Yan Coelho Albertin

SUPPLY CHAIN RISK MANAGEMENT

Understanding and Facing the Main Risks on the Chain

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Supply Chain Risk management:
Understanding and Facing the Main Risks on the Supply Chain

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Senior Lecturer Lassi Leppänen

Abstract

In the past years, globalization has become more intense, and the supply chain has become more complex and wider. It passes through many different countries and cultures, dispersed around the world and working in widely different conditions. At the same time, there is a constant pressure on managers to improve the efficiency of their supply chain, making the movement of the material cheaper and quicker, reducing the inventory and use just-in-time (JIT) or lean operations.

This complex and wide supply chain combined with this pressure on the managers bring many risks to the chain. These risks are unexpected events that might disrupt the flow of materials or the planned operations. They can be late deliveries, poor forecast or involve rarer scenarios such as hurricane and earthquake.

Nevertheless, the risk on the operations has increased significantly on the past years, the effective use of risk management is still far from the ideal. That happens for several reasons, as will be detailed later in this paper.

Supply chain risk management (SCRM) involves risk identification, risk assessment, risk mitigation, and risk control. This thesis will explain each of these steps and why they are so important on the decision-making scenario.

This thesis will first explain the main idea and concepts behind risk and supply chain risk management (SCRM), objectives, benefits and challenges. After that, the main steps and tools for SCRM are going to be presented. In this thesis, different approaches and strategies are going to be combined to elaborate 11 best practices, which make possible the increase of resiliency in supply chain and the resistance against disruptions.

Keywords

Supply Chain Risk Management, Risk, Supply Chain, Resilience

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1 INTRODUCTION

In recent years, many companies have faced supply chain disruptions which can strongly impact the performance of these organizations. The case of Ericsson is well known on this scenario. After a fire at a Phillips Chips fabric in New Mexico, Ericsson's only supplier, the production was disrupted. This disruption led to a loss of $400 million to Ericsson. The earthquake, tsunami, and the subsequent nuclear crisis that occurred in Japan in 2011 damaged Toyota's production and it led to a drop of 40,000 vehicles. The damages caused a loss of $72 million in profits per day. (Bloomberg News, 2011).

Risk occurs because it is not possible to forecast exactly what is going to be the outcome of future events. Even if a company uses the best analyses approaches and software to predict what is going to happen, there is always uncertainty in the future and this brings the risks. Daimler can meticulously plan its production, only to find out that an important machine in the production line is broken, or Sony can prepare a ship delivery, and find that the port will be on strike, or even that an earthquake will affects it chip suppliers in Japan.

The supply chain has become more complex and wider. It passes thorough many different countries and cultures, dispersed around the world and working in widely different conditions. The complexity of the supply chain combined with the pressure on the managers bring many risks to the chain. These risks are unexpected events that might disrupt the flow of materials or the planned operations. They can be late deliveries, poor forecast or they can involve rarer scenarios as hurricane or earthquake.

Although most of the managers are aware of the existence of risk on the supply chain and its importance, a very low number of companies has outside expertise in assessing the risks on their supply chain, and most of the managers have problems with handling risk effectively. This discrepancy between knowing its importance and not using the correct approaches to face the risks have many reasons.

For some managers, risk management is easy to understand but very difficult to use and handle in real situations. In other cases, companies recommend the usage of these practices to their managers but they fail in providing the necessary training or tools. There are also many companies that do not provide incentives or reward for risk management, which might not stimulate the employee's responsibility for these activities. (Dittmann, 2014, p. 1-4).

Supply chain management is a very complex set of operations and functions with an enormous range of inherent risks. These can be a minor irritation such as a small delay which does not cause a significant consequence or a major problem such as a fire in a supplier's warehouse which can cause the disruption of the entire chain. Risk on the supply chain consists in every risk that might affect the planned flow of material. (Waters, 2011, p. 48-49).

Supply chain risk management involves four basic steps:

- risk identification
- risk assessment
- risk mitigation
- risk control

This thesis will try to fulfill this lack of consistency between the researches, theoretical studies and the practical usage by companies. Therefore, this paper is going to start by explaining with simple and direct approach the main idea and concepts behind risk and supply chain risk management (SCRM), followed by its objectives, benefits and challenges. After that, the main steps and tools for SCRM and the best practices to achieve one resilient supply chain are going to be explained. The conclusion will provide some comments about what was experienced while developing this thesis and some possibilities for further research.

2 MAIN OBJECTIVE AND RESEARCH METHODS

Flick (2014, p. 11-15) describes the importance of qualitative research due the rapid social change and the new sensitivity to the empirical study. He describes the importance of starting a paper with a qualitative approach, since the information available about one specific topic might be too limited for starting and proceeding to make tests on the research. Flick (2014, p. 11-15) also points out some of the relevant features on qualitative research:

- Correct choice of appropriate methods
- Analysis and understanding of different perspectives
- Research's reflection as relevant part of the process of knowledge production

The start of each research is stimulated by questions and possible lack of information. The main objective of the thesis is to provide easily understandable material that supports companies to understand, face and handle supply chain risk management by answering these three original questions:

Research Question 1: Which are the main risk exposures on supply chain risk management?

Research Question 2: Which are the main steps and tools for supply chain risk management?

Research Question 3: What are the best practices for achieving a resilient supply chain?

Supply chain risk management is the intersection of two major fields: risk management and supply chain management, as illustrated in the Figure 1. Related literature in these fields will be used as a research method for this thesis.

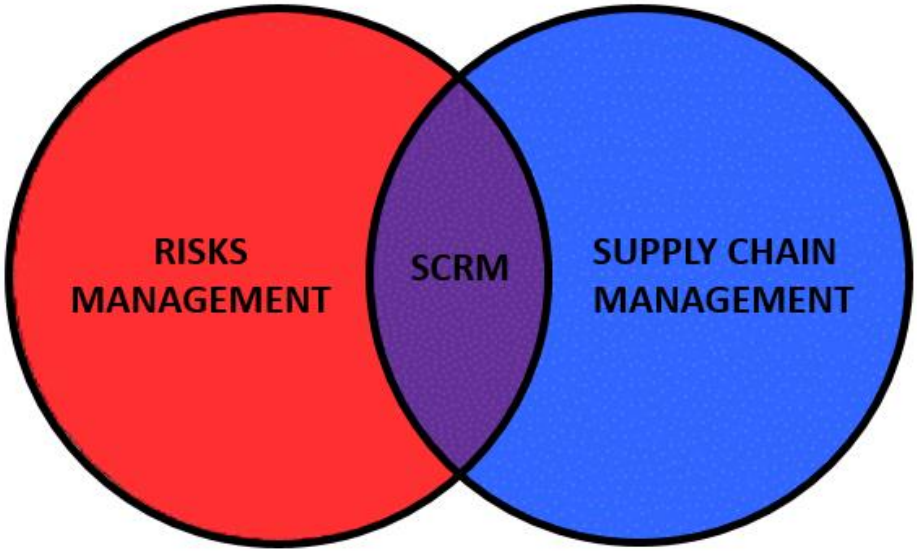

Figure 1. SCRM: supply chain management & risk management

Flick (2014, p. 112-132) presents different qualitative research sources. Some of these research methods include books, online platforms for articles and papers, case studies and comparative studies. This thesis will be based on different sources, such as the library, XAMK e-library , Google Scholar, SciELO, Scopus and other online databases for articles and papers.

3 RISK

Supply chain risk management (SCRM) is a complex theme and involves many variables. In order to have a better understanding of SCRM, it is important to first have the basic knowledge of what risk and risk management mean.

3.1 Definition of Risk

Risk occurs because it is not possible to forecast exactly what is going to be the outcome in future events. Even if a company uses the best analyses approaches and softwires to predict what is going to happen, there is always uncertainty in the future and this bring risks. Daimler can meticulously plan its production, only to find out that an important machine in the production line is broken; or Sony can

prepare a ship delivery, and find that the port will be on strike, or even an earthquake hits it chip suppliers in Japan.

