

# **Evolutionary Supply Chain Risk Management: Transforming Culture for Sustainable Competitive Advantage**

by

**Romain Lévy**

Ingénieur Centralien  
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Submitted to the Engineering Systems Division  
in Partial Fulfillment of the Requirements for the Degrees of

**Master of Science in Technology and Policy**

and

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## **Abstract**

In today's fast-paced and turbulent global economy, the topic of risk management has gained significant interest in the business and academic world. However, in practice, risk management remains rather underdeveloped and often dealt with in an informal and reactive manner. To this end, we propose a comprehensive approach to supply chain risk management based on academic and business research and apply it to a company to develop a case study.

We survey the state-of-the-art of supply chain risk management by exploring both the qualitative and quantitative sides of risk management in this thesis. We study in detail the reasons why risk is often neglected in organizations, and learn from several conceptual frameworks that have been proposed in the literature. On the more quantitative side, we explore tools that have been used or could be used for supply chain risk management, such as Decision Analysis or Real Options.

We apply our proposed supply chain risk management framework to the case company, focusing primarily on qualitative methods. Data for the analysis is collected by way of semi-structured interviews with business executives and relevant company documents. The results are presented to shed light on the current risk management practices at the company by highlighting their strengths and potential weaknesses.

The research also draws from fields outside the normal realm of supply chain risk management. A policy perspective is taken to isolate important drivers of risk that lie beyond the direct control of organizations, such as political uncertainty and regulations. The objective is to promote a more proactive outlook in organizations to anticipate and exploit the uncertainty in the business environment. Similarly, a market perspective is used to articulate a novel way to uncover information asymmetry in the domain of risk management. Instead of simply pointing to asymmetry as an undesirable fact of business world, we propose two approaches that could be used for developing creative solutions, specifically, prediction markets and credit derivatives concepts.

In conclusion, we argue that evolutionary risk management processes accompanied by a radical shift in business risk culture are required to achieve competitive advantage through supply chain risk management.

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# Chapter 1. Introduction

External disruptions such as terrorism, natural disasters, and pandemics cause incalculable harm to supply chains on a regular basis. In fact, big and small disruptions of this nature are becoming increasingly frequent and more dangerous. But most of these events are beyond the control of an organization and more often than not, there is little that can be done to prevent them from happening. As a result, the typical options to deal with them include a thorough investigation before locating plants, building redundancy in the form of extra capacity and inventory, and purchasing insurance to minimize losses.

In addition to the external events mentioned above, however, there are other potential disruptions that are introduced by various long- and short-term decisions made by the organizations over time. For instance, the new business organization models, expanding global supply footprint, and lean manufacturing, have made organizations vulnerable to a wide array of forces in a variety of ways. These forces frequently cause long and short disruptions that adversely affect the profitability and competitiveness of an organization.

In consequence, the topic of risk has gained significant prominence in the business and academic world lately due to a spate of recent disruptions that tested their ability to cope with unwanted situations. These disruptions were caused by events that were natural as well as man-made, for example hurricane Katrina and the terrorist attack on 9/11. Shaken by these developments, businesses have started paying close attention to potential risks that threaten their operations. Indeed, in addition to being a matter of survival, businesses are now realizing that these events can also lead to new opportunities, if managed effectively.

## 1.1. Background

The supply chain is a particularly important function from the point of view of risk. Since the supply chain of a company spans the four walls of multiple tiers of its suppliers as well as the customers in addition to its own operations, it is constantly under the threat of an

imminent disruption. Given the current level of inter-connectivity that permeates global corporations, it is no surprise that the ripple effects of a distant seemingly unrelated disruption can hit any company in the gut in a very short period of time. Exacerbating the problem is the dynamic business environment of today, in which any misstep could spell disaster. In short, risk is a key driver of supply chains and as such, it should be considered an integral part of its design and management.

A comprehensive risk discussion is therefore critical for every organization, big or small. Given the high level of interaction between companies across the world, even a very small company that is serving a local market can witness disruptions triggered by unexpected geopolitical events. The breakneck pace of technological innovation accompanied by shrinking product lifecycles is exerting enormous pressure on the supply chains, making them more vulnerable to a wide variety of shocks. In short, the dynamic nature of the current business environment is reshaping the risk exposure of a company on a constant basis such that any problem can quickly morph into a major supply disruption with a significant impact on its performance.

The current trends in the marketplace are showing no signs of let-up and suggest that more competition, innovation and higher uncertainty will be the norm in the future. The confluence of these counteracting forces is likely to create paralyzing confusion in decision-making domain. For instance, an unhealthy fixation on capital rationing and lean operations to remain competitive could worsen the problems created by higher uncertainty. Treating surplus capacity, inventory buffers, or system redundancy as expensive solutions and hence unacceptable could prove disastrous for a company unprepared to handle disruptions effectively.

Traditionally, tackling the challenge of supply chain risk meant additional capital outlay for building redundancy in the system. For instance, typical risk reducing decisions advocate buffers of capacity, inventory, and/or time, each having a financial impact for every added protection. Our detailed review of the literature also supports this fact and indicates that there is a lack of formal theories for supply chain risk management that will lead to actionable solutions. In fact, while the importance of risk management is widely

recognized, few theories exist to tackle this issue in formal manner. In many ways, the ill-preparedness of businesses can be attributed to a lack of deeper understanding of the issues surrounding risk as well as an inadequacy of tools and techniques at their disposal to analyze the situation effectively.

Furthermore, over the past decade or so, the continued pressure to show better financial results has forced the supply chain management function to adopt optimization techniques to improve performance at a fast pace. Albeit useful for squeezing out every last drop of benefit from the assets, an undesirable effect of the cost optimization-driven philosophy is a lack of emphasis on risk. As a result, investments are not evaluated holistically to include the adverse impact of risk and to factor in the cost of risk avoidance, mitigation, and resilience. In addition, there are no clear answers or magic formulae to help decision makers develop potent strategies for supply chain risk management. In the end, the costs associated with putting risk management practices into action are very clear and immediate, but the potential benefits are perceived as nebulous and often dismissed as remote, unclear, and hard to quantify.

Of late, there has been an increasing awareness of supply chain risk amongst decision-makers, especially since the 9/11 terrorist act and hurricane Katrina. But despite this heightened awareness there is a great deal of confusion about how to deal with such risks. In fact, it can be argued that these events have made us acutely aware of our limited knowledge in this domain and an absence of formal approaches to deal with risk.

In summary, businesses seem to be quite aware of the increasing uncertainty in the market and cognizant of the adverse impact of risk on their performance. But, the lack of formal ways to deal with this problem is paralyzing the decision makers, reiterating the need for an objective way to compare the investments in risk management with its long-term benefits.

## 1.2. Motivation

The challenge of managing risk essentially translates into the eternal tug-of-war between short-term and long-term benefits in the decision-making domain. It can be argued that

risk management should be an integral part of every company's DNA since a business is considered a perpetual entity when it is launched. Ironically, the very rules of the market in which businesses exist forces them to sacrifice the central goal of perpetuity in favor of meeting quarterly targets. It is not a surprise, therefore, that the average life expectancy of a "Fortune 500" firm is only 40 to 50 years, and a third of the 1970 "Fortune 500" companies had vanished by 1983. At the same time there are companies that are over 200 years old, a chosen few that have managed to survive for a few centuries.<sup>1</sup> What makes some companies resilient for hundreds of years while others disappear after the first few hard blows is indeed a very puzzling question.

To be sure, the immediacy of the market pressure will never allow organizations to take a breather and promote a holistic approach to plan for the future. In other words, the problem of supply chain risk management will not be addressed by myopic actions; instead it must be addressed in an objective and formal manner. It will require a judicious approach to balance the dynamic equation of brand and financial coverage with the cost of such protection.

Indeed, the awareness of risk often triggers excessively risk-averse reactions, which is also unfortunate and undesired. It is understandable to find that decision-makers sometimes try to reduce all risks at all costs without seeking a better and clearer understanding of risk. We truly believe that uncertainty and risk are at the heart of a healthy market and a successful business, because a level of risk is often tied to a certain reward. By choosing to compete in a certain manner, companies encounter different levels of risk and establish unique competitive advantages. So, instead of systematically eliminating risk, and consequently the rewards associated with them, a company should first try to gain a better understanding of their strategies for risk exposure. Only after a close scrutiny should a company pursue a particular strategy that is found to be consistent with the risk appetite of its various stakeholders. The framework that we propose and the subsequent analysis are aligned with this belief.

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<sup>1</sup> Arie de Geus, *The Living Company*

### 1.3. Problem Statement

As argued above, the market environment has become increasingly complex and competitive over the last decade or so. Outsourcing and offshoring lead to a loss of both visibility and control over the risks that can affect the company's ability to supply its products and services. An initial question is therefore: *How can we formally and holistically address the challenge of risk in the global supply chain context?*

Many companies have already started doing some sort of risk management, but this is most often an extension of existing practices rather than the required paradigm shift. Risk management practices too often take the form of infrequent and punctuated static evaluations. Consequently, the overarching research question guiding this research is: *How can organizations transform their very culture to achieve a sustainable competitive advantage through a continuous and evolutionary supply chain risk management process?*

### 1.4. Research Approach

First, an extensive review of the available academic and business literature on supply chain risk management was performed. This highlighted the areas of greatest interest, as well as some gaps in the literature. Additionally, it underlined that a distinction need be made between qualitative and quantitative approaches to risk management. On the qualitative side, we explored the state-of-the-art of supply chain risk management: we studied the reasons why risk is often neglected in an organization, and learned from several conceptual frameworks that have been proposed in the literature. On the quantitative side, we explored some tools that have been used or could be used for supply chain risk management, such as decision analysis and real options.

In addition, two separate exploratory studies were performed, looking at risk management from different contexts: a policy approach and a market approach.

To validate our learning and complement the research, we worked with a large Consumer Packaged Goods company as a case study for the project. The case study focused primarily on the qualitative approach. Semi-structured interviews were conducted, transcribed and

analyzed. Some internal documents were reviewed to supplement the interviews and several follow-up interviews with senior management were also conducted to clarify and enhance our understanding.

The analysis and comparison of the interviews with the knowledge of the state-of-the-art allowed us to objectively evaluate the current risk management practices at the CPG company and highlight areas of strength as well as those where improvement can be driven.

Finally, we used all the available information to carry out a structural analysis of the problem and focus the learning from this research to offer a detailed qualitative analysis of the barriers and the enablers of effective risk management.

## 1.5. Thesis Outline

First, an extensive review of the available academic and business literature on supply chain risk management was performed, and some selected articles are presented in Chapter 2. Chapter 3 and Chapter 4 present mind-opening approaches to risk management using, respectively, a policy and a market approach. Chapter 5 looks deeper at some state-of-the-art risk management frameworks after analyzing further reasons why organizations are often ineffective at dealing with risks. In section 5.3, we present some tools and methods for risk management. Section 5.4 contains the risk management framework that was developed for our case study based on the state-of-the-art. We performed a dozen semi-structured interviews of supply chain executives at this company and gathered documents to evaluate the current risk management practice at this organization. The result of the interviews and document analysis to evaluate the current risk management practice in the CPG company is presented in Chapter 6. Finally, a qualitative analysis, results and the resulting recommendations are presented in Chapter 7.

## Chapter 2. Literature Review

We undertook a detailed review of extant literature including academic and business articles, and books on the topic of supply chain risk management to gain a better understanding of the issues and challenges involved. An immediate revelation was the recognition that supply chains require better risk management practices. Although considered critical, the literature also highlighted a lack of measures by companies in terms of taking actions to secure their operations against risk. The authors went on to explain why so few organizations have actually followed formal risk management practices. On the solution side, various authors provided broad conceptual frameworks for approaching risk.

While recognition of risk and considering broad frameworks represents a necessary first step towards a more resilient supply chains, very few authors presented actionable ideas or quantitative tools to help enhance an organization's supply chain risk management practice. We strongly believe that it is not enough to be aware of risk and profile risk to become resilient: additional analysis using a variety of qualitative and quantitative tools is essential. An efficient risk management practice in today's fast-paced environment requires a comprehensive portfolio of well-defined objective actions. Indeed, following an objective assessment path will also enable a deeper appreciation of the drivers and reasons that influence decision makers in dealing with risk.

Therefore, we will present a review of valuable articles in two categories; first, the qualitative documents on risk management and the reasons for the lack thereof in organizations; and second, more quantitative documents that present tools and methods which might be applied to supply chain risk management.

A more detailed discussion will be presented as required throughout the rest of the thesis using these documents as well as additional ones.



## 2.1. Qualitative risk management methodologies

In *Predictable surprises: the disasters you should have seen coming, and how to prevent them*, Max H. Bazerman and Michael D. Watkins<sup>2</sup> argue that most events that catch us by surprise are both predictable and preventable, but we consistently miss or ignore the warning signs. Building on this argument, they explore many similar ideas to the ones developed in this thesis. They highlight the multiple reasons for the lack of event recognition, and propose a proactive methodology to detect those incoming disasters.

In *Enterprise Risk Management: An emerging model for building shareholder value*, the consultancy KPMG<sup>3</sup> develops on the recent topic of Enterprise Risk Management, advocating for a holistic and objective approach to risk management like this thesis does.

In *The effect of supply chain glitches on shareholder wealth*, Kevin B. Hendricks and Vinod R. Singhal<sup>4</sup> make a strong case using market data analysis for the importance of supply chain risk management. Based on a sample of 519 glitches announcements made during 1989–2000, shareholder wealth affects are estimated by computing the abnormal stock returns around the date when information about glitches is publicly announced.

In *Ericsson's proactive supply chain risk management approach after a serious sub-supplier accident*, Andreas Norrman and Ulf Jansson<sup>5</sup> describe how Ericsson, after a relatively minor fire at a secondary supplier, with a disproportionately huge impact on Ericsson, has implemented a new organizational structure, and new processes and tools for supply chain risk management. It advocates a role for insurance companies in a new approach to supply chain risk management. It discusses risk as related to traditional logistics concepts (time, cost, quality, agility and leanness) by arguing that supply chain risks should also be put into

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<sup>2</sup> Bazerman, Watkins, 2004

<sup>3</sup> KPMG, 2001

<sup>4</sup> Hendricks, Singhal, 2003

<sup>5</sup> Norrman, Jansson, 2004

the trade-off analysis when evaluating new logistics solutions – not with the purpose to minimize risks, however, but to find the efficient level of risk and prevention

In *The resilient enterprise*, Yossi Sheffi<sup>6</sup> shows using multiple real-world example how companies can build in flexibility throughout their supply chains, based on proven design principles and the right culture – balancing security, redundancy, and short-term profits. Furthermore, he shows how investments in resilience and flexibility not only reduce risk but also create a competitive advantage in the increasingly volatile marketplace

## 2.2. Quantitative tools and methods

In *Making Hard Decisions*, Robert T. Clemen<sup>7</sup> teaches the fundamental ideas of decision analysis and their applications in the real corporate world.

In *Real Options in practice*, Marion A. Brach<sup>8</sup> explores real option theory applied in practice and describes the challenges of implementing a real option framework in practice within a corporate setting. She identifies the classic types of real options-deferral, abandonment, switching, expansion, and compound-and explores the main concepts critical to understanding real option theory.

