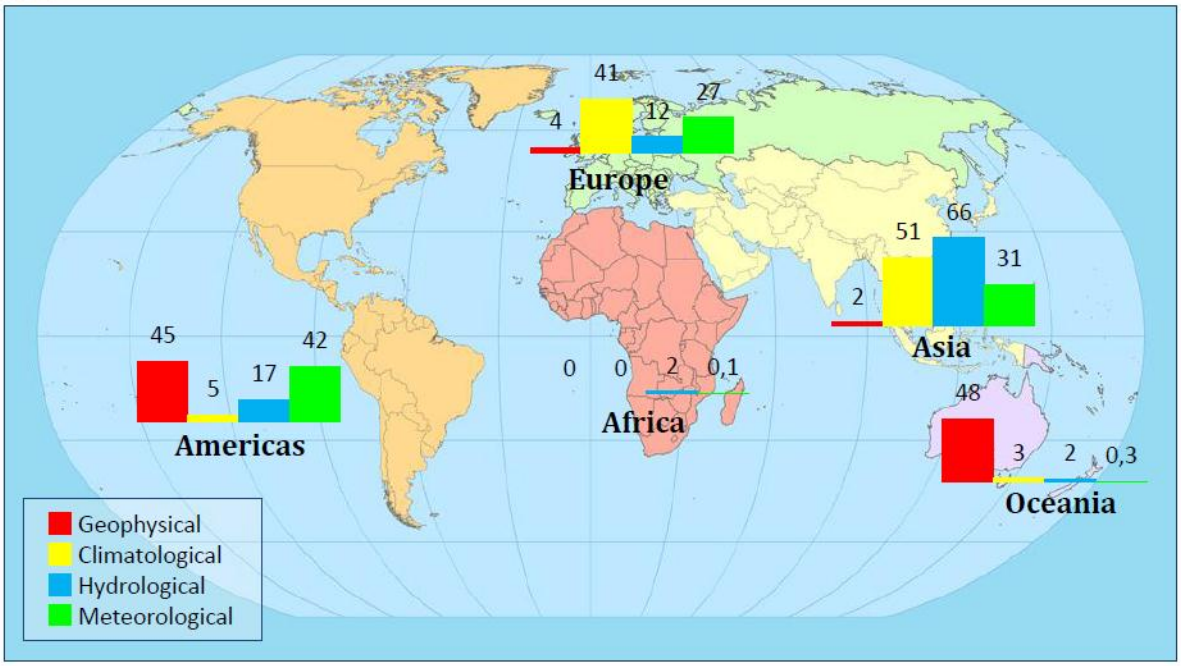


Map 2 – Percent share of reported victims by disaster sub-group and continent in 2009*



*Percentages ≤ 0.05 are displayed as zeros

Map 3 – Percent share of reported economic damages by disaster sub-group and continent in 2009*



*Percentages ≤ 0.05 are displayed as zeros

Source : CRED, Annual Disaster Statistical Review 2009 – The numbers and trends

Threats	Disruptions experienced in the previous years									Threats covered by BCM[1]
	2002 %	2003 %	2004 %	2005 %	2006 %	2007 %	2008 %	2009 %	2010 %	2010 %
Extreme weather e.g. flood/high winds	18	15	10	18	9	28	29	25	**58**	36
Loss of IT	19	24	25	41	38	39	43	40	**35**	41
Loss of people	-	26	20	28	29	32	35	24	**28**	34
Loss of access to site	5	5	6	11	13	13	16	13	**22**	40
Transport disruption[2]	-	-	-	-	-	-	-	-	**22**	25
Damage to corporate image/reputation/brand	15	7	8	11	8	11	10	11	**22**	18
Loss of telecommunications	-	-	23	28	24	25	30	23	**20**	38
School/childcare closures[2]	-	-	-	-	-	-	-	-	**18**	11
Loss of electricity/gas[3]	-	-	-	-	-	-	-	-	**15**	33
Loss of key skills	33	16	14	20	19	20	21	14	**15**	30
Employee health & safety incident	13	9	8	19	13	17	17	16	**14**	28
Supply chain disruption	19	11	12	10	10	13	12	9	**13**	21
Negative publicity/ coverage	24	17	16	17	16	19	18	14	**9**	16
Loss of water/sewage[3]	-	-	-	-	-	-	-	-	**6**	28
Customer health/product safety incident	11	6	4	6	6	6	7	4	**6**	19
Pressure group protest	10	7	7	6	7	7	6	7	**6**	11
Environmental incident	9	5	4	7	5	6	7	7	**5**	28
Fire	6	5	5	5	5	6	5	5	**4**	38
Industrial action	-	-	-	5	6	7	7	7	**4**	14
Terrorist damage	2	1	1	2	3	3	3	2	**1**	27

Base: 903 respondents (2010)

Table 2 Disruptions experienced in the previous 2002- 2010 years, %; perception of threats (2010) and threats covered by BCP (2010)

Source: Woodman & Hutchins (2010)

Appendix C

Interview protocol

In our master thesis we will analyze supply chain disruptions due to natural disasters and severe weather conditions in a business context. Through this interview we would like to understand how your company has prepared for the supply chain disruptions and what the possible strategies your company has in place to minimize the impacts from them.

1. Are you aware of Supply Chain Risk Management (SCRM)?
2. How is it organized in your company?
3. What is the main purpose for your company to have Supply Chain Risk Management?
4. Do you have a person in charge of Supply Chain Risk Management?
5. How does your company identify supply chain (transportation) risks?
6. Are there already tools or initiatives/programs (early warning systems, risk mapping, and business contingency plans) in place to identify and evaluate risks in your supply chain?
7. How do you prevent or mitigate the impact of supply chain (transportation) disruptions? Do you have any specific strategies?
8. Did your company experience any weather-related disruptions recently? Could you please describe this event? ***Which? Where? Why?***

Disruption discovery:

9. How and when was the disruption discovered?
10. How long the disruption did last until your company was able to recover from it?
11. What was the impact of the disruption?

Recovery from disruption:

12. What did your company do to mitigate or reduce the impact of the disruption?
13. Which conclusions were you able to draw from this incident?
14. What have been the main problems your company had to overcome?
15. How and what tools did you use to analyze and evaluate this incident?

Supply Chain Redesign//Restoration after the disruption

16. Is there a business continuity plan or disaster recovery plan in place? Or
17. Do you have a recovery strategy in order to bring business back to normal (initial conditions before the disruption)?
18. Do you have records or documentation on this incident?

Future vision:

19. Do you have any future strategies (plans) for supply chain risks mitigation? …and particular due to the extreme weather events?

- ***Event in Japan***

Did it touch your company business?

- ***Investments in prevention measures***

Do you see it reasonable to put money in mitigation and preventing measures?

- ***Insurance***

Do you have insurance on business disruption due to natural disasters?

Is premium changing over years?

- ***Perception***

How do perceive risks due to ND when assessing and evaluating your risks in SC?

Interviews date: 2011-03-24.

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