Although risk can be connected to positive results or good outcomes, it is usually associated with negative results and outcomes. Most of the times, managers talk about risk when they discuss the percentage or likelihood of some negative output, such as delayed delivery, accident on the production, some product doesn't sell as expected or other negative outputs. (Khan, 2010, p. 2).

As described above, different authors have many different definitions and meanings for risk. In order to have a better understanding of risk management and supply chain risk management, it is important to first understand what risk is and why it is important. One very accepted definition of risk is the following: risk refers to the uncertainty that surrounds future events and outcomes of operations. Therefore, risk is not only about negative outputs, but also the likelihood of these outputs, negative or positive. This is the definition that will be applied in this thesis. (Waters, 2011, p. 14-16).

3.2 Risk management

Risks can come from various sources. Some of them could be avoided, others not, but this uncertainty in the future events should be studied and analyzed. Risk management is about identifying operations which involve risk, trying to prevent the failure before it happens, stopping them when they do happen, reducing the negative consequences in these events and trying to recover the operations as planned. (Slack & Brandon-Jones & Johnston, 2016, p. 617).

Risk management is the identification, understanding and prioritization of risks, combined with actions to minimize or mitigate risks. After the risks have been, they should be monitored and controlled in order to reduce their negative impact in unfortunate events or to maximize the realization of opportunities. The risk management's objective is to assure the flow of the planned operations and to protect the company against supply chain disruptions.

Figure 2. Risk management (Florida Institute of Technology).

Khan (2010, p.18) points out that managers and investors daily need to take many decisions. In theory, they will always take the best decisions if they use the planned approaches or do the rational analyses methods as the company protocol predicts. Nevertheless, in praxis they must take several decisions, with fast-changing aspects, in some very complex scenarios and with many different circumstances as predicted in these protocols. Fast-changing conditions, tight deadlines, varied opinions from stakeholders and environmental considerations

and many other circumstances turn this decision-making progress very risky and complicated.

Risks come from various causes. Some of them could not be prevented, but most of them can. Some risks are extremely rare to occur but when they do occur, the damage to the company can be so intense that no recovery will be possible. The ability to understand the risks that surround the company operations and environment (natural, political and others) has fundamental importance.

The main reason for the expansion of risk management is the recognition that business and supply chain is becoming riskier. Supply chain are obviously risky and have many risky spots. The material is move through different operations, within companies with different objectives, cultures and with intense pressure to reduce costs.

Even through most managers and investors recognize the importance of risk management, they still face many difficulties to use it in practical situations. One of the reasons is the difficulty to quantify or measure the risk within many other reasons which will be discussed later in this paper. (Martin, 2016, p. 219-221).

3.3 Importance of Risk Management on Decisions

Managers and investors daily face challenges where they need to bring together many data and complex information for taking the best decision. Often this data can be incomplete or fast-changing, which combined with the pressure to always reduce the cost and improve the efficiency makes this process very complex and difficult. Although there are some methods or approaches which summarize the protocol for taking the decision, unfortunately they are often not comprehensive enough, and many times managers must rely on their own ‘’feeling’’ or instinct. In order to present some different possible views on the decision-making process and to show the importance of risk management, two small cases adapted from Waters (2011, p. 23-29) are going to be presented below in subchapters 3.3.1 and 3.3.2.

3.3.1 Case One: Application Launch

One independent programmer has developed an app and desires to launch it on the market. He has four main options: the first two options are to launch the app with his own money on the regional or international market. This is the riskiest of the options, but it also might provide him a higher profit later. The third option is to enter in a partnership with a large company where he will not need to invest his own money on the project, but part of the profit will be divided with the partner. The fourth option would be to sell the rights to another company. This option would be the most conservative and his profit would not be affected if the app do not sell so well as expected.

In order to have a better view of the different scenarios, the programmer decides to hire a company to evaluate and predict the different incomes of these options. After analyzing the market, the consulting company provides him with the table below. The table divides the acceptance of the market (demand) in three options: high, medium and low demand. The table also provides the expected income if any of the four options occur:

	High	Medium	Low	Avarage
Regional	**50**	**30**	**-15**	**25**
International	130	90	-70	50
Partnership	60	40	20	40
Sell the rights	40	40	40	40

Table 1. Taking decision with uncertainty/ without the probability. Adapted from Waters (2011, p. 24-29)

As can been seen in Table 1, making decisions can be really complicated and complex. It involves many factors and there is not necessarily one correct answer. If the probability of each event cannot be available, the programmer should see different approaches how to evaluate each of these choices.

A simple but efficient method is to attribute the same weight for each of the possibilities and to calculate the average. If the programmer decides for this approach, the best option would be to invest his own money and launch the app on the international market. Another very interesting approach to making this decision is to evaluate the possible losses and to evaluate the minimum return in the low demand. There are many approaches and the programmer should evaluate how great a risk he desires to accept and choose the option that better fits him.

3.3.2 Case Two: Decisions with Expected Value

A different situation is when the probability of the different events can be predicted. Probability is the measure of the likelihood that an event will occur. This scenario takes place when there is a possibility of estimating or quantifying the chance of different outcomes (Slack et al., 2016, p. 617). The main challenge here is the difficulty of achieving an accurate estimation. Some events can be well understood and estimated through a combination of rational causal analyses and historical performance. However, other types of failure can be much more challenging to predict such as a fire in a supply plant or a hacker attack.

In order to have a better comprehension of this issue, a simple case will be presented. A global company (with large investment fund) has two investment options, as presented below in Table 2.

	40%	30%	30%	Expected Return of Investment
Investment 1	200	100	-40	98
Investment 2	400	80	-50	169

Table 2. Decisions with likelihood. Adapted from Waters (2011, p. 24-29)

The first investment has a 40% chance of returning 200M€, 30% chance of returning 100M€ and either a 30% chance of losing 40€. Therefore, the expected return of investment is 98 M€. With a similar analyses, it is possible to evaluate the second investment and define the expected return as 169 M€.

In this scenario, there are two important ideas to discuss: the expected return of the second investment is much greater than the first one, but in 60% of the cases the first investment would be more profitable. Nevertheless, this situation should not be so complicated. Once the scenario concerns a global company with large investment funds, and the possible losses do not have such a great difference (from 40 to 50€), the company should choose for the long term and the second investment clearly is a better option.

As we described above, risk is not something negative. Taking risks is also important. Otherwise the company will let good opportunities escape. The most important thing is to have a balance and be able to understand the risk and the situation of the company or an investor. After analyzing and measuring the risk, the organization can have a better understanding of the situation and decide if the risk fits to the company's objective or not.

4 SUPPLY CHAIN

For any business transaction, there is a supplier or group of suppliers and there is a costumer. The processes and operations that connect these suppliers and

customers are called supply chain. Supply chains vary significantly in complexity and size but their fundamental principles can be applied to all operations, regardless of the size of the company. (Ronn, 2011, p. 1-3).

Supply chain consists of the set of processes and activities that move the material trough the supply chain from the initial suppliers to the final customer. Therefore, supply chain includes the internal divisions of the company as well as external partners such as suppliers. The supplier for a certain company has his own suppliers (second tier supplier). Supply chain is basically a network that links all these suppliers until the last costumer.

Another traditional definition is the following: "*Supply chain is the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer*" (Martin, 1992, p. 320). Figure 3 illustrates well this supply chain network and its complexity.