Richard de Neufville, Stephan Scholtes and Tao Wang's article *Valuing Options by Spreadsheet: Parking Garage Case Example*<sup>9</sup> provide an invaluable, simple yet effective example to real options utilization that is used throughout this thesis to describe the concept of real options.

In *Risk management in supply chain: a real option approach*, Cucchiella and Gastaldi<sup>10</sup> offer examples of using the real options theory to cover one or more risks in the supply chain. It

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<sup>6</sup> Sheffi, 2005

<sup>7</sup> Clemen, 1996

<sup>8</sup> Brach, 2003

<sup>9</sup> de Neufville, Scholtes, Wang, 2006

<sup>10</sup> Cucchiella, Gastaldi, 2006

can be argued that the Real Options approach can be used to evaluate supply chain risk management investment since it allows us to quantify complex decision alternatives under conditions of high uncertainty. Being derived from the options theory in finance, an industry that quantifies risk on a daily basis, the underpinnings of Real Options are well founded in theory and practice alike.

Cuchiella and Gastaldi identify the potential supply chain risks as studied in the literature, as shown in Table 1. Similarly, Table 2 provides an overview of different common real options strategies. Finally, the authors match the potential supply chain risks with the appropriate strategies; these are given in Table 3.

Type of risk	Definition	References
Accounting risk measures	Accounting ratios related to risk of ruin, default or bankruptcy	Baird and Thomas (1990)
Asset impairment risk	Reduces utilisation of an asset and can arise when the ability of the asset to generate income is reduced	Simons (1999)
Buy type	Perceived risk differs if it is considered a new buy, modified rebuy, or straight rebuy	Mitchell (1995)
Buyer demographics	The effects of factors such as age, professional organization membership, education, and job experience on risk perceptions	Mitchell (1995)
Buyer's personality	Intrinsic motivational factors exist, such as the need for certainty, self-confidence, and the need to achieve, which affect individual risk perceptions	Mitchell (1995)
Characteristics of customer/supplier interaction	The propensity to innovate, stability of the market structure, and growth rate affects risk perceptions	Mitchell (1995)
Company size	The occurrence of performance risk is much higher among buyers in small companies	Mitchell (1995)
Competitive risk	Affects a firm's ability to differentiate its products/services from its competitors	Simons (1999)
Country	Country of origin of buyer affects an individual's risk preference	Mitchell (1995)
Customer risk	Affects likelihood of customers placing orders, grouped with factors such as product obsolescence in "product market risk"	Meulbrook (2000)
Decision-making unit	The greater the risk involved, the greater the propensity to group, buy and share the risk involved	Mitchell (1995)
Degree of customer/supplier interaction	The extent of communication or state of the relationship between a buyer and supplier influences the degree of perceived risk	Mitchell (1995)
Downside risk	Risk being associated with negative outcome	Shapira (1995)
Financial risk	Exposes a firm to potential loss through changes in financial markets: can also occur when specific debtors defaults	Meulbrook (2000)
Fiscal risk	Arises through changes in taxation	Meulbrook (2000)
Job function	Risk perceptions differ according to the job and position of the buyer	Mitchell (1995)
Legal risk	Exposes the firm to litigation with action arising from customers, suppliers, shareholders or employees	Meulbrook (2000)
Market risk	The use of the capital asset pricing model to measure risk	Baird and Thomas (1990)
Operations risk	Affect a firm's internal ability to produce and supply goods and services	Meulbrook (2000) and Simons (1999)
Organizational performance	Risk taking is affected by the relationship between the company's current position and some critical reference points	Mitchell (1995)
Product characteristics	Technical complexity and value of the item are positively correlated with the degree of perceived risk	Mitchell (1995)
Regulatory risk	Exposes the firm with changes in regulations affecting the firm's business, such environmental regulation	Meulbrook (2000), Bowen <i>et al.</i> (1998) and Smallman (1996)
Reputation risk	Erodes value of whole business due to loss of confidence	Schwartz and Gibb (1999)
Risk as a multi-faceted construct	Risk cannot be captured with a single number, since multiple facets such as financial, technical, marketing, production and other risk aspect exist	Shapira (1995)
Risk as disaster	Strategies that could result in corporate disaster, bankruptcy or ruin	Baird and Thomas (1990)
Risk as entrepreneurship	Independence of action in venturing into the unknown	Baird and Thomas (1990)
Risk as innovation	Risk conditions equated with conditions characterized by newness, uncertainty, and lack of information	Baird and Thomas (1990)
Risk as lack of information	Information scarcity as a key facet of uncertainty in terms of the existence of important resources and commitment duration	Baird and Thomas (1990)
Strategic risk	Affect business strategy implementation	Simons (1999)
Supply risk	Adversely affects inward flow of any type of resource to enable operations to take place	Harland <i>et al.</i> (2001)
Supply risk	The transpiration of significant and/or disappointing failures with inbound goods and services	Zsidisin <i>et al.</i> (2000)
Supply risks	Adversely affects inward flow of any type of resource to enable operations to take place, also termed "input risk"	Meulbrook (2000) and Smallman (1996)
Variability returns risk	Firm performance evaluated in terms of return and growth criteria	Baird and Thomas (1990)
Variance risk	Variability of the probability distribution of returns	Baird and Thomas (1990)

Source: Cucchiella, Gastaldi (2006)

**Table 1 – Risk characteristics, definitions and references**

Description	References
<p>Defer: option to defer enables management to defer investment and benefit from more information. The management, with this kind of option, can wait <math>x</math> years to see if output prices justify constructing a building or a plant or developing a field</p>	<p>Ingersoll and Ross (1992), Trigeorgis (1996) and Benaroch and Kauffman (2000)</p>
<p>Time or stage (stop-resume): when an investment can be seen as a series of outlays, the stage option creates the opportunity to abandon the project in midstream if new information are unfavourable. Each stage can be viewed as an option on the value of subsequent stages and valued as compound option</p>	<p>Brennan and Swartz (1985), Trigeorgis and Mason (1987) and Pindyck (1988)</p>
<p>Explore (pilot/prototype): through an explore option is possible to realize a project on prototype scale. Both the costs that the payoff the prototype is proportional to those of the project realized on real scale. Observed the prototype results and on the base of the consequent results the management will decide if reply the project on real scale</p>	<p>Clemons and Weber (1990), Kulatilaka <i>et al.</i> (1999)</p>
<p>Lease: with this kind of option it is possible leasing or renting a property with an option to buy it at a future date. The future price of the property should be fixed at the time the lease-option is signed. Usually there is an up-front payment of some amount to purchase the option. The amount can vary. Sometimes the monthly payment is larger than normal and the excess is used to purchase the option</p>	<p>Clemons and Weber (1990)</p>
<p>Outsource: the resource required for the investments realization can be leased to external actors, in such way it is possible to transfer the risk of emergency costs or the costs due to an incapability to realize the investment in-house. Some times such option is connected to the stage option, in such way it is possible to avoid a penalty that would be imposed in the case of breakdown of the contract during the phase of realization</p>	<p>Richmond and Seidmann (1993)</p>
<p>Alter operating state: if market conditions are more favourable than expected, the firm can expand the scale of production or accelerate resource utilization. Conversely, if conditions are less favourable than expected, it can reduce the scale of operations. In extreme cases, production may be halted and restarted</p>	<p>Copeland <i>et al.</i> (1995), Trigeorgis (1996) and Kulatilaka <i>et al.</i> (1999)</p>

(continued)

Description	References
<p>Abandon (switch use): if market conditions decline severely, management can abandon current operations permanently and realize the resale value of capital equipment: it is an American put option on the project's current value with an exercise price of salvage value</p>	<p>Copeland <i>et al.</i> (1995), Trigeorgis (1996) and Hakan and Vandergraaf (1999)</p>
<p>Growth: an early investment (e.g. R&amp;D, lease on undeveloped land or oil reserves, strategic acquisition, information network) is a prerequisite or a link in a chain of interrelated projects, opening up future growth opportunities (e.g. new product or process, oil reserves, access to new market, strengthening of core capabilities)</p>	<p>Trigeorgis (1996), Zhu (1999) and Taudes <i>et al.</i> (2000)</p>
<p>Compound: real-life projects often involve a collection of various options. Upward-potential-enhancing and downward protection options are present in combination. Their combined value may differ from the sum of their separate values; i.e. they interact. They may also interact with financial flexibility options</p>	<p>Zhu (1999)</p>

Source: Cucchiella, Gastaldi (2006)

**Table 2 – Real Option strategies for Supply Chain Risk Management**

Uncertainty sources	The principals risks resulting from the selected uncertainty source	Real option types								
		Defer	Stage	Explore	Lease	Outsource	Scale down	Scale up	Abandon switch	Strategic grow
<i>Internal sources</i>										
Available capacity	Financial capacity: the project is not realizable of the excessive financial exposure	X		X	X	X				
	Production capacity: the project is too much great or complex		X	X	X	X				
	Structural capacity: the network does not have the necessary infrastructures		X	X			X		X	
Customs regulations	Development from the consumers of a own product	X		X			X		X	
	Not usability of product without right regulation		X	X	X	X			X	
Information delays	Lack of information necessary for the right definition of product characteristics		X	X	X	X			X	
	Lack of information necessary for the definition of the right moment of product emission on the market	X		X		X			X	
Internal organization	Not cooperation among the actors	X	X	X					X	
	Low ability to adopt the new technologies		X	X			X		X	
<i>External sources</i>										
Competitor action	Competitor actions can delete the achieved advantage	X	X	X	X		X		X	
	Detention from competitors of a competitive advantage	X		X						
Manufacturing yield	Low consumer demand of products	X	X	X	X		X		X	
	Consumer demand of products superior than forecast	X		X				X		
Political environment	An excessive demand of the consumer could make the mature product	X		X	X	X	X	X	X	
	Not forecast of the possible actions of the vigilance authority	X			X				X	X
	Changes in the reference context can modify the type of demand products			X					X	X
Price fluctuations	Not coverage of the costs sustained by the network due to product price fluctuations	X	X	X	X	X	X		X	
Stochastic cost	A new technology on the market could make obsolete the product	X			X				X	
Supplier quality	Not availability of specific skills required to the suppliers	X	X	X	X	X				

Source: Cucchiella, Gastaldi (2006)

**Table 3 – Appropriate Real Options strategies and Supply Chain risks**

# Chapter 3. A Policy approach to Supply Chain Risk Management

In this chapter, we present a policy-oriented view of supply chain risk management, focusing on the issue of trust in the supply chain. The case in point is the wave of recalls of products originating from China during Summer 2007. We show how information asymmetry can lead to market and institutional failures, and propose policy solutions to the problem.

## 3.1. Background: A Recall Frenzy

In the Summer of 2007, the headlines were filled with news about blatantly dangerous products that are reaching American shelves and households undetected. After the mainstream media coverage faded out, special interest groups kept the attention focused on the recall of imported products. Whether it originated from the brands themselves, from regulators or from the media's action, products continue to be recalled, tainting the name of involved firms and countries of origin. Interestingly, brands have promptly learned to recall products themselves when there is reasonable doubt about their safety, rather than trying to hide reality. Failure to recall tainted products and hiding of information could most certainly lead to disproportionate consumer boycott of the brand and potentially expensive lawsuits that may bring a firm to its knees.

More importantly, the recent recalls have hit a wide spectrum of companies: from brandless and relatively unknown companies to powerful, trusted and reputable brands. The products that undergo these recalls are often those that should be receiving the most scrutiny, such as healthcare and kids' toys, because they are used by the most vulnerable segments of the population.

Healthcare products such as cough syrup, in Panama (June 2007) or toothpaste in the United States (June 2007) were contaminated by diethylene glycol (DEG). DEG is a poisonous industrial solvent that was used as a cheap substitute for glycerin by



unscrupulous manufacturers, and products remained untested throughout numerous intermediaries, unsuspecting of forged certificates of authenticity. Food was also affected, for example the FDA banned all seafood from China in June 2007, fearing contamination. Mattel recalled millions of kids' toys during the Summer 2007 because they contained toxic lead paint or dangerous loose parts. The consequence of mislabeling and misrepresentation was the loss of human life: the DEG cough syrup in Panama caused the death of between 100 and 300 people.<sup>11</sup>

In response to these crises and other manufacturing mishaps, some companies are planning to relocate their plants out of China or find new suppliers to reduce their exposure to this high-impact risk, although it was previously perceived as low-probability. American consumers groups are pushing for products "Made in USA" and the most extreme of those even called for a boycott for Chinese-made products. A total of 75.8% of 1,000 people surveyed said they would not buy Chinese-made toys. A similar poll found that 16% were buying no Chinese-made goods at all and 23 percent would not buy food or toothpaste from China.<sup>12</sup> While the actual consumer response is unlikely to reach such levels, survey figures highlight consumers' awareness and fears on this issue. Businesses are already picking up on this new development and carving out a new niche, adapting their supply chains with the hope to achieve a competitive advantage through supply chain risk management.

This example shows how there is a high likelihood of mishaps when two very different approaches to the concept of market economy work together. Because of this crisis, global trade has inevitably been reduced. The possible counteracting measures (border controls, additional quality assurance) may lead to further reductions in efficiency. These are key symptoms of a market imperfection.

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<sup>11</sup> Investigation article by the New York Times, May 6th, 2007, "From China to Panama, a Trail of Poisoned Medicine."

<sup>12</sup> Reuters, October 22<sup>nd</sup>, 2007, "China boycott means no action figures"

Meanwhile, it is also a striking example of the power of markets. Thanks to consumer and media attention, the market is playing its balancing role. Products “Made in USA” are sometimes privileged, and companies are bringing home part of their production, or at least being more attentive to the quality of products coming from abroad.

## 3.2. Shared Responsibilities

Numerous stakeholders have had – or could have had – a role to play in the China–USA product safety crisis, and were severely criticized for their share of responsibility in the crisis.

- The Chinese government has still to put in place the legal framework that properly deters business dishonesty.
- Chinese regulatory bodies (and in particular its national equivalent of the Food and Drug Administration) have been criticized for their virtual nonexistence at worst, and for their corrupt officials at best. Right after the wave of recalls that shook up China, the Chinese FDA chief was executed after he was found to have abused his powers to obtain bribes from drug companies. Under pressure, the government pushed for a prompt and unusually harsh sentence in a move to rebuild the country’s business image<sup>13</sup>. The execution was meant to show the world, in very blunt terms, the Chinese government’s seriousness about improving product safety, and to create internal deterrence against dishonesty. However, the method used also sends a mixed message to the world: it shows the government’s lack of control over its top officials, and a propensity to overreact; characteristics that may not reassure businesses.
- Chinese manufacturers have been criticized for their lack of responsibility, accountability, transparency and their focus on short-term goals, boosted by the absence of brand equity to protect.