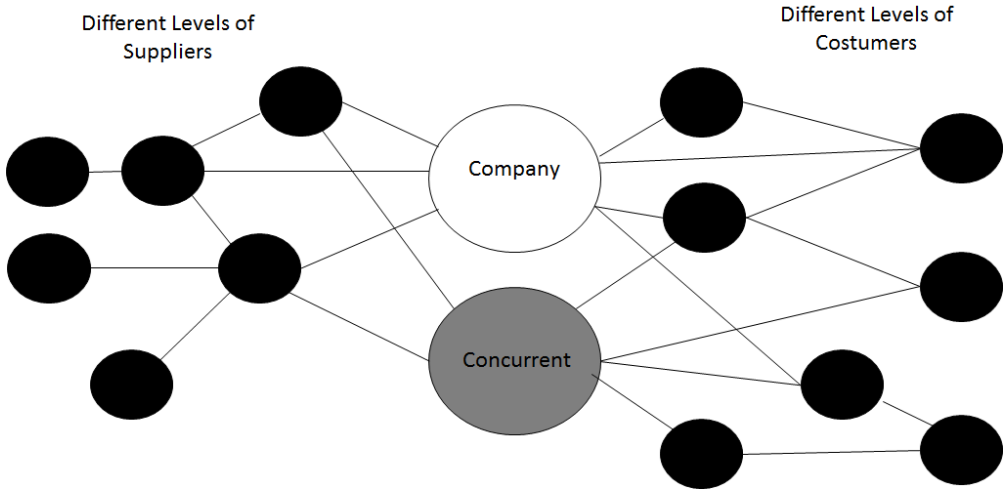

Figure 3. Supply chain network. Adapted from Martin (2016, p. 4).

In the past years, the globalization has been more intense. The companies now focus on their core function and outsource the rest of the production. Thus, the supply chain has become more complex and wider. It can pass thorough many different countries and cultures, dispersed around the world and working in widely different conditions. One example is the supply chain of the Apple Inc. This

company has several sources/suppliers, such as China, Taiwan, United States, Singapore and many others spread on different continents. The components are assembled in China and sent to the main Warehouse in Elk Grove, USA or to another intermediate before they are sent for final distribution (Lu, 2014).

4.1 Supply chain Management

Because of the increasing size and complexity of the supply chains, companies have started to realize the necessity to have a broader view of the movement through all the related organizations that constitute the supply chain and to manage this chain as one integrated organization.

Although in the last 30 years the industry and academic community have increasingly used the term supply chain Management, there is still no consistent definition of this term. As a result, there is still a lack of consistency, which can generate discrepancy of understanding within the chain.

Although many managers focus them supply chain analyses only trough their own organization, it is also important to manage the conjunction of all integrated supply chains, once companies are strongly connected and any impact on one organization brings also consequences to the following organizations. Supply chain Management exists to overcome the lack between different partners within a supply chain until the last costumer (Water, 2011, p. 39-40,).

Supply chain management is the management of materials, information, and finances as they move from the different suppliers to the manufacturer, wholesaler and/or retailer until they reach the last consumer. Supply chain management, then, is the active management and coordination of supply chain activities to increase customer value and achieve a competitive advantage. It represents a conjunct effort by the supply chain partners to develop and operate the supply chains in the most effective and efficient ways. Figure 4 represents well the supply chain network and the complexity in its design.

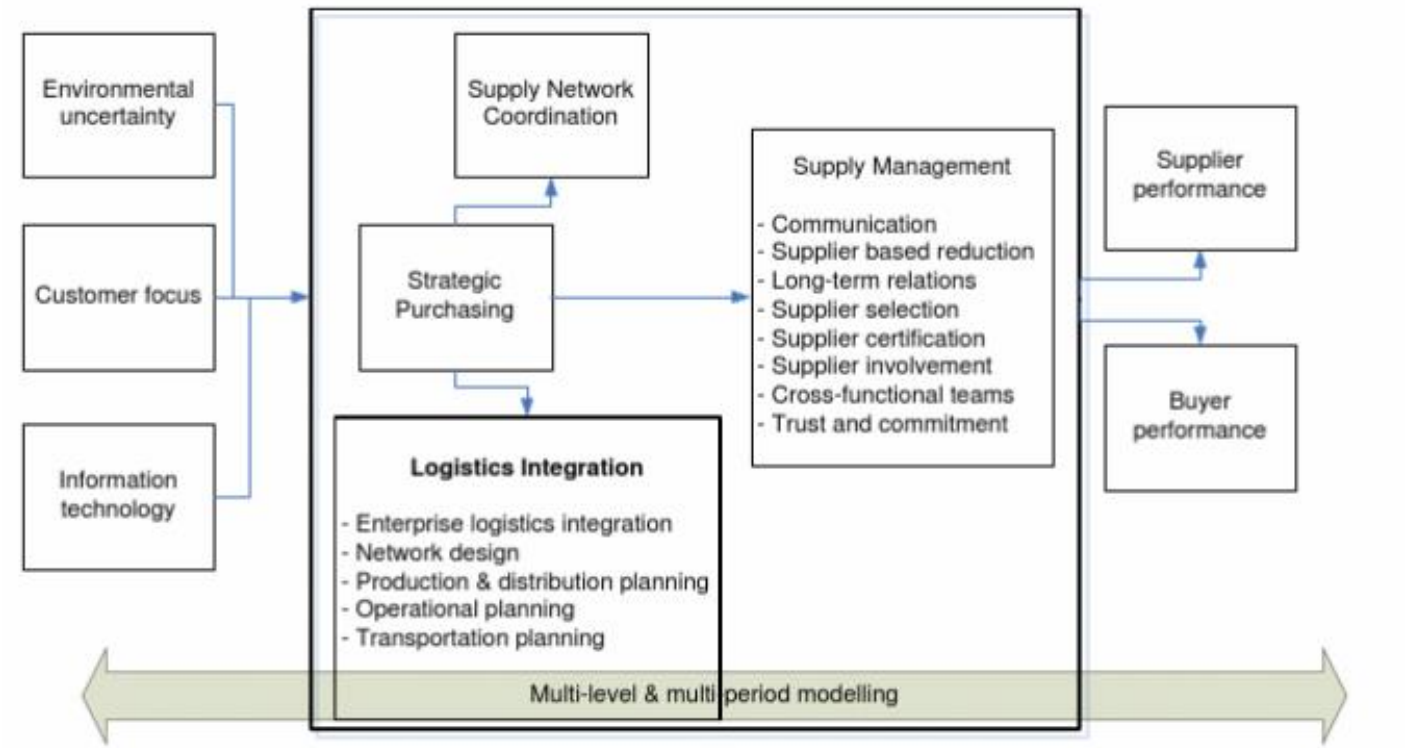

Figure 4. Strategic supply chain network (Samson, 2010, p.173)

Klemencic (2006, p. 39-40) comments on the fundamental importance of the coordination and integration of activities between different partners in the supply chain. This network coordination is a win-win relationship and can reduce the inventory level, increase revenue by improving the customer service and achieving many other benefits.

Therefore, supply chain management is concerned with the efficient integration of operations, suppliers, warehouses and stores, in order to produce and distribute the right good, at the right time and location and for the right price.

4.2 Supply Chain Tends

Supply chain is evolving quickly and is no longer an afterthought for, CEOs, investors and managers. In the past 50 years, many researches have been made, and many companies have increased the attention to supply chain and

logistics. Managers are under constant pressure to find better ways and improve the activities and operations.

The internet and the intensification of the usage of computers have made possible a revolution on every company's activities. New technology will continue to, as it has over the last decades, drive change in supply chain management.

Waters (2011, p. 52-74) points out some of these trends below:

- Integration of supply chains- Managers stopped to separate the activities within the organization and start to adopt an integrated strategy.
- Cost Reduction.
- Agile Logistics- Activities must be flexible and respond quickly to changing conditions.
- E-business
- Globalization- The chains are becoming longer and spread in different continents.
- Outsourcing- Companies focusing on their core activities. That influences on the supply chain size and complexity.
- Increasing of environmental concerns
- Concentration of ownership- With some global companies dominating the market.
- Postponement strategy

This chapter tried to summarize briefly the contents in supply chain and supply chain management. This knowledge will be important for the next two chapters, where the main ideas behind supply chain risk management and resiliency on supply chain are going to be presented .