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<sup>13</sup> Reuters, July 10th, 2007, retrieved from <http://www.reuters.com/article/worldNews/idUSPEK2206820070710>

- American firms have been criticized for failing to “do their homework” to ensure product traceability and to check for product safety. They were said to rely unreasonably on untrustworthy intermediaries. They were also said to be somewhat greedy in overly pressing for cost reduction, therefore pushing unscrupulous manufacturers to cut on quality or safety.
- American regulatory bodies have been criticized for also failing to check for product safety upon entrance on the territory
- Finally, the American government has been criticized for “disdaining” and cutting in personnel and budget the regulatory system (FDA in particular), at a time when it was most needed.

### 3.3. “The Outsourcing Trap”

Trust between business partners has always been critical for the relationship to be successful and efficient, yet it is often a forgotten aspect in supply chain risk management. The increased vertical disintegration<sup>14</sup> of companies that we have witnessed in many industries has added to the complexity of the challenge, and made the trust issue even more central to businesses. One rationale for vertical disintegration is that firms can achieve better results when focusing on their core competencies, and letting others focus on their less critical capabilities. Businesses leverage a healthy competition for their procurement, allowing most of the time a better economic efficiency and fostered innovation. It is not uncommon for intermediate inputs to be procured in “modules” from a

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<sup>14</sup> This vertical disintegration is very marked in some industries (e.g. the automotive industry). However, in some regulatory regimes or cultures that foster the creation of large consortiums (South Korea, Japan...), this effect is not as clear.

variety of global suppliers<sup>15</sup>, or even for the final product to be procured directly, if marketing or distribution is considered to be the firm's core competency.<sup>16</sup>

However, the additional economic efficiency of these new models cannot be fully achieved if, for example, all procured items need to be retested for quality assurance upon delivery. Because of outsourcing mistakes, precipitation or exaggeration, some firms have been prone to what is sometimes known as the "outsourcing trap."<sup>17</sup> This is another example of how an extreme focus on cost has led to forgetting supply chain risk management. If those firms abandon parts of their business that were more critical than they expected, they may disconnect from some of the realities in the market. Some companies end up losing the critical technical competencies that foster their capacity to innovate in the long term: an outsourced supplier may not have the same incentive to invest in innovation as an integrated company. An overly outsourced company is also more sensitive to disruptions in supply: the company may not have as much early warning before a disruption, and it will have less control over the recovery process.

Yet, many businesses have found innovative solutions to enjoy the benefits of a less integrated firm while recreating the advantages that an in-house supplier brings, an excellent example of the evolutionary nature of supply chain risk management. Such solutions include the creation of partnerships with suppliers that go far beyond a traditional business relationship: information sharing, employee, process or capability exchanges, quality agreements, or a close but efficient monitoring of business processes and financial health. Toyota is well known for being a long-term leader in supplier relationship management. For example, in 1997, a sole-source supplier of a \$5 valve went offline because of a major fire, while Toyota only held a 4-hour inventory of those parts.

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<sup>15</sup> Dell is a champion in this model: Dell computers are "made in USA" but this is in fact a 3 minutes and 30 seconds assembly process from mostly Asian parts.

<sup>16</sup> Apple illustrates this point with verve: all computers are made in Southeast Asia from the strict Apple design, and shipped by air as finished products. Apple core competencies are centered around design and marketing.

<sup>17</sup> Sheffi, Fine (forthcoming book)

Toyota's production was still able to recover in just a few days, from a situation where other companies have suffered a hard blow for several weeks or months. It worked hand in hand with this supplier, and other suppliers that were able to manufacture this part also offered their capacity to minimize the delay on Toyota's production<sup>18</sup>.

### **3.4. The Offshoring Trap**

Globalization takes the issue of trust in the supply chain to a totally new dimension. The improvement in transportation and most importantly in information technologies has created extremely exciting opportunities for competitive advantage that have almost triggered a "gold rush" from Western businesses, but also played a great role in the development of countries. Outsourcing in a globalized world means that suppliers are not necessarily next door, but they may be at the other end of the world, and companies may never have met some their suppliers or even know who they are, because a supply contract has been signed through several intermediaries.

It is not solely distance that creates the new challenges that arise when supply partners are abroad, but also differences in regulations, in cultures, and in level of development of the countries.

### **3.5. Information Asymmetries in the Supply Chain and the Market for Lemons**

The main source of market failures here are the information asymmetries between business partners. In the cough syrup crisis that was deeply investigated by the New York Times, the representation of the product that was made by the Chinese manufacturer was not trustworthy. The corruption and ineffectiveness of local officials made it possible to label DEG as "glycerin" without any further control. The additional intermediaries though

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<sup>18</sup> Wall Street Journal, May 8th, 1997, "Toyota Motor Shows Its Mettle After Fire Destroys Parts Plant"

which the product transited did not bother testing for the product and believed the description from the Chinese manufacturer. The DEG was used in Panama as glycerin to manufacture cough syrup, which ultimately led to the death of several hundred people.

This example explains why the information that is received by a firm about the products sourced from China has little value. It comes down to the classic definition of information asymmetry: one party in the transaction has relevant information while the other does not. This, in our case, empowers the seller and can ultimately lead to destructive consequences as outcome of the transaction. The problem becomes even more complex when it involves several intermediaries, because the ultimate buyer may think that the intermediary is trustworthy, but it is only a relocation of the problem: at one point in the chain there was a significant information asymmetry between the seller and the buyer.

A consequence of this information asymmetry is similar to what is described in “The Market for Lemons” by George Akerlof<sup>19</sup>: there is an adverse selection of the goods that are manufactured in China and sold abroad. Because buyers are aware of the information asymmetry, they take the quality of the goods to be uncertain, and only consider the average quality of goods in deciding what price to pay. Therefore, the sellers with the lowest quality will make more profit, so that the overall quality of the goods eventually decreases over time. Akerlof<sup>20</sup> underlines in his 1970 paper the higher risk of encountering a market for lemons in developing countries, mainly because of the lack of public quality assurance (accountability by brand equity or by regulation, as mentioned earlier). Because of the strong pressure on costs that is imposed by buyers, there is, what we call, a “game theory” incentive to cheat and pass off a low quality product as a higher one.

To illustrate this idea, let us assume that a Chinese manufacturer has the choice between “cheating” and “honesty”, and that cheating is cheaper than being honest. On the one hand, if he chooses to be honest, then any “cheater” in the market will be able to have lower prices and will win the supply contract. So the honest manufacturer will lose in the short

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<sup>19</sup> Akerlof, 1970

<sup>20</sup> Akerlof, 1970

term, and will not even have to worry about the long term since he has no contracts. On the other hand, if he chooses to cheat, then he will earn contracts and therefore yield short-term gain. When looking in the long-term, there is a potential for high losses if discovered, but it is offset, on the one hand, by the lack of accountability, which decreases the chance of discovery, and on the other hand, by the human mind's inclination towards short-term thinking (over discounting the future).

The individually rational selection leads to a collectively suboptimal outcome: China and its manufacturers are suffering from a decline in reputation, which eventually reduces trade and incoming wealth in the country.

The key in overcoming this market for lemons is in making sure that there are clearly defined, well communicated disincentives so that the long-term losses of cheating are perceived as strong enough to offset the short-term gains derived from cheating. The following explores solutions against this market failure and the potential institutional failures that may arise from implementing these.

The institutional solution that was hastily adopted by the Chinese government following the negative impact on the country's image was to direct unusually harsh prison sentences against corrupt officials, and to execute the former chief of the Chinese FDA equivalent. As much as these measures set an example and may discourage some future violations, they pose ethical issues. They remind more of ancestral practices of public executions than of modern business and government rules. They also highlight the limits of the Chinese government: a government that uses terror to govern shows that it lacks the control needed in a legally constituted state. Furthermore, this solution is prone to its own institutional failure: as the government tries to punish the cheating officials, some actors could falsely denounce as corrupt some officials that bother them (in particular the honest ones), so that they would be removed from their current duties.

A simple, short term and relatively inexpensive solution fostered by many US consumer groups is to strengthen the testing requirements for quality and security on American soil. These can be made at the regulatory level (FDA) or directly by US companies. This will certainly reduce the risks that a new food or drug scare arises, but will not solve the market

failure at its roots: this will lead to a reduction in the overall market efficiency and increase the lead time in the supply chain, and ultimately increase the price of the product.

Another solution to adverse selection issues is Coasian bribes. A Chinese manufacturer can be “bribed” against the incentive to cheat, so that it offsets the potential gain of cheating. The bribe can come from his American client, or even from the US government. As potentially dangerous goods get exported, the public health externalities extend outside of China, giving the US government an indirect incentive to “invest” in Chinese product safety, through the Chinese government or directly to manufacturers. A potential caveat from this solution is that the incentive to cheat remains, even under the bribe, until a proper regulatory structure is in place.

### 3.6. Coordination Problems and Regulatory Harmonization

A further major source of market failure in our specific issue is the coordination problems and the lack of regulatory harmonization between both countries. “The Market for Lemons” presented by Akerlof<sup>21</sup> are mostly markets that are internal to a regulatory regime, so international coordination represents an additional difficulty that comes on top of information asymmetry and makes matters even worse.

It can be argued that China has been (purposefully or not) competing on laxity. Such a competition results in significantly low quality standards that are below the overall social optimum because of the health or environmental externalities. With improvements in transportation and information exchange, and its borders opening to ‘free’ trade, China is virtually closer to the developed world. Western firms have been attracted to lowest cost sites, and sometimes less stringent regulations, and continuously transferred their production overseas. China managed to attract a lot of capital and businesses, which led to the economic boom we know, with its double-digit growth.

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<sup>21</sup> Akerlof, 1970



To some extent, the sources of market failure participated to the economic development, which can be considered a good thing on both the Chinese and the international level. It can be argued that temporary market failures could be acceptable, when they ensure a better long-term outcome and are limited in their impact. But now that China plays such a big role in the international economy (and joined the WTO) it will have to play by the rules of international trade. Such rules aim at increasing the trust among international business partners by ensuring that a single contract is respected in the same way in different countries. Ultimately, if an American business can trust what is procured from the Chinese supplier as glycerin is indeed glycerin, because the laws are sufficiently harmonized for a contract to have the same value in both countries, then the source of the market failure has been removed.

The Chinese government has an incentive to fix this problem if it wants to sustain its gain in importance on the world economic scene, and to avoid backfire from its fast growth. Recent articles suggest that the Chinese government has understood the criticality of trust on the international trade scene, and the long-term interest that China has in not being a rogue market player: the Commerce Ministry has said that it blacklisted 429 Chinese exporters for violating trade rules. In August 2007, “officials pledged to spend more than \$1 billion to improve food and drug safety by 2010, and to give regulators stronger oversight powers.” Later in October 2007, the rules for drugs manufacturers were tightened.<sup>22,23</sup> While there should be some caution on whether those reassuring statements from Chinese public officials will actually lead to action, those issues are so blatantly important for the future of China’s place in the global economy that it would be damaging if Chinese officials did any less than what they promised.

The solution to coordination problems lies in a better regulatory standardization, which entails a strong partnership between countries and a will to work together for better consumer product safety and overall social welfare. However, firms in both countries suffer

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<sup>22</sup> Reuters, August 17<sup>th</sup>, 2007, “Factbox: China’s recent steps to quell product safety fears”

<sup>23</sup> Reuters, October 29<sup>th</sup>, 2007, “China tightens rules for drug manufacturers”

from a collective action dilemma: following Olson’s “Logic of Collective Action,”<sup>24</sup> even though the public benefits would be high, the private costs of organizing such regulation deter businesses from pushing for action in that direction (which would likely benefit their competitors as well). They can find short-term solutions at their level that are less expensive and easier and faster to implement, such as tight quality controls, or a switch in production sites. Therefore, implementing a regulatory standardization should be done at a government level. Regulatory bodies such as the FDA or its Chinese equivalent should then be working together to reduce the losses in the international trade process. The Chinese regulatory bodies are certainly not the only ones that need some reforms: the FDA and the consumer product safety commission are also considered underfunded and understaffed to effectively prevent substandard goods from crossing the border.<sup>25</sup> American regulatory bodies are also subject to numerous institutional failures that hurt its impartiality: bureaucratic interests of the regulatory bodies, influence of the executive or legislative powers, or influence from firms and lobbies.

### 3.7. Summary

All the policy solutions presented earlier can work but they follow different timelines. In the short term, American businesses and regulators can reduce the risks by being more careful and increasing border controls or quality controls. Regulatory harmonization, on the other hand, takes time and political effort to implement, but it solves the problem to its deeper roots, and is possibly leading to new institutional failures.

The stated objective of this study is to explore areas where there is a large potential to build a sustainable competitive advantage through effective supply chain risk management. Because human beings and markets risk are collectively irrational and skewed towards short-term thinking, the role of the regulator is to force a long-term thinking and to provide the regulatory or judicial framework to make individual and collective rationality meet. The

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<sup>24</sup> Mancur Olson, *The Logic of Collective Action*

<sup>25</sup> New York Times editorial, August 15<sup>th</sup>, 2007

firms who will be leaders in developing the appropriate supply chain risk management practice to anticipate this move and provide trustable goods from developing nations such as China will benefit from a significant first-mover advantage.

# Chapter 4. A Market approach to Supply Chain Risk Management

We have previously highlighted the lack of accountability of decision-makers regarding the risks they take on behalf of their organization. In the previous chapter, we discussed the lack of transparency resulting from an asymmetry of information in the risk domain. As it is often the case for information asymmetries, this market failure is mainly a consequence of a principal-agent problem: the agent making the decision (manager) has objectives and incentives that are different from the principal (shareholder, for example) whom will be most affected by the long-term consequences of that decision.

Therefore, we would like to touch upon some potential market solutions to address this failure in order to reconcile the incentives between the principal and the agent. Because markets that are liquid enough are excellent enablers of tacit information sharing, such a mechanism could provide a solution to this issue.

We will first look at the financial industry, which is deeply rooted in market practices, and then explore possible applications of common practices to the financial industry to supply chain risk management of both *internal* and *global* markets.

## 4.1. Risk Management in the Financial Industry

Risk Management is at the core of the financial industry, and financial institutions are considered to be highly advanced in their risk management practices and processes. Decisions that financial institutions take are about the risk/reward tradeoff, about hedging strategies when the risk is too high, etc. Recent news have shown that this does not mean that banks are necessarily always successful at risk management, and the Subprime crisis, Bear-Stearns, or the Kerviel scandal at Société Générale are blatant billion-dollar examples of risk management failures.

One argument supporting why financial institutions would be more advanced in risk management than other industries is that they only have one unit of measure to deal with: money. They do not have any manufacturing issues or hard assets, and they run an information-based business, their most valuable assets being their people and their data.

Another reason why financial institutions are more formal about risk management is simply that they are statutorily obligated to do so. Because they are considered the plumbing of the economy, resting on an intricate financial system, there is a fear that the whole system will go down with a ripple effect if one institution goes down. Therefore, the government mandates greater visibility and control over risks carried by financial institutions.

There are additional restrictions imposed on financial institutions, such as the Basel Accords. These rules govern the amount of capital that banks need to carry to protect against risks. It is important to note that these rules were not developed by the regulators; instead, they were promoted by the Basel Committee on Banking Supervision. The Basel 1 accords of 1988 were simply focused on credit risk, and banks were required to hold capital equal to 8% of their risk-weighted assets; and the weights were pre-defined based on the category of assets.

The Basel 2 accords aim at dealing with a much larger number of risks. It separates credit risk, operational risk, market risk, and residual risk (which comprises systemic risk, pension risk, concentration risk, strategic risk, reputation risk, liquidity risk and legal risk). The first three are quantitative risks i.e., credit, operational and market, and the accords provide standardized approaches for calculating such risks. The accords provide a framework to address the residual risks. Finally, the accords give the regulators a better set of tools to manage and control the risks borne by institutions, and it greatly increases the disclosures that banks must make to the market, so that stakeholders can have a better view of the risk positions of the bank.

What is key to making the Basel system worthwhile is not so much the metrics themselves, but rather the standardization of the metrics. This standardization allows various institutions to assess and compare risk over time, and across organizations, to get a relative

sense of risk. In order to have a consistent risk management process, there needs to be an agreement on what risk is, and how it should be evaluated.

## 4.2. Prediction Markets

There has been a lot of recent literature devoted to the topic of “prediction markets” (also known as “information market”, “internal markets”, or “event futures”), following the successes of markets in predicting events more accurately than with more traditional methods.<sup>26</sup> A prediction market is a collective space (for example, a website) where participants can buy and sell “contracts” that will pay a set amount of money at a set date based on the value of a particular parameter or the realization of a designated event.

For example, a contract can pay \$100 if the next U.S. President is a Democrat, and \$0 otherwise. The contract can then be traded between actors of the market, and the current market price reflects the probability of the event as assessed by the market. If the contract is exchanged at \$45, there is an estimated 45% chance at this time that the next President will be a Democrat.

The power of prediction markets is realized because it automatically enables the collection of the latest information from the market actors. For example, if someone has specific information that may favor the Democratic candidate, that person will be willing to buy the contract at a higher price, driving the price up in the bargain. That person may not be willing to share the specific information, but he or she has an incentive to benefit from it through the market, and the resulting actions, i.e. offering a higher price, sends a signal by proxy to the market.

This mechanism differs from a traditional estimation approach, which is based on a consensus or averaging of forecasts, where the experts setting the forecast do not necessarily have the incentives, willingness or ability to share the most accurate information they have available, if any. In addition, prediction markets add a powerful

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<sup>26</sup> Wolfers and Zitzewitz, 2004

dimension by allowing not just one but many continuous bets until the market closes. This creates a constant feedback loop of updated information.<sup>27</sup>

Many firms have successfully used prediction markets internally for decision-making. Hewlett-Packard<sup>28</sup> pioneered the applications in sales forecasting and now uses prediction markets in several business units. As reported by Hewlett-Packard, internal markets consistently produced more accurate sales forecasts than the firm's internal processes. The reason for the success of internal markets in predicting product release dates or sales numbers comes from the anonymity provided by the market in disclosing information. While someone who knows that a product will be delayed has certainly no willingness to tell his or her manager, he or she is willing to drive some benefit from that information through the market, thus improving the collective forecast.

### 4.3. Internal Risk Markets

We will now look at the potential applications of prediction markets to manage supply chain risk inside a company. These are provided more as concepts than as directly actionable recommendations. Even though such markets may be difficult to implement, there is value in going through the learning process that they provide to an organization that implements them.

A first direct application of prediction markets would be to use them to more accurately evaluate the risks of certain disruptions, or the risk of disruptions in certain locations. One could imagine, for example a future contract on a given disruption happening before a certain date. However, we need to be careful about some of these contracts creating perverse incentives, a criticism that has often been made to prediction market. Therefore, the contracts need to be carefully chosen.

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<sup>27</sup> Dye, 2008

<sup>28</sup> Plott, Chen, 2002

Another application that is not so much based on predictions but still market-based would lie on the creation of a “risk credit” market inside the company. This is comparable to “cap-and-trade” programs in place in the European Union for carbon emissions. The idea is that the company’s central management would issue a certain number of “risk credits” that reflect its company-wide risk appetite. Business units would then be able to purchase and exchange risk credits in an internal secondary market. One unit of risk credit would effectively lower the net risk of the project owner and influence the reward-adjusted risk level, so that any investment project is worth a certain number of risk credits. If the manager decides to go ahead and make the investment, he or she needs to purchase an appropriate number of credits from someone else who will, in turn, need to decrease his amount of risk in order to be able to sell his credits (this can be as simple as carrying more inventory). The cost at which a manager will be willing to sell a credit reflects his cost of decreasing risk.

This mechanism has the advantage of helping to align the incentives, because risk becomes perceived as something concrete that must be considered immediately when making a decision, and not as a remote issue or a “freebie.” Another advantage is that this allows the company to control its risk appetite by selling or buying back credits. An obvious drawback is that, similarly to carbon trading, there need be a central measurement entity (a “risk evaluation group”) that decides that a project would be worth so many risk credits based on its risk/reward profile. And as we have seen earlier, evaluating the level of risk is far from being an easy task, but doing it using a market structure makes it more efficient.

#### **4.4. Global Risk Exchange**

An extension of a risk market would be the creation of a global risk market, in which contracts on the risk of a company can be exchanged on a liquid secondary market. Similarly to prediction markets, the price of such contracts would be a proxy for the company’s risk.



### 4.4.1. Credit Default Swaps

A Credit Default Swap (CDS – see Figure 1) is a credit derivative financial instrument, whereby the beneficiary makes periodic payments to the guarantor in exchange for the promise of a fixed payoff in case the reference entity defaults on a debt contract. This is a transfer of the risk of default from bank A to bank B. Typically, banks use them to hedge against the default risk when they have a pending loan or bond with the reference entity (company C). Since their introduction in 1995, there are now an estimated \$45 trillion worth of outstanding CDS contracts; they are also traded for speculation on a company's credit quality.

The key difference between CDS and a traditional insurance contract is that CDS are traded in real-time, so that their price reflects effectively the credit risk of a company, using the market principles outlined before.

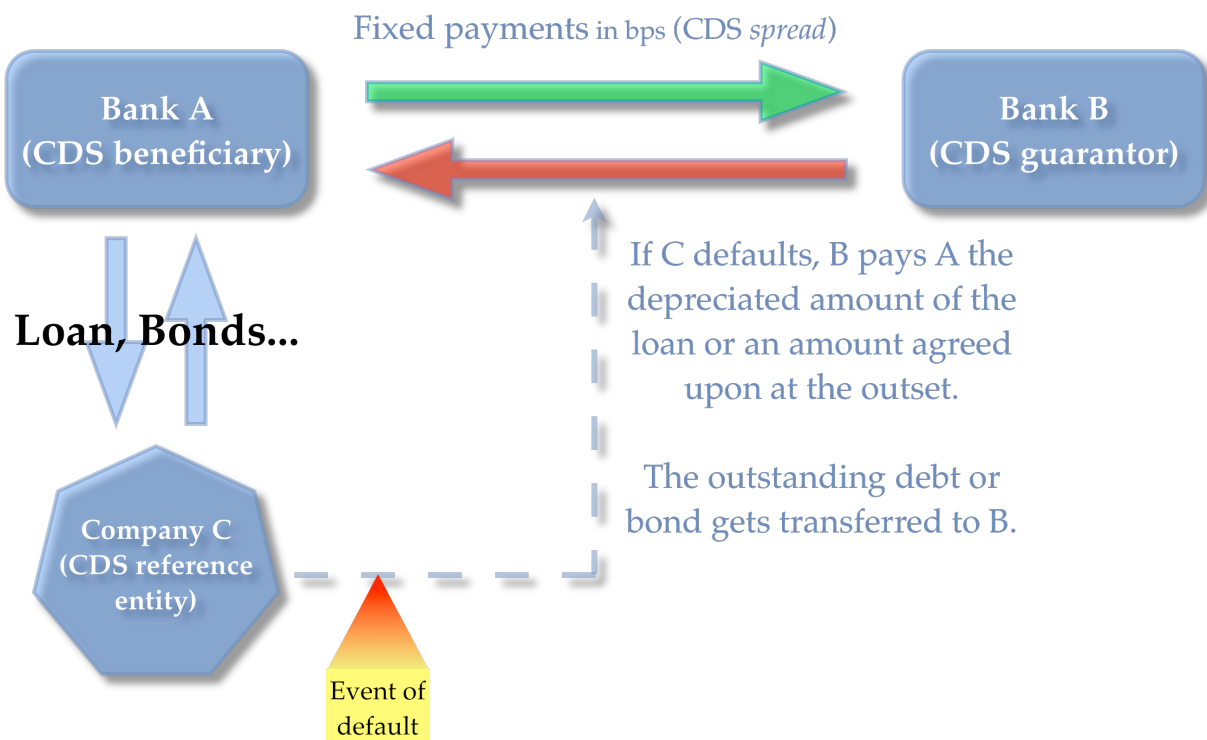


Figure 1 – Credit Default Swap mechanism

The value of a CDS is listed on the secondary market and measured in basis points (1/100<sup>th</sup> of a percentage point) and used by financial institutions to measure the credit quality of a

company. The efficiency and liquidity of the CDS secondary market drives the quality of this estimate.

#### **4.4.2. Supply Default Swaps**

The mechanism of Credit Default Swaps could be applied to supply chain events, therefore creating “Supply Default Swap” (SDS) contracts. One can think of the flow of items within the supply chain as the flow of money in the CDS. An SDS can protect its buyer against the risk of “supply chain default” of the reference entity, providing a pre-determined payoff if the entity does not deliver its goods or services. Similarly to CDS, if a secondary open market is in place, the value of the SDS is a proxy of the supply chain risk borne by the company.

#### **4.4.3. Self-regulation**

A question that can be raised is how can firms be offered incentives to disclose their risks more transparently than they are currently doing. The common belief is that companies have all the incentives to keep their risks hidden and hope for the best, both to please the market and to avoid showing their weaknesses to their competitors. One obvious way is that a government could suddenly decide to regulate, similarly to what has been done in the financial industry. But there are also bottom-up approaches to regulation just one firm can push for a regulation and be rewarded by the first-mover advantage.

This mechanism is known as Stiglerian capture. It consists in building the capability to be able to product at stricter standards than required, and only then pushing for a regulation, through lobbying or simply by influencing the consumer’s choices. For example, car manufacturers who were able to produce with tougher emission standards have advocated for a reduction in the emissions regulations. When this was implemented, those firms who pushed for the regulation had a serious first-mover advantage, while others were lagging to meet the new regulation.

In the case of risk transparency in the market, the consumers of market information are shareholders. Those could be willing to give a premium to firms who are openly sharing

their risks. Risk transparency can be a way for small competitors to differentiate in front of investors.

Gradually, risk transparency can become the new standard and eventually lead to the creation of a market for non-financial risks that would allow to finely evaluate the risks borne by an organization.

## 4.5. Summary

Supply chain risk management can learn several interesting practices from market approaches. The financial industry is one that lives around the risk and reward tradeoff, carefully evaluating both of them to yield profit. It is also interesting to note how regulations have been consensually developed to protect financial institutions against themselves and guarantee their solvency. Even though successes are mixed, one key element to note is the importance of standardized metrics to evaluate risk.

Prediction markets are a successful recent area of development that prove the power that markets can have in unveiling hidden information, even in medium-sized organizations. Using a parallel with cap-and-trade programs for carbon emissions, we explain how, in theory, market power can be leveraged to better manage risk in an organization and create the right incentives for managers. However, it also highlights the need for a central quantitative risk evaluation group.

Finally, we explored how, a global supply chain risk market could be developed, following the exponential development of the credit derivatives market over the last decade. Companies that are first-movers in a formal and holistic evaluation of risk could leverage that capability to create competitive advantage in the global marketplace.

# Chapter 5. Supply Chain Risk Management Practices: State of the Art

In this chapter, we analyze in further details many of the articles presented in the literature review to develop a state-of-the-art of supply chain risk management practices. We first analyze several reasons for the lack of formal risk management practices in organization, before exploring conceptual frameworks used to tackle supply chain risk. On the more quantitative side, we will describe tools and methods that have been used or could be used to analyze supply chain risk from a more numerical approach. We put together these learning to develop a framework for supply chain risk management improvement, which will then be applied to our corporate partner.

## 5.1. Unsympathetic attitude towards Risk

### 5.1.1. Risk Management: A driver of Cost

Most models used to evaluate risk management decisions relate to risk purely in terms of costs or constraints, and not as potential drivers of revenue and competitive advantage. It is true that effective management of supply chain risk often involves a capital outlay and other expenses. For example, developing deeper relationships with multiple suppliers is time-consuming and costly; similarly, the cost of adding or switching vendors to mitigate supplier risks is also not cheap. But what is too often forgotten is the value, sometimes hidden, of those risk management actions.

To illustrate, in the examples given above, a deeper relationship with suppliers can also be source of value if it can be leveraged to collaborate on product design or offer additional services to the consumer at the end of the chain, a distinct value proposition. Perhaps, the key question that we need to ask here is not if we should address risk, but what is our risk profile and how can we achieve our objectives in the most effective manner. Clearly, choosing the right level of risk requires a careful evaluation of cost-benefit and risk-reward

trade-offs of various options. Which is, in turn, based on where a company wants to be on the risk-reward frontier in line with its risk appetite.

Cisco surveyed its managers and asked what were the primary drivers for implementing Enterprise Risk Management practices<sup>29</sup>. The following were the top five answers:

- Corporate governance requirement - 66% of respondents
- Greater understanding of strategic and operating risks - 60% of respondents
- Regulatory pressures - 53% of respondents
- Board requests - 51% of respondents
- Competitive advantage - 41% of respondents

In summary, the survey suggests that risk management is predominantly perceived as a constraint imposed by regulation or higher management, even though Cisco is one of the most advanced organizations in terms of risk management culture.

Cisco refers to this perception as a “defensive posture” to risk management. Defensive posture means that a company is primarily focused on how much it is going to cost in order to mitigate risk. A cost orientation forces even large successful companies to treat risk management as a practice of protecting only some key assets and operations against different risks.

### **5.1.2. Crisis Management vs. Risk Management**

Another prominent theme in the risk domain is crisis management. Crisis management is primarily focused on preparing an organization to do its best and deal with disruption once it occurs. Detailed account of actions outlining what to do in a crisis included: recognition, containment, quick resolution, learning from the event, and communicating effectively. The crisis management literature is distinct from the risk management one in that it does not mention preventive measures, such as minimizing the probability of adverse events, mitigating the effects of disruptions before they happen (contingency planning), or even

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<sup>29</sup> Erickson, 2006

avoiding the disruption altogether (prevention). It can be argued that this thinking is rooted in the underlying assumption that both the event and its effects are unpredictable. Another possible reason for focusing on crisis management could be the cost orientation that considers any effort spent in preparing for or avoiding risk as waste in case nothing happens. Since crisis management is outside the scope of our project, it will not be discussed in great detail.

As part of a thesis for the MIT Master of Engineering in Logistics (MLOG), Chang and Lee (2007) undertook a detailed study of two back-to-back major disruptions in a major American chemical manufacturer's supply chain: a sole-source supplier unforeseen bankruptcy (supplier A), and the disruption caused by Hurricane Rita on another supplier's plant (supplier B). In the former, the disruption came as an unannounced surprise: supplier A simply stopped delivering the necessary raw material. In the latter, the organization had a few (precious) days notice before the hurricane struck on supplier B's plant.