5 SUPPLY CHAIN RISK MANAGEMENT

Supply chain Management is a very complex set of operations and functions with an enormous range of inherent risks. These can be a minor irritation as a small delay and doesn't cause a relevant consequence or could be a major problem as a fire in a supplier and cause the disruption of the entire chain (Waters, 2011, p. 48-49).

The increasing complexity in supply chain leads managers to face a constant pressure to reduce cost on the operations and to solve many complicated situations in a small amount of time. Combined with the fast-changing scenario and the challenging daily decisions, this might lead the managers to choose decisions or change processes and operations without considering the risk and consequences. Therefore, the supply chains are becoming more efficient but also increasing the vulnerability.

Dittmann (2014, p.2-3) claims in his research that, although most of the managers are aware of the existence of risk on the supply chain and its importance, none of the companies he surveyed has outside expertise in assessing risks on their supply chain: 90 % of these companies do not quantify risk when outsourcing production, and 100% of the managers recognize insurance as a mitigation tool but do not effectively use this tool.

Disruptions in companies are becoming more frequent since managers are not completely aware of the full risk and consequences of their decisions. Although some risks can not be eradicated, they can be identified, assessed, quantified and mitigated. In order to have a better understanding on supply chain risk management and how to face these different risks on the supply chain, this chapter will start with an introduction and categorization, followed by risk identification, risk analysis, strategies and approaches for risk mitigation and ending with risk control.

5.1 Different Risks on Supply chain

Supply chain consists of the set of processes and activities that move the material trough the supply chain from the initial suppliers to the final customer. Risk on the supply chain consists in every factor that might affect the planned flow of material (Waters, 2011, p. 7-8). Although many of these risks can be common and well known such as supplier delays or excess stock, others could be more complex and unusual, such as wars or outbreak of disease.

The truth is that these risks can be very diversified, complex and from different sources. It is important to categorize them to have a better understanding in how they originate and how their consequences might impact the company. On their research for General Motors, Elkins et al. (2004) have identified an enormous amount of risks and divided them in four main groups, as can be seen in Figure 5: Financial, Hazard, Strategic and Operational Risks.

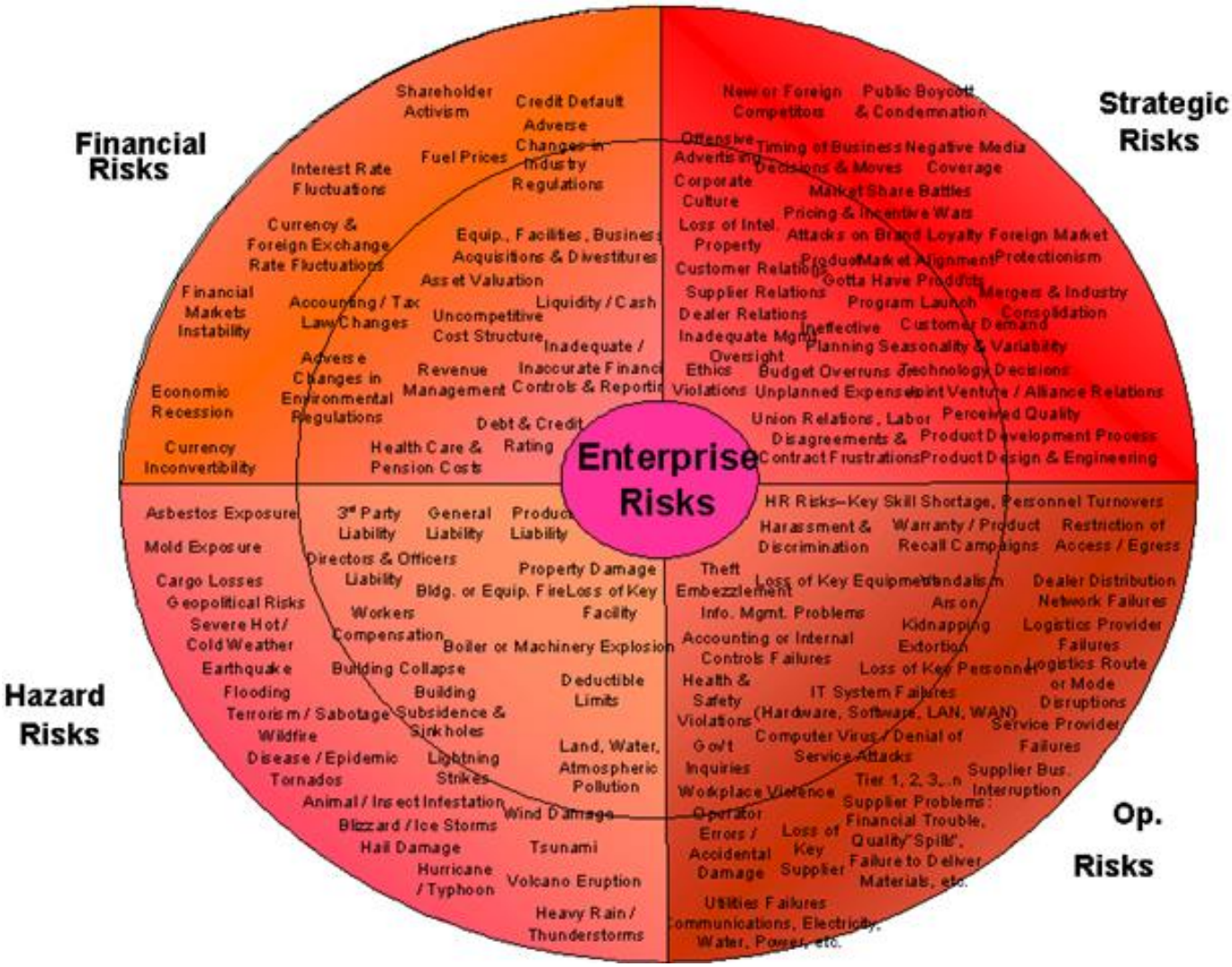

Figure 5: Potential risks on the supply chain (Elkins et al. 2004)

Waters (2011, p. 7) suggests another possibility for dividing the different types of risk. He points out that these risks could be assorted in two main groups: external risks and internal risks. Supply chain is inherently vulnerable to many kinds of

risks and the external risks cover risks that are originated from outside of the supply chain. This has a major effect on financial markets and interest rates, which in turn will affect business decision-making. This includes not only the national political situation but the volatility of the global political scenario. Two good examples that are occurring now and have uncertain impact (at the time of this study) are:

- Exit of the UK from the EU: Companies have contemplated scaling back in the UK market if the Brexit really occurs, and among these firms are food maker Nestlé, car companies Hyundai and Ford, and US investment bank Goldman Sachs. (Borguer, 2015)

- President Donald Trump's international politics: It is still early to comment about the consequence of this, but it has been agreed that his strong political measures bring certain instability on the international policy (Kaletsky, 2016).

This thesis is not going to make a deep analyses of these scenarios, but they are relevant and companies should take risk management into account in these situations since they affect most of the international market and organizations.

One important feature of these external risks is that they are beyond the managers' and companies' control. They are rarer than the internal risks but when they do occur, the consequences can be drastic. Although the company cannot influence the likelihood of the event, they are able to design stronger operations that are less influenced by these risks or develop contingency plans in order to return the operations to the planned level or to reduce the consequences. Other examples of external risks are earthquakes, hurricanes, currency changes, political instability, financial irregularities and cyber or terrorist attacks.

Internal risks are all the risks that come from inside of the supply chain. Although they usually bring smaller consequences than the external risks, they are not less important since they occur much more frequently. They are common and well known risks such as delay on deliveries or machine-break-down and production line downtime. One very good example is the risks regarding the stock size. If the company works with low stocks (Just-In-Time, JIT), they might be more

susceptible to risks such as delayed deliveries of raw material, which could eventually cause interruption on the production line and significant losses. On the other hand, if the company prefers to adopt a high stock strategy, they are also susceptible to other kinds of risks, such as obsolesce, deterioration or internal robberies. There is not one absolute answer for these problems. It is important to analyze the company situation (what kind of goods are going to be stored for instance) and find a balance that better fits to the company's inventory strategy.