Although the chemical manufacturer had expressed concerns about the supplier A's financial health, no specific action was taken to mitigate the possible consequences of a bankruptcy. In response to this event, a special cross-functional "task-force" was formed overnight, and the team scrambled over the next couple of months to secure any inventory from the bankrupt supplier A and to contact and qualify other (more expensive) suppliers. Overreacting to the crisis, the company ended up with a huge inventory of raw materials at their plant. Another three months were needed to resolve the quality issues that resulted due to the supplier change. The bankrupt supplier A was eventually bought by another firm and still remains a supplier to the company, but not the sole vendor.

As Hurricane Rita was approaching Houston, Texas, the location of supplier B, another critical supplier. In this case, however, the company had some time to prepare for the disruption. After the psychological shock of Katrina and during the notice period, the company was able to secure part of the inventory in preparation for an eventual crisis. It was also able to contact other vendors to establish contingencies should the urgent need to purchase from other sources arise. The Houston-based supplier B was disrupted as

expected and became operational again only one month after Hurricane Rita. Acting proactively, in this case the company was able to minimize the impact of a natural disaster.

Through interviews of managers and the use of the ERP software to track the evolution of key inventory data, Chang and Lee evaluated, in both cases, the cost of managing the supply chain crises. They considered the cost of the additional, more expensive raw material purchased, the cost of additional management hours, the extra raw material inventory costs, the cost of additional hourly worker hours, and the impact on finished goods inventory. This amounted to a total of about \$635,000 for supplier A's bankruptcy, and \$30,000 for the consequences of Rita on supplier B – a significantly lower impact on the bottom line as a result of pre-existing multi-sourcing policy and the preventive inventory build-up.

Further examining supplier A's disruption in detail, Chang and Lee found that if a pre-emptive risk-mitigation strategy had been in place via a multi-sourcing of the raw material, the total cost of such a strategy would have included the cost of switching suppliers and the marginal cost of buying more expensive raw material, or about \$355,000. Managing risk, even in a very simple manner, would have been 45% cheaper than managing the crisis in that case.

We must, however, acknowledge a major issue with this calculation, in that it is *made a posteriori*. To decision-makers, the value of such an analysis is only relevant when it can be calculated *a priori*, before disruptions happen – or, as a result of the plans, do not happen. And this is often a much less easy calculation, and one of the reasons why this risk management research was launched.

### **5.1.3. Cognitive reasons for the lack of Risk Management practices**

Bazerman and Watkins (2004) explore cognitive reasons why we deliberately ignore the threat of – even predictable – disruptions. They argue that people tend to hold positive illusions that lead them to interpret events in an egocentric manner and to undervalue future risks. Even though we are typically risk-averse, when it comes to future events, we

suddenly become risk-addicts without knowing it. From an economic perspective, this is equivalent to mentally over-discounting the future. We are unwilling to invest now in order to prevent a future disaster that may be quite distant and vague. Most of us are indeed naturally more willing to run the risk of incurring a large but low probability loss in the future than accepting a small but sure loss now. This is made worse by our tendency to avoid fixing anything that is not yet broken.

There can also be a serious discrepancy between the peace of mind and the actual level of protection, which is at the core of a major issue with insurance. Risk management should not be confused with purchasing insurance. An industrial disruption certainly includes monetary, assessable losses, such as damage to a building, to machines, penalties to customers for late deliveries, or immediate lost sales. But most importantly, it also includes long-term impacts on the sales, on the brand and company image, and losses in market share and customers. The problem is that these losses are far less tangible but could be significantly higher, making it very hard to buy protection for given their unique nature.

When the brand image is severely damaged and there are not enough customers, insurance is not the solution. Insurance provides a safety of the mind, a feeling of protection that can be overvalued and make decision-makers more relaxed about actual resiliency planning. In short and as we will see in greater detail in the “Tools and Methods for Risk Management” part, while purchasing insurance should most certainly be a part of comprehensive risk management plans, it surely cannot replace it.

#### **5.1.4. Misalignment of incentives for Risk Management**

Bazerman and Watkins (2004) also explore organizational reasons for a generalized lack of risk management. Most of the reasons preventing organizations to plan ahead, at all levels, can be linked to misalignment of incentives.

Firstly, mitigating a future risk event would result in cost outlay in the present, while benefits would be delayed. The natural tendency of organizations to reward and focus on current results (quarterly, yearly...), in addition to the constant movement of managers



around the organization, hinders the ability to spend money today for tomorrow's problems.

Secondly, addressing a potential risk requires a certain cost, while the reward is avoiding a cost that is uncertain but much larger. How can a decision-maker justify an investment that does not *physically* yield any result, precisely because a disruption does *not* happen? Even *a posteriori*, how could we prove for sure that the investment was the reason why the disruption was prevented? There is no reward for something that does not happen because of a cost incurred earlier.

Compounding a lack of incentives to focus on risk management is the presence of perverted reverse incentives against supply chain risk management. In many cases, promotions and rewards are based on the ability of an employee to deal with pressure demonstrated by their involvement in past crises. Crises can sometimes justify the very existence of a job, and how important the job is because it is so hectic. Often times, the hierarchy does not realize that the reason why some managers are so good at firefighting is because there are unable to plan ahead. And, although frequent crises make the job more stressful, it also makes it a lot more "exciting." In summary, rewards and kudos come from a (sometimes costly) fix to a crisis that was believed to be unavoidable, not from spending money to avoid or plan ahead for future crises.

Edward Erickson from Cisco (2006) also underlined the disassociation between the way the business was run operationally (with quarterly targets for cost, lead time or customer service level) and the holistic view of the supply chain that the supply chain risk management group was trying to explore. It took time and effort before risk management practices were present at all levels of the pyramid, and built into the design and operational processes. The goal was to have managers take into account their risk appetite, both qualitatively and analytically, when making a decision.

The lack of incentives goes all the way up to the shareholders who, especially when speculating, have no direct and immediate interest in long-term risk management. Because it is so difficult to evaluate, the inherent risk within a company's supply chain is not really

factored into its stock price (until disruptions actually happen), therefore discouraging risk management investments at a very high level.

The MIT Center for Transportation and Logistics recently convened a discussion to consider an objective evaluation of risk and developing “risk metrics.” The ultimate goal was to measure the risk borne by an organization because of its structure, geographical locations, supply and distribution strategy, etc. Ideas that were discussed included the creation of a supply chain “risk market,” where the market would decide what the “Risk Index” of a company is. This assumes, of course, that these financial instruments are liquid enough and traded on a secondary market that fully exploits the information discrepancies. Such instruments currently exist for financial risks (Credit Default Swaps), and provide a measurement of the risk that a company will default on a payment.

### **5.1.5. Role of Business Culture in Supply Chain Risk Management**

In many industries, risk is considered an unwanted aspect of business. Because supply chain risk management decisions involve hard choices, the need and value of protection must be progressively embedded in the organization’s culture.

Diana Coutu explores the reasons why some organizations (or people) buckle under pressure, while it makes others bend and ultimately bounce back<sup>30</sup>. She concludes that “ritualized ingenuity,” a mix of careful preparation with inventive crisis management, enables individuals to improvise a solution to a problem with whatever is at hand.

A very interesting instance is used as a case study in her article. The investment bank Morgan Stanley occupied 22 floors between the 43rd and 74th on the South Tower of the World Trade Center. On 9/11, when the first plane hit the North Tower at 8:46am, and Morgan Stanley started evacuating at 8:47. Out of the 2,700 Morgan Stanley employees at the World Trade Center, only 7 died in the attack, although the second plane hit the South

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<sup>30</sup> Coutu, 2002

Tower only 15 minutes later and the offices received an almost direct hit. While it was just luck that they were in the South Tower, Morgan Stanley had hired someone with a military background to design and carry out the fire drills, which were planned, rehearsed and executed in military fashion. The preparation allowed them to save numerous lives, and at the same time invaluable company assets.

Furthermore, Morgan Stanley had not only just one, but three fully operational recovery sites where employees could congregate and business could continue if work locales were ever disrupted. “Multiple backup sites seemed like an incredible extravagance on September 10, but on September 12, they seemed like genius.”<sup>31</sup>

Risk management is at the core of the financial sector and hence an integral part of its culture, as we have seen in Chapter 4. It can be argued that since a financial company relies on two main assets, its people and its data, it is simpler to protect their assets and bounce back in case of disruptions. In addition, data is a relatively “easy” asset to protect, and quite inexpensive to replicate.

In manufacturing-oriented companies, in contrast, the context makes it a lot more challenging to embed supply chain risk management sensitivity into the organization's culture. Due to the involvement of physical assets in how value is created, investing in any redundant system is much more capital-intensive and visible. And, because a lot of value is created by focusing on process efficiency and asset utilization, the opportunity cost of extra capacity is perceived as very high and often a barrier to decisions in that direction.

## 5.2. Conceptual frameworks

A variety of conceptual frameworks for addressing risk are available in the literature. A summary of the common frameworks is presented below.

Chang and Lee (2007) offer a framework to manage supply chain risks based on their investigation of two supply chain disruptions. Specifically,

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<sup>31</sup> Coutu, 2002

- understand the current risk-management protocol,
- study past disruptive events and near-misses and determine the key impact factors,
- evaluate opportunity cost of managing crisis,
- continuously evaluate suppliers and rigorously apply the key impact factors to the analysis of its supply chain practice, evaluation and identification of current vulnerabilities, and
- proactively monitor event-based warning signals, or disruption indicators, and assess potential supply chain risks.

Bazerman and Watkins (2004) develop a prescriptive framework that focuses on three core surprise-avoidance ideas:

- recognition of emerging threats,
- prioritization of action, and
- mobilization of available resources to mount effective preventative responses.

Pochard creates a “roadmap” to help managers embrace uncertainty and define adaptive strategies. Her study is based on two books by McGrath and MacMillan (2000) and Courtney (2001). She recommends that a prerequisite for any process change is to adopt a new mindset to exploit uncertainty. The roadmap is as follows:

- determine the strategic issues and define the level of uncertainty,
- frame possible solutions,
- analyze possible solutions and make the strategic choice, and
- execute the strategic choice adaptively.

Erickson presents the following process, which is in place at Cisco:

- Mobilize and Scope issue
- Identify and quantify key risks
- Develop action plan
- Obtain approval
- Integration and implementation
- Report and monitor

Clearly, these frameworks share a lot of similarities yet each one offers some new insights. The following section presents a comprehensive view of current practices found in the literature.

### **5.2.1. Recognize and accept the existence of Risk and potential disruptions**

A first step towards risk management may seem obvious and simple to accomplish, yet it is easier said than done. It is about removing the blindfolds that many organizations have about risk due to various reasons. It is important to recognize that things can go wrong every now and then, suppliers can go bankrupt, trucks can get hijacked, plants can catch fire, etc. And, as an important corollary, it is also critical to believe that something can be done about disruptions, and most importantly about their effects.

Bazerman and Watkins (2004) present a few techniques to enhance early problem detection:

- Redesign Measurement systems by putting in place key performance metrics and specific variables for the organization, and monitoring them. Each variable or metric should have pre-defined, unbiased action triggers beyond which response needs to be taken. However, a few issues emerge with measurements. If a measurement system directs people to focus on issues or domains in which predictable surprises are likely to emerge, then it will contribute to the surprise-avoidance process. If not, it will tend to divert attention away from emerging problems until they rise to a crisis level.
- Intelligence Network building is a process to establish units within the organization devoted to environmental scanning and integration of internal knowledge. Because leaders are too often the last ones to learn about a growing issue, they suggest establishing one or more cross-functional team responsible for collecting and synthesizing relevant information from all corners of the organization.
- Scenario Planning to employ structured processes for identifying and educating the organization about potential future events or trends. Scenarios are internally

consistent and challenging descriptions of possible futures that are means to represent the range of possible future developments and outcomes in the external world.

- Disciplined Learning processes to create institutionalized systems for capturing lessons learned from past disruptions. It builds on the idea that, often, emerging threats are not novel and the organization has confronted a different version of the process before (a reaffirmation of the event versus effect thinking). Since people constantly get reassigned to new positions, divisions or companies, organizations must define a formal detailed process to capture and retain such knowledge.

### **5.2.2. Evaluate and prioritize risks**

In the complex and dynamic business environment of today, it is easy to imagine that multiple competing priorities with respect to risk would emerge on a constant basis. As a result, it will be the leader's key responsibility to prioritize them and focus on the most critical ones at the right time.

Most authors suggest that, to be better understood, risks should first be categorized in an objective manner. Categorization helps by ensuring that different types of organizational risks are captured, and not only traditional financial or operational risks.

In the report "Enterprise Risk Management", KPMG identifies the following categories for risk assessment:

- Strategic risk
- Operational risk
- Reputation risk
- Regulatory or Contractual risk
- Financial risk
- Information risk
- New risks

Another effective way to categorize risk involves a graphical “mapping” of different risks to assess the relative risks facing the organizations. A commonly used tool<sup>32</sup> is the “heat matrix”, which evaluates qualitatively each risk according to its likelihood (probability of occurrence) and its magnitude (the impact that the risk would have if it really occurred). A sample heat matrix is shown below – see Figure 2.

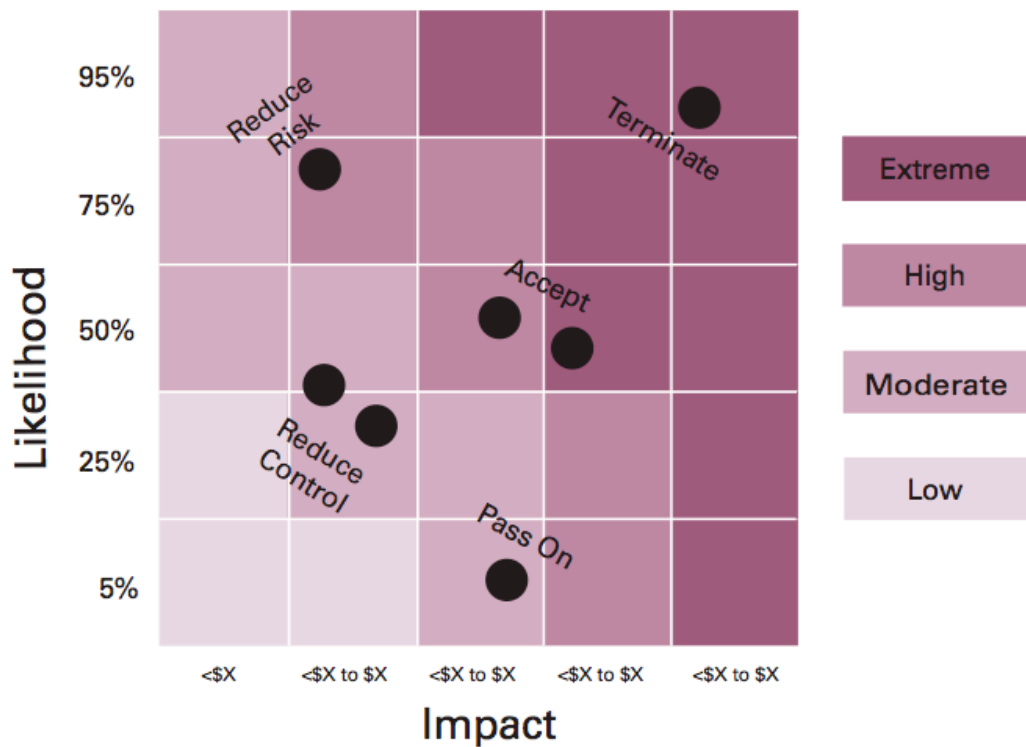


Figure 2 – Business “heat matrix”<sup>33</sup>

An initial analysis of risk using various categorization schemes can help a management team gain a deeper understanding of the challenges. Armed with the newly gained insight, they can obtain a better sense of appropriate strategies to tackle their potential risks. For example, some risks may not require any action or may need less control than they currently receive. On the other hand, risks falling in the “extreme” likelihood/impact

<sup>32</sup> Sheffi, 2005 and KPMG, 2001

<sup>33</sup> KPMG, 2001

quadrant should be considered seriously and eliminated or dealt with to reduce their severity, based on the risk and reward that such action can bring to the entire organization.