Other examples of internal risks are poor forecast, corruption, lack of staff, financial risks, factory strikes, incompatible softwires, inadequate assessment and planning, human mistakes which come from inside of the supply chain.

5.2 The Supply Chain Risk Management Steps and Tools

In this chapter, this thesis will present the four main steps for risk management: risk identification, analyses, mitigation and control followed by tools to improve each of these steps.

5.2.1 Risk Identification

It is generally agreed that risk identification is the first step and one of the most important processes in supply chain risk management. There is a extremely large number of possible risks in an almost endless variety. This step should identify anything that might interrupt the flow of materials or information and impact significantly in the company's supply chain. Thus, the risk identification should develop a list of the risks that are likely to affect the supply chain and bring consequences to the company, negative or positive (Vilko, 2012, p. 45-46).

Risk identification is the process of determining risks that could potentially affect the company. The sooner these risks are identified, the better actions can be taken to mitigate or manage them. If the company does not identify the risks, they are not able to analyze or mitigate these risks. A proactive tool for risk

identification can bring important impact on the SCRM. This thesis will present some of the best options accepted for risk identification.

The best approach for risk management depends on the company size, field or resources. The company Apple Inc, for instance, will need a much more detailed and complex risk management analyze than a small bakery. Each company should study some approaches and determine which one could best fit to their needs. This chapter will present and explain shortly some of the options below (Waters, 2011, pg 103-118):

- Consultants: this option could fit better to large and global companies. Experts are able to give some valuable insights and to identify more precisely the risks that surround the company and give some advices on how to mitigate them.
- Group Meetings and Brainstorming: this option is one of the main approaches for risk identification. In this method, a group of differently skilled managers can analyse different operations and processes and are encouraged to identify risky spots in a judgment-free environment. These meeting can also involve different partners and companies (networking). This action is important for achieving the integration of the risk management in the supply chain.
- Checklist available on the intranet any worker can identify risks at any time and actualize the risk list which is available for anyone to see. After that, one expert group should evaluate each of these risks and the ideal mitigation responses for the relevant ones.
- Pareto analyses Pareto Analyses is based on the observation that 80% of risks come from 20% of causes. Thus, a frequency diagram which presents the risky events that have occurred in the past might help the companies to identify the events that are more likely to reoccur in the future, as shown in Figure 6:

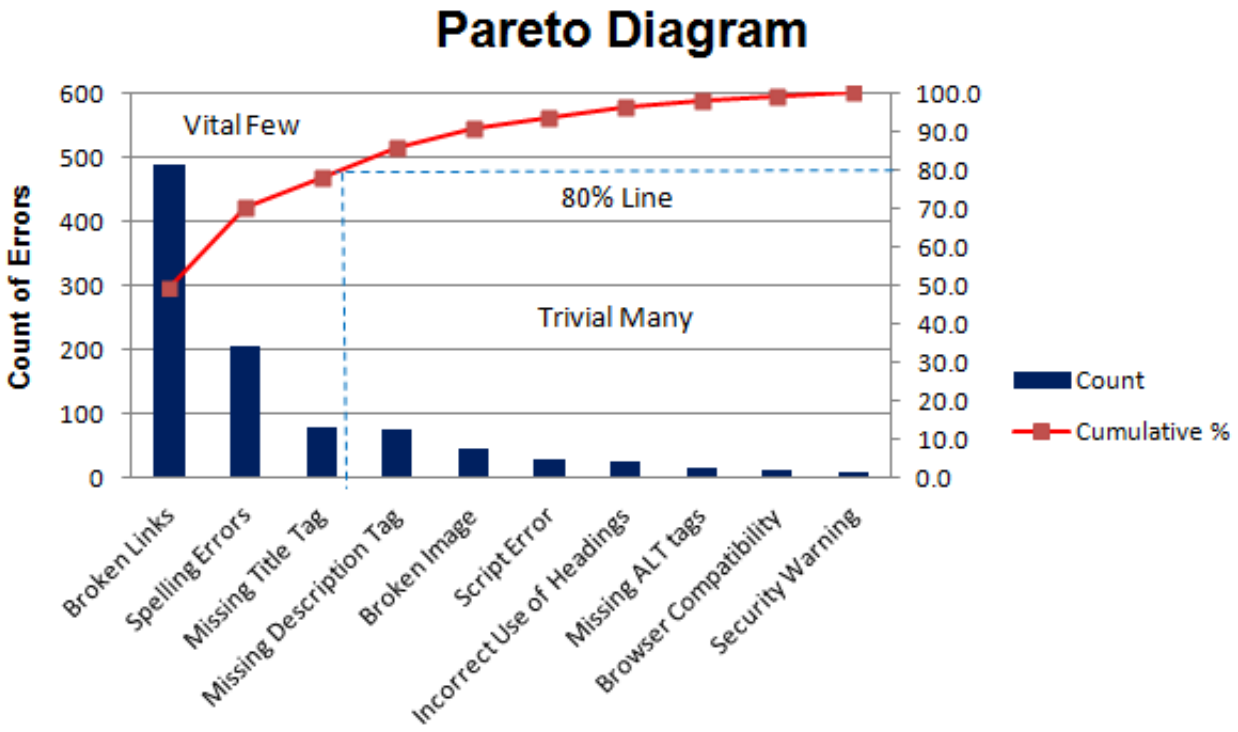

Figure 6. Example of Pareto Analyses Haughey (2015).

- Failure modes and effects analysis (FMEA): this methodology was developed by NASA (The National Aeronautics and Space Administration) and it is a step-by-step approach for identifying all possible failures in operations or systems. It is considered a proactive tool for risk identification and analysis.
- Cause-and-effect diagrams: this approach starts with the identification of events that could go wrong, such as late delivery, capacity problems and production disruption. After that, the company should identify the possible risks that would cause these events.

Supply chains are subject to many kinds of risks, and these risks can be greatly diversified. It is important that each company can study and understand their operations, market and environment in order to have a better understanding of what kinds of risks they are more likely to face and might be susceptible to. Dittmann (2014, p. 13-14) specify in his research the top 10 concerning on the supply chain by managers. Companies that are not so familiar with SCRM can take this example as a starting point. Figure 7 illustrates these risks:

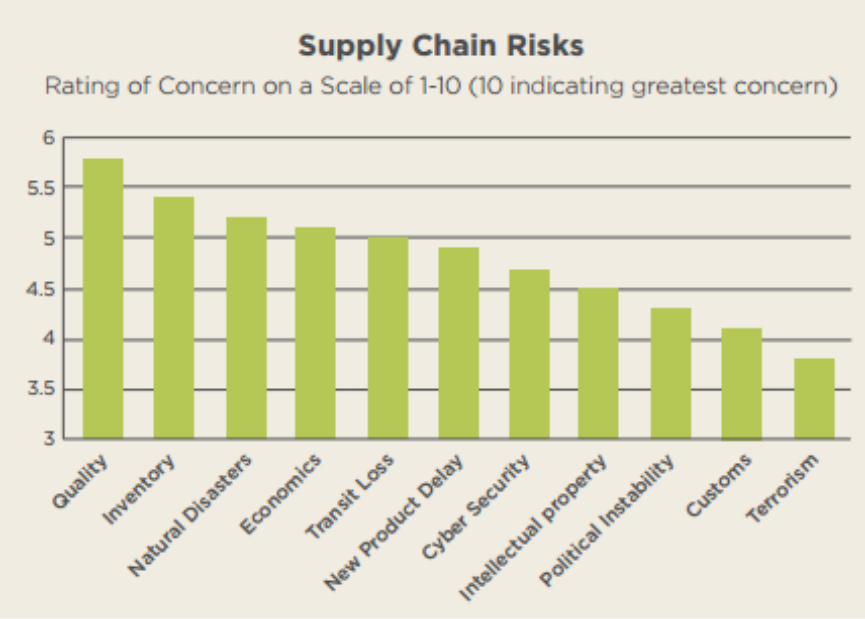

Figure 7. Supply chain risk, scale-rating on concern (Dittmann, 2014, p.13).