### **5.2.3. Create potential action strategies**

Once all identified risks facing the organization are prioritized, the key risks should be further fleshed out and evaluated. Appropriate high-level potential strategies should be developed for further consideration by looking across short listed risks. The risk management team should try to develop strategies that can deal with several risks at once and avoid narrowly defined strategies that can compromise other segments of the operations. For example, possible strategies that can be used to deal with supplier risk are:

- **Supplier Relationship:** Establishing a long-term relationship with vendors is crucial to maximizing long-term profitability for all partners in the supply chain. Deep customer-vendor relationship is especially important when a firm only has one or two suppliers of a critical component. In any case, a company can gain competitive advantage by building tighter relationships with its suppliers and viewing them as business partners.
- **Supplier Locations:** Selecting suppliers that are dispersed geographically or choosing a supplier that owns multiple manufacturing sites in different regions that are far apart could also help minimize the chance of a total supply disruption, as capacity can be promptly shifted to other plants to avoid material shortage.
- **Supplier Contracts:** buying guaranteed capacity from a third-party supplier in advance for use only when needed is a common practice in the semiconductor industry. It helps deal with demand surges or unexpected disruptions from other suppliers.

### **5.2.4. Quantify costs and benefits of potential strategies**

Literature is rather vague on the topic of quantification of risk, one of the key motivations for the SNRM project. Despite the general acceptance that risk management decisions need to be taken based on quantified information, like any other investment decision, only a few models are available. Indeed, this is not an easy problem, especially because potential



disruptions and their probability distributions are very company- and issue-specific. Being highly dependant on the business collaborations and the overall environment, it is difficult to employ generalized ideas and solution.

Pochard (2003) notes that traditional tools, either qualitative ones like SWOT analysis and Porter's Five Forces, or quantitative models like discounted cash flows analysis, are at best marginally helpful and at worst dangerous in an uncertain environment.

Additional modified tools and frameworks to develop a portfolio of strategies under uncertainty have been created, for example decision analysis, scenario-planning exercises, game theory, real options, system dynamics models, or management flight simulators. Many companies have developed their own, proprietary models to take risk management decisions using quantitative techniques as well. Some relevant models will be described in section 5.3, "Tools and Methods for Risk Management".

#### **5.2.5. Mobilize resources to implement chosen strategies**

Once the strategy is selected, the next challenge is to implement it. In an organization that may not yet be risk-aware, change management may hold the key to the success of the implementation. It may be necessary to persuade, negotiate, and build coalitions to achieve desired results. Within a hierarchical organization, where management can coordinate efforts over several teams, this can be an achievable goal. However, because the implementation of such comprehensive strategies is likely to also involve external supply-chain actors, the challenge of coalition building is not limited to controllable actors whose incentives can be adjusted internally.

Bazerman and Watkins (2004) suggest using the technique of persuasive communication to mobilize the organization around a common cause. From the previous steps in the process, clear arguments and quantified data should have emerged. These now need to be presented in ways that raise awareness of the problem and the need for action. The process itself, if explained and followed clearly, should also be a guarantee that the issue that is brought up is real and not an attempt to cry wolf. Because many decisions are taken based on numerical data, it is important to highlight the potential gains or losses at stake.

Pochard (2003) also suggests that under uncertainty, it is necessary to monitor and adapt the strategy over time. She also describes different approaches that can be used under the constraint of uncertainty, namely contingent road maps, option portfolio management and strategic evolution.

### **5.2.6. Identify and monitor “Sensors in the Ground” to predict disruptions**

Some supply chain risk management strategies may not involve the elimination of a risk, but rather a thoughtful preparation for the potential effects of a risk. In such cases, it is necessary to be informed about potential disruptions as early as possible. Any advanced information on disruptions is of extreme value and can make the difference between a near miss and a crisis.

A trusting relationship between a supplier and a customer can be of primary importance to gather vital information on the partner’s health. When working closely with a business partner of confidence, the partner should share information about a disruption rather than try to hide it. Businesses can minimize uncertainties and reduce supply chain risks through collaboration by proactively involving suppliers in purchasing management and product development.

Chang and Lee (2007) list the following sources of information to monitor supplier’s overall health: Supplier’s financial reports, public records, Dun and Bradstreet reports for private firms, Moody’s Industry Review, Standard & Poor’s, trip reports from on-site visits, internal communiqués pertaining to the supplier, relevant meeting summaries, and news about the supplier. Indicators such as management change, workforce reduction, impasse with union representatives, closing of plants, prolonged financial losses, etc. also represent alerts that are worth probing and paying attention to when evaluating a supplier.

Analyzing the sole-supplier bankruptcy for the chemical manufacturer discussed earlier, Chang and Lee highlight the importance of following the local newspaper at the supplier’s home city, where it is a major employer and as such is often the center of attraction in the local paper. Information on nearly all the aforementioned indicators was available in the

articles and commentaries by the local community, starting over a year before the bankruptcy. For example, there were mentions of erratic work hours, discontent employees, management changes, reduction in worker wages, worker accident, reports of low margins and high operating costs. Monitoring the “sensors in the ground”, while imposing certain moderate costs, can yield huge benefits in the form of advance notice on potential disruptions.

## **5.3. Tools and Methods for Risk Management**

By definition, risk is related to uncertainty. It’s therefore impossible to come up with a perfectly accurate measurement technique to capture risk in a general manner. A practical approach in such a situation is to first understand the objectives of measuring risk and then find an effective way to capture risk to serve those objectives. In this part, we will review various tools and methods that have been deployed by different disciplines in evaluating risk, both quantitatively and qualitatively to meet their respective objectives.

### **5.3.1. Insurance**

Risk is at the core of the insurance industry. It is important to note that the key business objective of the Insurance industry is not to decrease the actual loss from an unexpected event but to spread the financial impact of loss on individual client among all its policyholders. Indeed, in order to minimize their payouts, the insurance industry encourages the policyholders to invest in risk mitigation strategies by offering financial incentives and rewards.

Clearly, it’s critical for the insurance companies to know the risk very well before selling a policy to an individual or an organization. In fact, insuring companies make every effort to quantify risk to the extent possible before taking on any risk. According to Kunreuther and Michel-Kerjan, “Two conditions must be met before insurance providers are willing to offer coverage against an uncertain event.” And, one of the conditions is “that the provider must be able to identify, quantify and estimate the chances of an event occurring and the extent of losses likely to be incurred.” To be sure, the goal of profitability requires an insurance

company to do much more than measuring risk, but we will limit our scope to cover only this aspect of the insurance business.

However, insurance has shown its limits, and therefore is not at the core of many large companies' risk management processes:

- Insurance protects against only one type of risk: financial risk. All other types of risks need to be converted into financial terms. However, companies sell products or services, and money is ultimately not going to save their markets. If product supply is disrupted for an extended period of time, then customers will switch suppliers and may do so definitively.
- The time delays between a disruption and the payment of any insurance coverage is quite long, so insurance money often comes too late for disruption recovery.
- Insurance is expensive, and large companies end up paying for their claims through their future annual fees.
- Insurers may not even be willing to protect against some catastrophic risks in certain areas: following hurricane Katrina, the insurance industry has taken a large hit, and is acting more conservatively.

This leads large companies to carry very high deductible (sometimes several millions dollars) and to self-insure against most of the disruptions.

### **5.3.2. Failure Mode, Effect and Criticality Analysis (FMECA)**

FMECA is an extension of FMEA (Failure Mode and Effects Analysis). FMECA is a process to assess and classify risks by severity, and to determine their effects, with the intention of tackling the most important ones.

The method used to evaluate the "importance" of a failure mode involves the calculation of Criticality and a Risk Priority Number (RPN), for each of the risks that is identified during the analysis. Similarly to what was presented by KPMG, 2001 (discussed earlier), the Criticality is calculated by multiplying two indices for Severity and for Probability of occurrence. The RPN is calculated by multiplying Criticality by a third index for Detectability, as a result, this index is higher in cases when the risk is hard to detect.

Typically, these three indices are evaluated by a panel of experts or decision-makers in the organization. Criticality and RPN then provide a basis on which risks should be addressed first.<sup>34</sup>

FMECA is widely used in the manufacturing industry and in military setting, for two main applications:

- Design: FMECA can be used to break down the risks in different parts of the system to see where the most important risks are located and where the design needs to be adapted to tackle them. FMECA can therefore be part of the design and development process, to reduce the risks in the final design.
- Process improvement: FMECA can be used in quality improvement efforts or other process improvement, in which each part of the system can be looked at separately and individually improved to reduce the risk for the general process.

The general FMECA methodology is very similar in its essence to the state-of-the-art risk management methodology that we presented previously:

- System break down
- Risk identification
- Risk assessment by a panel of experts using RPN or Criticality indices
- Risk mapping and categorization
- Risk mitigation: actions to reduce, hedge or remove the risk

Although we did not find any references addressing directly the use of FMECA for supply chain risk management, it is a flexible enough system-based approach that could most certainly be used to analyze risks in the supply chain using a similar methodology.

### **5.3.2.1. Limitations**

We list below some of the limitations of FMECA:

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<sup>34</sup> ASQ, 2004

- Because the technique examines individual faults of system elements taken singly, the combined effects of coexisting failures are not considered.
- If the system or process is very complex or has many sub-parts, FMECA becomes a very tedious and time-consuming process, because of its systematic approach.
- The evaluation of the RPN or Criticality is subject to the human bias and to the biases already in place in the organization. A risk that is perceived as important in the organization in general (because management said so, for example) will tend to receive a high RPN, even though an objective assessment would have determined that it is less important than some other risks. Gilchrist (1993) notes that the calculation of the RPN is internally inconsistent and potentially misleading.

A key additional limitation of FMECA is that it is only looking at the risks and their consequences, but not at what it takes to tackle a risk, or at the opportunities that may come along with some risks. While FMECA provides a good basis to categorize and prioritize risk, it does not yet look at risk in an objective manner to understand which risks are worth taking and which are worth hedging or suppressing.

As with other methods, following an FMECA approach forces discipline in identifying and assessing risk in an objective manner. As a result, the organization is able to raise its level of awareness and prioritize issues facing the business and make investments judiciously.

### **5.3.3. Decision Analysis**

Decision analysis is one of the most commonly used approaches for evaluating uncertainty in general business situations. As such, it is naturally used for risk management decisions.

Rigorous decision analysis methods combine a systematic assessment of the probabilities of future events with an evaluation of the cost of benefits of each particular outcome.

Although simplistic in approach, and based on the challengeable “expected value” calculation, it is a very efficient tool to help decision-makers overcome the biases that obstruct them in estimating the likelihood of uncertain events.

Decision analysis begins with a clear definition of a specific decision to be made, followed by the identification of potential courses of actions and their consequences. The technique

instructs decision makers to explicitly assess each course of action and take decisions based on the potential costs and benefits of different courses of action, and the probabilities of each outcome. The expected value of each course of action is then evaluated in order to make the decision.

A proper decision analysis requires a careful quantification of the costs and benefits, the extent of uncertainty associated with different potential outcomes, and the tolerance for accepting a certain amount of risk. While those assessments are inherently subjective, the process of quantification is very valuable as it forces participants to express their assumptions and think about the possible courses of action.

A decision analysis example is presented in Appendix 2.

#### **5.3.3.1. Pros and Con**

Decision analysis offers particularly valuable tools in considering low-probability but high-impact outcomes, which are often overseen. In the absence of a rigorous decision analysis process that quantifies costs, benefits and probabilities, subjective biases, self-service assessments and the tendency to over-discount the future can downplay the presence of low-probability but catastrophic risks.

However, decision analysis has the disadvantage of diluting the effect by merging the impact of a range of potential outcomes, which may lead to undesirable strategies. To build on our example, when the future will unfold, the area will develop successfully, or it will not. Therefore, demand will be either high or low: it will not be 60% high and 40% low. This seemingly simple observation has huge implications for decision-making in terms of system flexibility.

Another key aspect of the decision analysis approach is its static view of the situation under consideration and the consequent failure to recognize our ability to intervene at an opportune moment to modify decisions and correct the course of the project. Furthermore, decision analysis is not focused as much on the opportunity offered by carefully delaying decisions until later to retain our ability to capture the upside while limiting the downside of a decision (thereby allowing us to manage risk more effectively). Clearly, flexibility is a

viable option to deal with risk but it is not optimal to value flexibility using standard decision analysis techniques.

### 5.3.4. Real Options theory and practice

#### 5.3.4.1. Definition and Background

Real Options is a theory that allows the evaluation of capital investment strategies made under condition of uncertainty, while integrating flexible future decision-making processes.

A Real Option is:

- a **right**, but not an obligation,
- to **buy** or **sell** an underlying asset (or grow/change a system, etc.)
- defined in a determined **future timeframe**
- valued at a **pre-determined price** (the “strike” price).

The price paid upfront for having an option is called the “premium”. The option is indeed not an obligation because, in the given timeframe, an option is “exercised” only if it is advantageous to do so. If not, only the initial premium is lost, generally much less than the price of the underlying asset itself.

Like it is the case for financial options, there are two basic types of real options:

- **Call** option: right to take advantage of an opportunity
- **Put** option: right to limit losses of a bad situation

It is possible to build options strategies for any desired complexity. An organization may want to combine a call option and a put option, to both take advantage of a potential future growth opportunity, and limit the losses in case of an unlucky event. Similarly, nested options are created when exercising a first option creates a second option (for example when research create an option for development, which then creates an option for market release).

The Real Options approach is very focused on leveraging the value of new information that may become available at a future date. Instead of using the initial information on



probabilities of an event to make a decision, the Real Options approach encourages the decision maker to **invest a small amount judiciously now** without sacrificing the upside of the future to:

- **defer** the decision until later hoping that new information unfolds with time, or
- **defer** decision and proactively **seek new information** (market research for example).

In both cases, the final decision will be made under less uncertainty since more information will be collected before the final decision to invest is made. The Real Options approach takes away the diluting bias that is introduced by the concept of expected value, as mentioned earlier, because, in the end, only one branch of the decision tree will unfold (and not both). Thus, it is more valuable to be able to make a more informed decision as the future unfolds, whenever and to the extent possible.

An example of Real Options application is presented in Appendix 3.

#### **5.3.4.2. Real Options and Decision Analysis**

Whereas Decision Analysis is an **evaluation method** to calculate the expected value of different courses of actions, Real Options is more of a concept, a different way of thinking than traditional decision-making. Real Options is *not* an evaluation method, instead, it **makes use of various evaluation methods** to value the options created using Real Options thinking. Decision Analysis is the most simple of these evaluation methods, but it very quickly finds its limits when the options become complex. Way of thinking and evaluation method should not be confused.

A more accurate valuation of Real Options requires the use of tools derived to value financial options. Such tools include the lattice or binomial model, the replication of the portfolio, an application of the Black-Scholes formula, or a Monte-Carlo simulation of the various scenarios and their probability distributions to evaluate the outcomes. The detailed study of those tools is not within the scope of our literature review.

### 5.3.4.3. *Pros and Cons*

There are significant limitations to the Real Options methodology, such as:

- It is not always possible to defer a decision to gather more information or to break a decision down into stages. Sometimes, a decision just has to be made, under uncertainty, with a risk of high losses.
- The cost of flexibility can sometimes overwhelm its value.
- A Real Option can be difficult to construct and evaluate in a complex, real-world, multi-variable problem. With its roots in the financial investment world, it can be challenging to communicate in terms of real options within an organization. Evaluating complex real options may require the use of mathematical or statistical methods (Lattice model, Monte-Carlo simulations...) that make it appear as a “black box.”

But, the primary appeal of the Real Options approach is conceptual in its ability to increase the value of projects by including the value of flexibility and recognizing new classes of design alternatives. A Real Option looks at uncertainty as an opportunity and forces us to consider choices in a more dynamic fashion. In fact, the value of an option is driven more by the characteristics of the external conditions as opposed to the specific internal specifications of the system that we are building, which are no doubt important. In a way, options internalize key external elements into design alternatives.

In short, higher uncertainty will lead to a higher value for the Real Option, whereas in the Decision Analysis domain, the change in probabilities will dilute the consequence of each alternative. We will typically react to higher uncertainty by increasing the discount rate to calculate the expected value in a decision tree and focus more on near term consequences. This has the potential to eliminate very profitable alternatives in the long run from the mix as they appear risky based on our current understanding of the environment, which is likely to change in the future.

## 5.4. A Framework for Supply Chain Risk Management improvement

Using the results from the literature review and the analysis of qualitative and quantitative state-of-the-art methods, we developed the following framework, which we then used for in our case study with our Consumer Packaged Goods partner. After the qualitative part of the framework was complete, it allowed us to gain a certain level of insight in the organization's supply chain risk management and already make recommendations that can be generalized to other companies.

### **Step 1: Literature review and industry research**

- Review Supply Chain Risk Management practice in general
- Review Supply Chain Risk Management practice specifically for the chosen industry
- List potential risks faced by the industry, past, present and future
- Review quantification and decision-making methods for Supply Chain Risk Management

### **Step 2: Risk management practices in place**

- Evaluate the internal risk management processes already in place
- Evaluate managerial support and involvement
- Evaluate the alignment of those processes with the general strategy

### **Step 3: Qualitative Analysis and Recommendations**

- Supply Risk Identification – Develop a comprehensive list of risks faced by the specific supply chain by assimilating information from various sources, both primary and secondary.
- Supply Risk Valuation – Identify the direct and indirect costs associated with various risks, to the extent possible.
- Risk Scope – Explore the immediate problems along with the second and third order effects triggered by various risks.

- Supply Risk Location – Determine the weak spots by mapping the risks on the overall supply chain.
- Supply Risk Drivers – An understanding of risk drivers is essential to make effective decisions. For instance, certain organizational factors may exacerbate a known risk.
- Risk Categorization – To facilitate a better understanding of potential risks from a systems point of view, group them into meaningful categories. For instance, the Concentric Vulnerability Map (Figure 3), which has been used effectively by General Motors, proves useful in classifying risks.



Source: General Motors Enterprise Risk Management

**Figure 3 – Concentric Vulnerability Map**

Similarly, other ways to organize risk can be explored based on the specific concerns and vulnerabilities identified in the supply chain; a very common one being the “heat matrix” (see Figure 2), which sorts risk on two axis: Likelihood and Impact.

- Initial analysis and recommendations: based on the qualitative data accumulated, an analysis can be performed on the interviews and with tools such as the risk mapping charts presented here. This can lead to initial, qualitative recommendations to improve the supply chain risk management process.

#### **Step 4: Quantitative Analysis and Recommendations**

Although this part is not touched upon in the case study presented in this thesis, the next step in the research project is to develop a quantitative analysis, through a mathematical model, to understand the risks in a formal manner. This will then be used to evaluate possible strategies numerically and develop specific recommendations.

- Supply Risk Probability Estimation – Develop probability estimates based on available information for an objective evaluation of risk and possible solutions. Use the company’s experience vis-à-vis industrial risks and publicly available industrial data to accomplish this task.
- Identification and analysis of regular supply chain operation tasks from supply risk exposure perspective.
- Scenario building (the level of details to be included in the scenarios will be driven by the value of the scenarios in risk analysis)
- Formalize business objectives (e.g., level of desired risk protection in terms of market coverage, financial exposure, recovery time, products, investment etc.)
- Model development
- Identification and testing of possible strategies (ideas motivated by flexibility, redundancy, supply contracts etc.)
- Sensitivity analysis and design selection
- Recommend process enhancements to keep the supply chain design and operation aligned from the risk point of view on an ongoing basis.

# Chapter 6. Case Study: Supply Chain Risk Management in a large CPG organization

Through our research partnership with a large Consumer Packaged Goods organization (which we will call “CPG Co” for the purpose of confidentiality), we were able to apply and validate the framework presented in the previous chapter with an actual company. After completing the first task, or literature review, which is presented in this thesis, we conducted a number of semi-structured interviews with CPG Co executives to gain a first hand understanding of the business environment and the current approach to supply chain risk management.

The result of the second task, or “analysis of the current risk management practices” is presented here. Based on the results of the literature review and other previous research, we were able to highlight key challenges that come out of the interview, in order to ultimately lead to improvements in the supply chain risk management processes.

The data from the interviews was reviewed and transcribed as needed. Data analysis involved collection of themes and ideas by iterating over the transcribed notes and information. The themes were reviewed to identify recurring theme for which there seems to be a general agreement among the interviewees and themes on which we heard diverging views. The themes based categorization of the data was synthesized to develop a consistent discussion around the theme and presented below.

## 6.1. Anecdotal understanding of Business Protection Level

**Background:** A consequence of a somewhat informal manner of dealing with supply chain risk is that there are divergent opinions on the true level of protection that is available to CPG Co, should a need arise. For example, in the case of two existing factories that are very similar, one in the United States and one on another continent, the current understanding in terms of business continuity planning is that these plants will support each other if there

is a crisis. In other words, if anything serious were to happen to either of these plants that would disrupt operations for more than a few days, CPG Co would rely on the other one to serve its markets. Because CPG Co operates in an asset-intensive environment, it carries only a very limited amount of extra capacity. The asset utilization is maintained above 85%, often at an even more aggressive (higher) number.

It is widely understood that only a part of the lost capacity could be covered in case of disruption, and once the inventory is depleted, choices would have to be made as of what markets or customers should be served based on priority. Having an extra machine to cover for disruption is not an acceptable value proposition, but it is understood that dual sourcing offers protection only if there is extra capacity. Furthermore, the practicality of moving some of the production across the Atlantic on short notice was also questionable.

**Core Issue:** A lack of objective risk assessment facing CPG Co and formal assessment of actual level of protection that CPG Co has against various risks.

**Possible Actions:** A formal process to objectively evaluate risks and protection should be developed.

## 6.2. Cost Reduction or Market Coverage – Shifting business objectives

**Background:** Cost was a paramount element in most decisions across CPG Co provided everything is running smoothly. There was managerial pressure from the top to constantly compensate for the overhead growth, explicitly making cost-cutting a core part of the strategy.

From a market point of view, CPG Co was involved in a business where brand loyalty is critical. There were suggestions that CPG Co is not seriously concerned about its competitors' businesses because of its technological superiority. Interestingly, despite the apparent importance of brand loyalty and technological superiority, the switching costs are fairly low. Therefore, shelf availability is critical for the continued success of the business. In short, the product must be available when and where the consumer wants it.

To this end, several interviewees emphasized that their job was to make sure that the firm is able to make and deliver product at all times. In times of crises, inordinate amounts of resources are made available with the objective of minimizing the impact on the market. The direct financial risks, such as incremental recovery costs are considered a lesser evil.

**Core Issue:** Managing risk is a complex challenge that requires careful evaluation of short term and long-term impact of investment in a holistic manner. Deployment of large resources to protect market share could quickly erode the company's brand and balance sheet. At the very least, such events partly offset the savings of the day-to-day cost reduction focus driving the organization.

**Possible Actions:** It can be argued that most cost-cutting measures also contribute to an increase in probability and impact of a disruption or invite a new disaster. Without a formal process to objectively evaluate strategy, it will be difficult to guide decision makers when faced with a choice. Furthermore, a clear policy should be framed to address adverse situations to facilitate fast decisions that are consistent with the overall strategy of the organization.

### 6.3. Business Continuity Planning vs. Risk Management

**Background:** The key objective of Business Continuity Planning (BCP) is to prepare a detailed plan for the organization to recover after a disruption has affected its normal functioning. It is focused on restoring partially or completely compromised functions after a disruption. This includes identification of risks faced by a facility, hardening of system defenses to minimize the impact of a disruption, creation of emergency procedures in case the system is disrupted etc. In short, BCP refers to preparing for incidents or accidents that are most likely to impact the current supply chain and essentially operational in nature.

On the other hand, the scope of Risk Management is broader as it integrates future-focused and company-wide process that go beyond impact mitigation. It is strategic in nature as it calls for explicit knowledge of company's risk appetite, and dynamic management and



optimization of risk as a portfolio with each representing also a certain potential reward. In short, risk is a part and parcel of every decision, long or short term. To an extent, BCP can be considered as a component of Risk Management but the opposite is not true.

**Core Issue:** There seem to be an unclear distinction between Risk Management and Business Continuity Planning. A lack of clarity in the approach to deal with risk often relegates risk to operational domain, which could have serious ramifications for the long-term viability of the business.

**Possible Actions:** While continuing to maintain effective BCP processes, CPG Co should enhance its capabilities in the risk management area and think beyond business resumption after a disruption has hit the system.

## 6.4. Crisis Management vs. Risk Management

**Background:** From the numerous examples of disruptions or near misses collected from the interviews, we believe that CPG Co has excellent operational capabilities to recover once a crisis arises. CPG Co knows how to leverage its size to react promptly and efficiently and get back on its feet quickly, even when situation appear to be out of its hands, for example when the surrounding infrastructures are inadequate.

But more importantly, we have learned that a part of this crisis management process is ad hoc and not necessarily formalized. To be sure, CPG Co's size and its economic importance to its suppliers and the communities, offers a clear advantage and a large network to fall back if needed. For example, we were told of a crisis when a CPG Co executive who had a special relationship with a supplier, or utility company, was able to call in a personal contact to expedite the process to get a CPG Co facility operational again.

At the same time, most interviewees acknowledged that there was a lack of clearly defined processes to deal with supply chain risk from a long-term perspective. Risk is addressed and dealt with when needed efficiently, but mostly informally. It appears that when dealing with an important supply chain decision, such as an addition of a new location or significant measures to reduce cost, the matter of associated risk comes up for discussion

informally with the decision-makers, who address the risk subjectively. But, quite often, a decision that implies a significant amount of supply chain risk is still made with the expectation that operational supply chain executives will be able to deal with any situation that may arise. For instance, tax or tariff incentives offered to CPG Co to establish a plant in a (sometimes remote) location often seem to outweigh additional supply chain-related difficulties resulting from limited infrastructure.

**Core Issue:** Excellence in crisis management is a double-edged sword. CPG Co seems to be compensating its limited focus on long-term supply chain risk management with excellence in operational flexibility and responsiveness. Risk Management procedures and guidelines for decision making may be considered less important possibly due to exceptional operational capabilities to handle crisis.

**Possible Actions:** A balanced approach that integrates risk and crisis management.

## 6.5. Evolution in the level of risk

**Background:** Interview data suggests that there is a feeling that CPG Co has become less risk-averse in the last decade or so even though there is no formal process to evaluate risk. This is motivated by the observation that operations have been consolidated considerably. This strategy leverages economies of scale to lower the production cost as well as reduce probability of disruption by settling in more stable locations; but it also increases the impact of a disruption, as the facilities are larger if disaster strikes. CPG Co is also sourcing some key parts from China, something that interviewees said would not have happened before. An important implication of this strategy is an increase in the likelihood of supply chain risk but a reduction in dollar impact due to lower capital investment.

**Core Issue:** Strategic choices and actions suggest that CPG Co is operating at a higher level of risk compared to the situation a decade ago. More importantly, all this has happened without formal risk evaluation or management processes, which is cause for concern.

**Possible Actions:** Adding more risk to the portfolio should be a deliberate strategic choice of the company rather than a de facto consequence of multiple decisions over time.

Detailed processes around objective evaluation of risks and reward should be a part of standard planning process.

## 6.6. Keeping track of disruptions

**Background:** Interviewees acknowledged that CPG Co is not formally keeping track of disruptions, and therefore the firm may not be fully leveraging learning from past events. There is no database keeping track of them as it is for environmental or health & safety concerns because of regulatory requirements. As a result, disruptions are sort of “popular memory”, and disappear as people move around the company.

An important part of disruption analysis is not only recalling the event itself, but also the effect that it had, the learning drawn from this disruption that could be useful for other parts of the business and the cost implications of the disruption. To this end, we propose a structure that can be used to build a disruption database to keep track of events.

**Core Issue:** The interviewees are well aware of the need for and the value of learning from past events and prefer a tracking tool for supply chain disruptions.

**Possible Actions:** Creation of a comprehensive disruption or near-miss database at the corporate level. This would offer decision makers an effective tool for cross-fertilization of ideas between business units and better learning and improvement opportunities from past disruptions.

## 6.7. Summary

Our detailed analysis of several semi-structured interviews highlighted several interesting ideas, which can certainly be of value for other organizations and industries:

- A formal process to objectively evaluate risks and protection should be developed to counteract the lack of objective risk assessment facing organizations and formal assessment of actual level of protection that they have against various risks.