The risk with the greatest concern on the supply chain is related to quality. A long and complex supply chain makes it very difficult to recover from quality issues. This refers to cover situations, for example, where the product is not safe or does not perform as promised. This sometimes happens in automobile industries and is commonly known as recall.

One famous example of recall was the Volkswagen Emission Scandal in 2015, where over 11 million cars were delivered with an electronic device on the engines that was cheating on emissions tests in the USA when engines were emitting nitrogen oxide pollutants up to 40 times above what is allowed on the regulations. The brand suffered billions of dollars of liquid losses and inestimable damage to their image.

Inventory is the second greatest concern on the supply chain. This is caused by the strategy of reduction of inventory combined with the long and complex supply chain. This situation makes it extremely difficult to achieve the inventory turnover goals. This concern also includes the uncertainties derivate from the suppliers, such as supplies delay, limited available and material cost. (Hotten, 2015).

Natural disaster, such as hurricanes and tsunamis, is the third greatest concern on the list. They do not occur so often but when they do, they bring intense consequences. Other important risks are economics (market growth, concurrent, taxes), transit loss, new product delay, cyber security, intellectual property, political instability, customs and terrorism.
Waters (101-103) points out other risks which can be relevant for this risk identification step, such as:

- New regulations
- Currency exchange and inflation
- Traffic accident
- Equipment failure
- Demand fluctuation
- Competition
- Theft and fraud
- Human errors
- Labor accidents

This chapter aimed at summarizing some of the best practices in order to support companies, identify the basic ideas behind the risk identification and give some examples of the most common risks on SCRM. Each company should gather information about one segment and analyze which approach might best fit their own needs.

5.2.2 Risk Analysis

In the previous subchapter, different approaches and tools to identify risks in the supply chain were described in this subchapter, some methodologies will be explained, which can support companies to analyze and evaluate these risks and identify the potential impact on the company.

Although risks can be much diversified and involve complex circumstances, Waters (2011, p 131) points out that there are two main factors to evaluate the risks:

- The likelihood of a risky event to occur
- The impact when the event does occur

Berg (2012, p 85) and Waters (2011, p. 129-130) describes the two main approaches to analyzing risks. The first one is the qualitative technique. This approach can be used, for example, when the likelihood of the events is very difficult to estimating such as a fire in the warehouse, or when the risks are being subjected to more expensive quantitative techniques.

Although this practice can be subject to different opinions, often the managers are to evaluate and estimate qualitatively well enough the situations and offer a low budget and faster answer. Possible tools are hazard matrices, risk graphs and risk matrices. Usually a qualitative analyze should involve:

- Description of the risk
- Impact and likelihood
- Scope (areas affected)
- Relationship to other risks

Another and more sophisticated approach is to use quantitative analyses. With this technique, the likelihood of the event and the impact should be quantified. Although it is really difficult to measure and evaluate the likelihood of such complex scenarios such as a fire in a warehouse or earthquake, many probabilities from different events can be quantified or at least one appropriated approximation can be found. The main approaches to quantify the likelihood are (Waters, 2011, p. 132-134):

- Use of theoretical and mathematical knowledge to calculate the exact probability of an event. This is the most reliable technique, but it can be difficult to use in real scenarios and complex operations.
- Use of historical data to see how often one event has happened in the past and predict its probability for the future. This approach can be interesting for situations such as the fire example (if taken in a large databank, including other companies).
- Use of the available data and predict the likelihood of an event by judgment. It is less reliable method, but can be used and put in a range of probability.

The other important feature of risk analyses is the impact on the supply chain. The consequence from each risk can vary from almost insignificant risks which will not bring relevant impacts on the supply chain to catastrophic events that might cause complete and irrecoverable damage to the chain. Therefore,

managers should try to measure and attribute a possible cost (or gain) for each risk. This can be achieved by analyzing the operations involved by each risk and evaluating a possible range of damage caused by the risk.

There are many tools that might support companies in making risk analyses. The most commonly used tools are:

- Failure modes and affects (FMEA): see subchapter risk identification.
- Simulation: through computer simulation it is possible to test different variables and evaluate risks in a sophisticated way. This requires programing knowledge, but the results can be very attractive.
- Probability-impact tables: in these tables, companies can put different risks in order to evaluate their respective significance. Because of efficiency and simplicity, this is one of the main tools used nowadays. This method in Table 3 is illustrated.

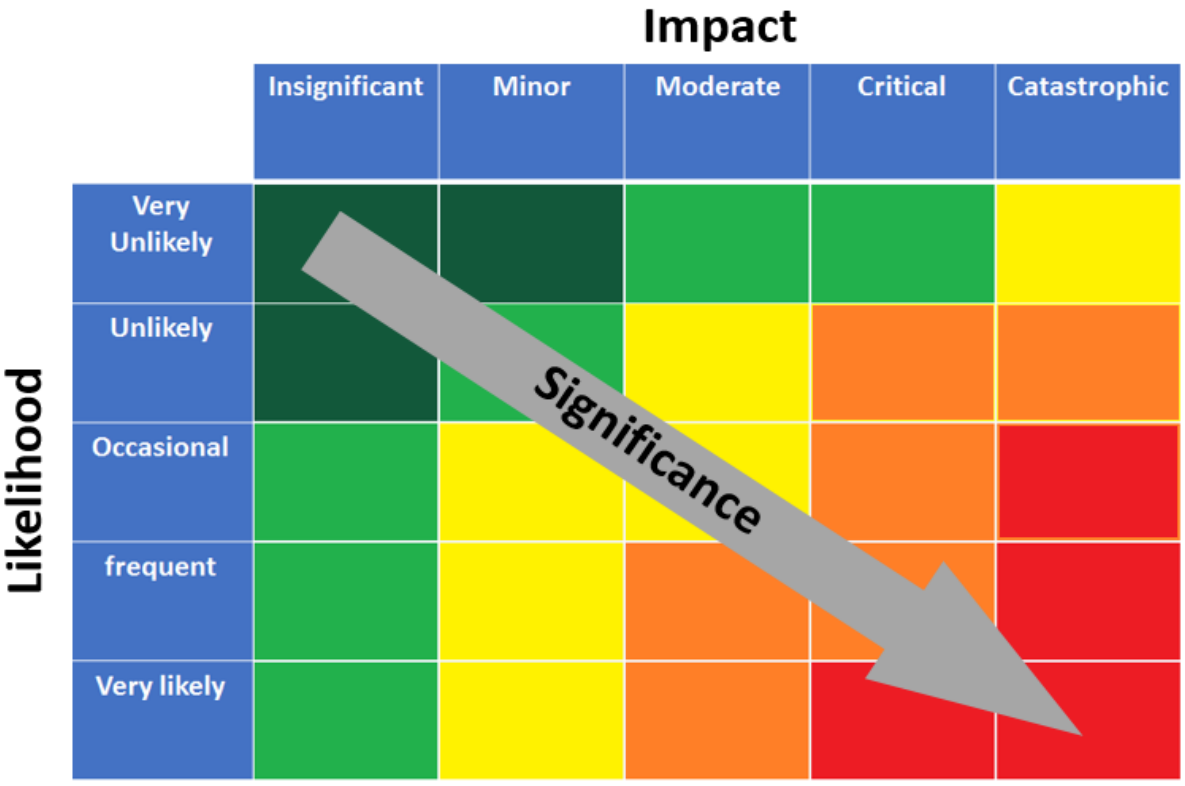

Table 3: Probability-impact table

There are many tools that might support companies in making risk analyses. The Probability-impact table is one of the most widely used for that because it provides a simple, efficient and illustrative approach for risk analyses.

5.2.3 Risk Mitigation Strategies

In the previous chapters, different approaches how to identify and analyze risks were presented. Once they have been identified and prioritized, and the amount of attention that each risk deserves has been assessed, the company should after consider carefully the importance of each risk and the amount of resources required to deal with them. Thus, the company needs to define the most appropriate way of dealing with these risks (Vilko, 2012, p. 47-48).

Berg (2012, p 86-87) presents the most traditional ways of mitigating risks:

- Avoid the risk: not undertaking an activity or operation that might cause the risk.
- Reduce the likelihood of the event: companies are often able to review the risky spots and through preventive maintenance and quality assurance they are able to reduce the likelihood of risky events. One example is increasing stocks for the materials with varying demand.
- Reduce the impact: Although many events cannot be influenced by the company (such as the Brexit), managers are still able to reduce the negative impact and its influence on the company. One example is that by reducing the lead time of deliveries from suppliers, companies are able to reduce the consequence of material shortage. Contingency plans are also another possibility. The preparation of protocols and actions to manage a situation before it occurs can prevent managers from making mistakes and save precious time when responding these events.
- Transfer the risk: In this option, risks are transferred from one organization to another. One major company can use its influence and put the other smaller partners under pressure for undertaking these risks. Another traditional way of transferring risks is insurance. Insurance can be very beneficial for the company in some scenarios where the likelihood of an event is very small, but the impacts are too serious to be ignored and, the company prefers to face uncertainty with a small additional cost.
- Accept and ignore the risk: In this scenario, the expected value from the risk must be considerably smaller than the resources needed for mitigation actions. The company should wait and, if the event does occur, they can formulate a response to it.

There are different approaches to mitigating risks. In this thesis, the most commonly accepted ways for mitigating actions are presented . In the next subchapter, the next step for SCRM, risk Control, will be presented .

5.2.4 Risk Control

Because supply chains are very dynamic and can change very fast, the risks' impact or likelihood can change as well. It is essential that the risks are regularly monitored. Changes in the organization and the environment in which the company operates must be identified and the appropriate changes actualized on the system. Another important point is that in the future, more data and information will become available and other will become obsolete. Therefore, it is also possible that the company will have a better understanding of the risk scenario and decide to undertake another strategy to face it. (Berg, 2010, p 87).

6 RESILIENCE AND BEST PRACTICES

Resilience is the ability of a supply chain to resist disruptions and to recover operational capability after possible disruptions occur. Supply chains vary significantly in complexity and size, but the actions taken by companies to prevent risky events have many similarities. Waters (2001, p. 198-200) states that an organization should start the process of creating a resilient supply chain internally by understanding the concept of SCRM, followed by taking a strategic view of SCRM and by starting this first analyze within the organization. This means that the company should have already installed and working properly the SCRM before taking further and more complex steps, such as increasing the integration, collaboration and creating agility within the supply chain.

This thesis is based on different researches and combine different approaches and strategies to elaborate 11 best practices, which make possible the increase of resiliency by increasing the resistance against disruptions recovering the operational capability as soon as possible. These 11 best practices are:

1. Quality
2. Contingency Plans
3. Increase of Stock Level
4. Add Spare capacity
5. Increase Collaboration and Visibility
6. Agility on Operations
7. Vendor Rating
8. Increase Forecast and planning

9. Dual or multiple Source Strategy
10. Insurance
11. Rationalize Product Range

This list of best practices was made by combining different sources, such as Waters (2011, p151-177: 195-214), Strom et al. (2013, p. 1-29), Dittmann (2014, p.1-31), Q9 Quality Risk Management (2006), Tse (2012) and Sparta Systems Guideline (2016).

1) Quality

This is one of the major concerns for managers in different fields and segments. As companies have pursued this broadened supply chain strategy, the ability to manage quality risk has become more challenging. Effective supply chain quality risk management (SCQRM) is the key for mitigating the quality risk issues and helping the company to face challenging scenarios.

Quality risk management is a very complex subject, the Q9 Quality Risk management (2006), Tse (2012) and Sparta Systems Guideline (2016) provide a very useful and well explained papers in order to achieve a better-quality risk management. Some of the best practices are:

- Increase visibility in the supply chain.
- Invest in infrastructure and increase the communication with the suppliers.
- Establish clear measurement programs.
- Use tools such as Failure Mode Effects Analysis (FMEA), Fault Tree Analysis (FTA), Hazard Analysis and Critical Control Points (HACCP), Hazard Operability Analysis (HAZOP).
- Make quality risk management as part of integrated quality management, development, materials management and production.

As presented in the Figure 7 on the chapter 5 of this thesis, quality is one of the top concerning risk-issues faced by companies. This is caused because of the difficulties in identifying quality issues in early stage in the supply chain, in repairing this quality issues due the broad and complex supply chain and the high costs and the damage to the image involved. The correct usage of these tools and practices can support companies to face better these risk issues.

2) Contingency plans

Contingency plans have fundamental importance against external risks. These are usually outside of the manager and companies' control and can not be influenced by the company. A contingency plan is a protocol or course of actions

designed to help a company by responding effectively to an unexpected event that might harm the supply chain (Waters, 2011, p. 158). Therefore, contingency plans are elaborated preventively and come into effect after a risky event actually occurs. Prepare protocols and actions to manage a situation before it occurs can prevent managers to commit mistakes and safe precious time on responding these events, as illustrated in the Figure 8. The main benefits of these plans are:

- Minimizes Loss
- Prevents Panic
- Assure the Continuity of Work
- Increases Credit Availability

Level	Criteria	Interpretation	Warning signal	Required action
0	No flood	Classes ongoing	None	Conduct classroom instruction as usual.
1	Floodwaters clogging and overflowing school drainage ditches	Alert	5 rapid whistle blows	Move all school records, lesson plans and materials to an elevated shelf.
2	Floodwaters beginning to enter classrooms	Prepare to evacuate	10 rapid whistle blows	Shut down all power sources. Move pupils to an elevated place.
3	Floodwaters reaching one foot high from the floor	Campus completely evacuated	15 rapid whistle blows	Evacuate to a safe location outside the campus. Bring priority items along.

Save the Children

Figure 8. Example of a contingency plan (Cabalquinto, 2015).

Contingency plans cover different range of risks, such as: environmental catastrophes, geopolitical instability, cyber-attacks, terrorism or supplier and partner instabilities.

3) Increase the stock level

Stock are the most traditional way of reducing risks regarding to raw material and suppliers. Inventory prevent the company against variations and uncertainty on the supply of raw material and assurance the production in shortage time. The company should look for a balance between too much stocks (with higher holding

costs, losses…) and to little stock, which enable disruptions in the production and increase the shortage cost. There is no correct number on how much stock should one company have. The amount varies in different fields and depend on how variable is the supply and how uncertainty is the demand.

Although many companies have reduced the level of stock to the minimum, this operation often bring risks to the chain and the companies usually do not visualize or calculate this risks. Therefore, higher stock lever or safety stock is an important tool and should be used more often (Waters, 2011, p. 162).

4) Add spare capacity

Spare capacity is when a company or industry has the factories, equipment and other form of resources to produce more than it usually produces. If one unexpected event take place it might be necessary to increase the production level. Relatively small amounts of added capacity can make a big difference in lead-time reduction. Therefore the spare capacity has a similar effect as the inventory and it helps the companies to face some variations on demands. This can be in a form of renting facilities or machines for at a short notice, subcontracting operations, adding some extra workers for a short time and many other approaches (Waters, 2011, p. 163-164).

5) Increase collaboration and visibility

The most effective way of creating a resilient supply chain is through collaboration, with partners closely working together and sharing information. It is very important this form of cooperation with the first and second tiers on the supply chain and the full transparency between these members. This actions enable the visibility on the supply chain and each member can have a clear view of what is happening on the supply chain. It prevents the organizations to be surprised if any unexpected event takes place, and enable the company to prepare itself by undertaking the ideal response.

Some of the methods for collaboration are:

- Collaborative forecast
- Collaborative operations planning
- Synchronizes material movement
- Shared resources

Connectivity and visibility can provide an optimization level on different activities and provide real cost reductions. Some direct benefits of collaboration and visibility are: improvements on warehouse and supplier performance, increase of data availability for taking decisions and many others (Strom et al., 2013, p. 9-10).

6) Increase agility on operations

It refers to the flexibility on the operations of a company and its capacity to adapt quickly and effectively to changing conditions. It includes, for example, to redefine plans or strategies, when the company face changes on the market, demand or supply volatility. Perhaps another alternative for holding stocks could be to improve its agility and enable the production and delivery of new goods with very short lead times.

There are many options for a company to increase its agility. Some of them are:

- Reduce the lead time
- Cross-trained employees
- Alternative and/or flexible suppliers
- Postponement
- Standardized materials (same raw material used for different products)

One example of a company that has shown great agility in its operations is the Apple Inc. In 2007, a little over a month before the iPhone was scheduled to appear in the worldwide stores, Steve Jobs decided that his prototype of the device was not ideal because of the excessive screeches on its screen. Within one month the company was able to redesign the product and manufacture it quickly and cost effectively while maintaining the highest quality. Apple was able to capitalize on its suppliers' flexible operations; in particular the contract

electronics manufacturer Foxconn, which was able to hire 3,000 people overnight when needed (Duhigg, 2012).

7) Vendor rating

The constant pressure for reducing the operation costs might have negative influences on the company's supplier evaluation. Many companies tend to pay attention almost exclusively on the price and forget to take in account other very important aspects, such as reliability and potential risks. Once one of the supply chain management trend is to reduce the supplier's number to the lowest possible level, it is very important that company evaluate carefully the supplier options and choose the ones with better risk-benefits. The effectiveness of the supplier is judged by its quality and reliability. The Figure 9 presents one of these evaluations possibility.

Alternatives	Criteria of evaluation								
	Cost			Quality			Delivery		
	Unity price	Transport costs	Cost reduction plan	Rejection level	Requests answered	QMS	Lead time	Time flexibility	Quantity flexibility
F01.M08	R$ 10.95	R$ 1.10	2.50%	7.60%	81%	48	5	70%	15%
F02.M08	R$ 7.70	R$ 1.85	2.13%	12.30%	88%	36	7	24%	58%
F03.M08	R$ 8.63	R$ 1.17	0.80%	8.70%	53%	47	18	68%	65%
F04.M08	R$ 7.19	R$ 1.43	2.47%	7.93%	92%	9	10	64%	61%
F05.M08	R$ 8.97	R$ 1.50	2.35%	8.15%	95%	44	8	73%	18%

Figure 9. Example of Vendor Rating (Schramm & Morais, 2012).

A strong and reliable supplier is one of the main keys for achieving resiliency in the supply chain. One of the most accepted methods is the checklist, which evaluate different aspects, such as: competitive pricing, image or company stability, reliability, punctuality on deliveries, collaboration interest and many others (Waters, 2011, p. 165).

8) Improve forecast and planning

Predict the demand efficiently and be able to plan the production is essential for any company. Very often companies are surprised by imprecisely demand and it might increase considerably the costs or minimize the profit. One way of achieving more accurate forecast is to use more refined quantitative forecasting methods and choosing for a short-term-forecast strategy. Two of the most accepted methods are the explanatory method and the time series.

This practice, combined with partner's collaboration and supply chain visibility, are the main key to reduce the risks and uncertainties regarding to: Raw Material price fluctuation and scarcity, currency fluctuations and market changes, some of the most relevant risks for the managers, as described on chapter 5 on this thesis (Strom et al., 2013, p. 9-12).

9) Dual or multiple sourcing strategy

The selection of the purchasing approach has great importance at a strategic level. Single sourcing is the supply chain global trend and can reduce apparent costs though high volume orders and might increase the collaborations between partners. This strategy is the best for stable environments, but in real scenarios can amplify a firm's exposure to risk.

As already presented in this thesis, the supply chain has became susceptible to many risks on the chain, which might cause disruption in the flow of materials or the planned operations. These disruptions can result in excessive downtime of production resources and important losses in the market value. Dual sourcing involves usually higher cost due the need for managing more than one supplier. The flexibility granted by dual or multiple sourcing is acquired at a ‘‘cost premium’’ and can be presented as an insurance cost or a risk expense.

Constantino and Pellegrino (2010) and Burke et. al (2006) have studied and compared the two different approaches, computational (simulation) and

mathematical respectively, and have concluded the superiority of dual source against single source on the long term analyze. The companies should evaluate different criteria's before choosing the single sourcing strategy, such as service price, supplier strength, supplier capacities, historical delays and the specific product inventory cost; or at least already prepare a preventive research with possible safety suppliers, even that those would cost more.

10) Insurance

Insurance was already mentioned on this thesis and has fundamental importance for risk management. It provides a powerful tool against very unlikely risks, but which could have a major impact on the supply chain. The main idea is to transform the high uncertainty loss (high variance) into an affordable fixed cost. This enable the normal flow of operations and reduce the variance, protecting the company against strong financial losses following a supply chain disruption. Companies can seek insurance for protection against: natural catastrophes, such as hurricanes, earthquakes, flooding or fire; or even against internal peril such as machinery breakdown (Dittmann , 2014, p. 7-8)

11) Rationalize product range

To reduce the number of products or invest more in the products that make the most profit. A company might reduce significantly its exposure to risky spots by rationalizing its product's range. It might be an easier and more profitable approach to focus on some core activities or less risky ones.

Risks can be very diversified, complex and from different sources. Although, supply chains also vary significantly in complexity and size, the actions taken by companies to prevent risky events can be very similar. This chapter illustrated and explain some of the best practices provided in the literature for achieving a resilience supply chain. The main idea is to support companies by its initial actions against different risks on SCRM (Waters, 2011, p. 167).

7 CONCLUSION

This final chapter presents the conclusions of this study. It has been a pleasure to work closely with this topic, which has grown a lot in the past two decades and has daily challenged companies to face risky environments.

The main objective of the thesis is to provide a material of easy understanding that support companies to face and handle these risks by answering these 3 original questions:

- Which are the main risk exposures on supply chain risk management?
- Which are the main steps and tools for supply chain risk management?
- What are the best practices for achieving a Resilience supply chain?

Although most of the supply chain executives acknowledges the importance of supply chain risk management, it is clear that most of the companies still have difficulties by facing these risks and taking the necessary actions. In other cases, managers might not feel motivated because of the lack of incentives for risk management.

This thesis started by reviewing the literature and introducing the main concepts of risk and supply chain in one simple and direct way. These are important as background-knowledge, once they are the basis of supply chain risk management.

After this first part of the research, the concept of supply chain risk management was presented on chapter 5. This chapter also presented the main risks in the supply chain, explained different tools for SCRM and the 4 main steps for handling these risks: risk identification, risk analyses, risk mitigation, and risk

control. This content can support companies to have a better understanding on the topic and to possibly get to know some different tools and approaches.

On the last part of this research, the main concept of resilience in supply chain and the most importance practices to improve the chain against different kinds of risks were presented: the 11 Best Practices.

There are many methods available for assessing the risk management in the supply chain and to create solid and resistant supply chain. As result, this thesis presents one easy-understanding review of the available literature regarding to supply chain risk management and one guideline with some of the best practices accepted within the literature in how to improve companies' supply chain resiliency. One possibility for further studies from this thesis is the analysis of the implementation of these 11 Best Practices within Finish companies.

I believe the results of this thesis are reliable, once I focused on well know researchers and big companies papers, who has proven expertise on this field and are able to present the topic applied in real business environment. I hope this thesis will support different companies by providing different ways and perspectives of handling risks in the supply chain.

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