- It can be argued that most cost-cutting measures also contribute to an increase in probability and impact of a disruption or invite a new disaster. When faced with a disruption, deployment of large resources to protect market share such events partly offset the savings of the day-to-day cost reduction focus driving the organization. Without a formal process to objectively evaluate strategy, it will be difficult to guide decision makers when faced with a choice. A clear policy should be framed to address adverse situations to facilitate fast decisions that are consistent with overall strategy of the organization.
- Often, there seem to be an unclear distinction between Risk Management and Business Continuity Planning, which relegates risk to operational domain. Organizations should enhance their capabilities in the risk management area and think beyond business resumption after a disruption has hit the system.
- Excellence in crisis management is a double-edged sword. Organizations sometimes try to compensate a limited focus on long-term supply chain risk management with excellence in operational flexibility and responsiveness. A balanced approach that integrates risk and crisis management is instead needed.
- The level of risk in the organization can evolve without formal risk evaluation or management processes, which is cause for concern. Adding more risk to the portfolio should be a deliberate strategic choice of the company rather than a de facto consequence of multiple decisions over time. Detailed processes around objective evaluation of risks and reward should be a part of the standard planning process.
- The need for and the value of learning from past events is paramount and relates to the concept of *evolutionary* supply chain risk management. The creation of a comprehensive disruption or near-miss database at the corporate level would offer decision makers an effective tool for cross-fertilization of ideas between business units and better learning and improvement opportunities from past disruptions.

# Chapter 7. Qualitative Analysis and Recommendations

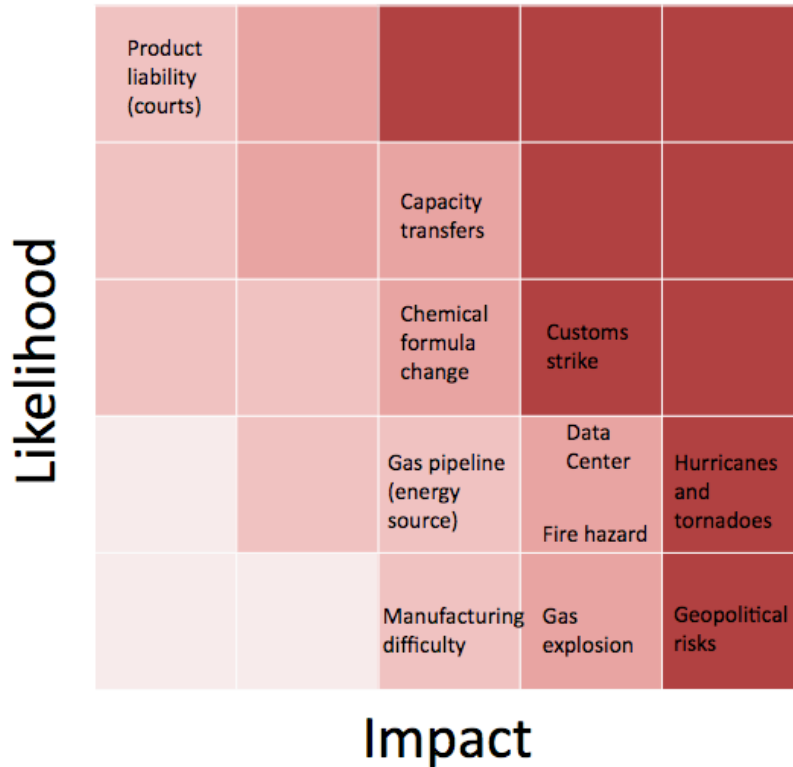
Following the steps laid out in the framework, we carried out a qualitative analysis of the collected data using a variety of approaches. The methods used for analysis along with resulting insights are described below.

## 7.1. Risk Mapping

We mapped and evaluated the risk data collected from the interviews using the two risk-mapping frameworks presented earlier in the report, namely the “Concentric Vulnerability Map” and the “Heat Matrix”. While we do not claim to have expert opinion on where exactly various risks should be positioned on the maps from CPG Co’s point of view, Figures 3 and 4 represent our judgment based on the interviews. This type of qualitative analysis can be done fairly quickly and used to identify key areas that need to be tackled, hedged, or abandoned.

### 7.1.1. Heat Matrix

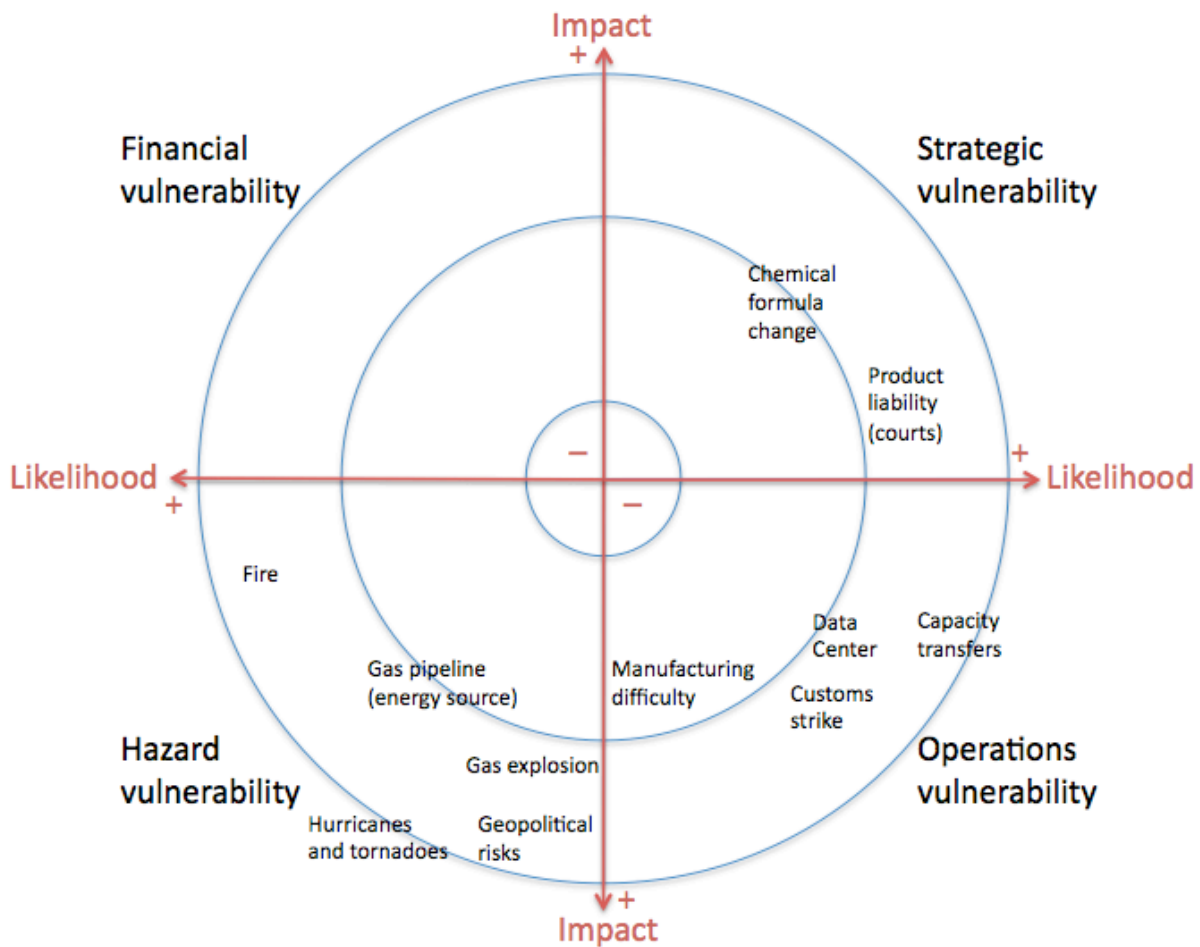
On the heat matrix shown in Figure 4, the vast majority of disruptions discussed during the interviews fall into the “high impact, low likelihood” region. This is a typical pattern because these disruptions are the most difficult ones to address and remain itched in the memory. Such events come as a surprise and cause extensive damage and leave a deep impression on the organization. Others, such as “low likelihood, low impact” are deemed irrelevant because they do not significantly impact the supply chain and often forgotten and overlooked; “high likelihood, low impact” disruptions are also more easily identified and typically well addressed due to their certain nature.



**Figure 4 - "Heat Matrix" applied to CPG Co**

The “high likelihood, high impact” disruptions are often avoided by abandoning altogether the cause of those disruptions or finding a definitive fix. But when such disruptions are an essential aspect of the core business of the organization, dealing with them becomes an integral to the normal operating processes. For example, the case of oil companies whose oil platforms in the Gulf of Mexico get damaged every year during the hurricane season. These disruptions cost several hundred million dollars to repair but it has become a part of the business-as-usual. Now, very thorough processes are in place to evacuate the employees and then repair the damages as efficiently as possible.

### 7.1.2. Concentric Vulnerability Map



**Figure 5 – Concentric Vulnerability Map applied to CPG Co**

A key observation that can be made from the concentric vulnerability map – Figure 5, is that very few disruptions were mentioned that belong to the strategic or financial categories. Such disruptions include currency fluctuations, competitors’ actions, fuel prices, recession, public boycott, loss of intellectual property, etc. When asked about disruptions of these types, the typical response was that this was not part of the interviewees’ responsibility. More than the absence (which could be easily explained by not having a corporate finance person in the interview list), the lack of appreciation of the interconnectedness of these different categories was very revealing and disconcerting.

It is easy to show that the aforementioned items actually do affect supply chain in a variety of ways. For example, if there are currency fluctuations or a geopolitical instability in a

country, it will affect CPG Co's operations in that country and therefore a different kind of supply chain will be necessary to protect supply. So, even though one can argue that the response received by us can be considered normal in that supply chain team need not focus on such issues, we want to emphasize that it is important that total risk management ultimately becomes the new culture throughout the company. In this culture, the idea of risk-informed decision making is promoted at all levels and where everyone is aware of variety of risks at all levels.

## 7.2. Investigating the cause-and-effect relationships in Risk Management

Based on the literature review as well as on the interviews, we have developed a "Causal Loop Diagram" to analyze and visualize our learning. A Causal Loop Diagram is a tool that links variables sharing a cause-and-effect relationship. The relationship can be positive (+), when more of the cause leads to more of the consequence; or negative (-), when more of the cause leads to less of the consequence, and vice-versa. Linking such relationships often create loops. The loops can be "reinforcing", or "balancing", depending on the sequence of positive and negative relationships that form the loop.

In addition, often there are time delays (represented with parallel lines on the arrows) in that a cause-effect relationship may not be immediate but instead the response can be delayed. This can lead to interesting behaviors such as oscillations in resulting patterns. Causal Loop Diagrams can be further developed into mathematical models using simulation packages.



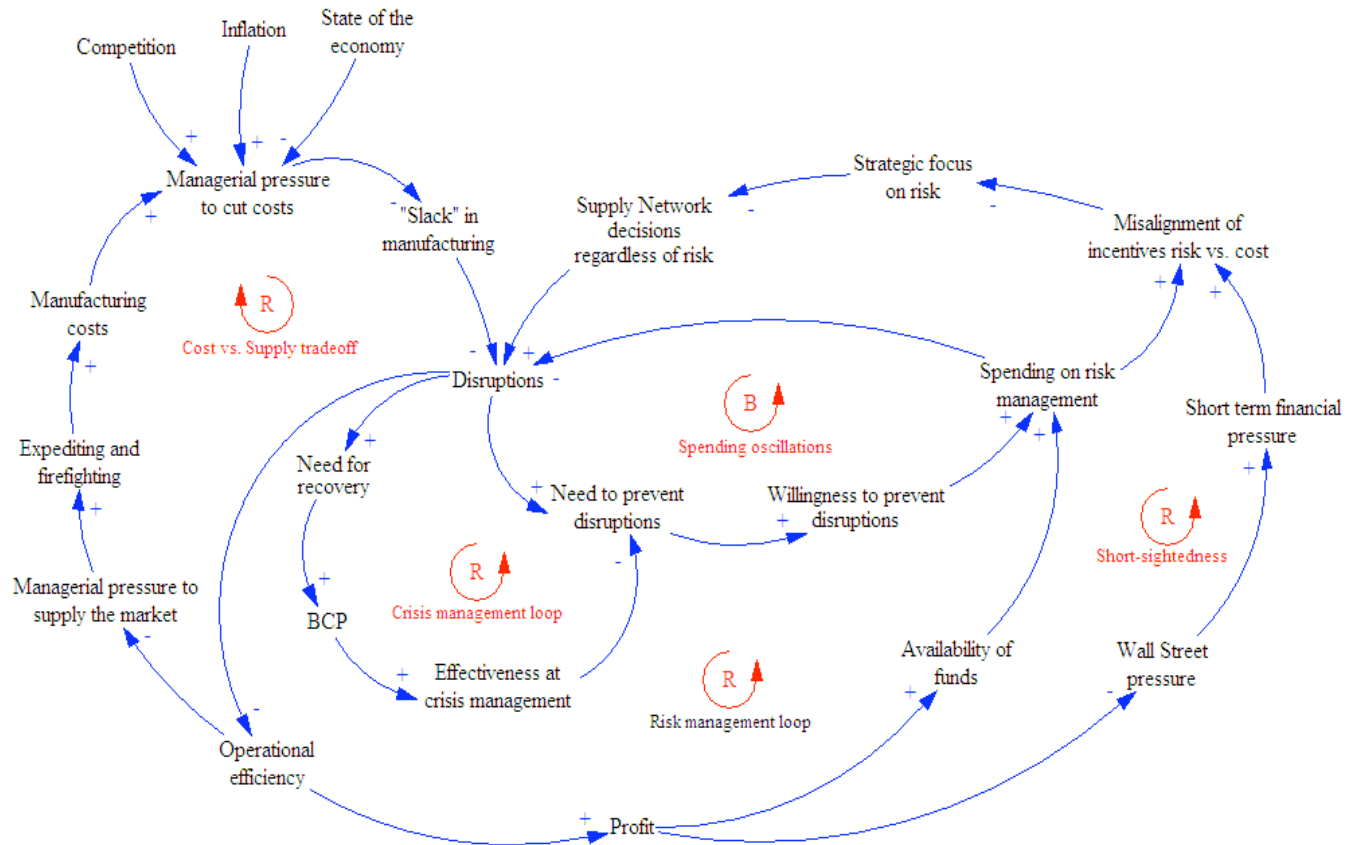


Figure 6 – Causal Loop Diagram for Risk Management

### 7.2.1. Risk management loop

This loop highlights the positive consequences of engaging in a risk management process and the danger of cutting the risk management budget. It also shows the long time delays that exist between spending on risk management and the impact on disruptions. This is a key reason why companies are reluctant to engage in formal risk management processes. Spending on risk management reduces disruptions typically after a long delay, which in turn increases operational efficiency, increases profits, the availability of funds, which in turn increases the spending on risk management.

### 7.2.2. Crisis management loop

The crisis management loop shows that there is value in undertaking business continuity planning, but also a danger as repeated success will encourage the organization to perceive it as a replacement for risk management. If there are more disruptions, there will be a

higher need for recovery prompting increased funding for Business Continuity Planning (BCP), and the organization will become more efficient at crisis management. In consequence, the need to prevent disruptions will decrease resulting in lowering in spending on risk management, which in turn leads to more disruptions. Although the organization is able to recover effectively from disruptions, often the hidden cost of recovery tends to linger on for a long period of time and practically impossible to account. In other words, it is not an easy task to objectively compare the cost-benefit of risk management and BCP.

### **7.2.3. Short-sightedness loop**

This loop highlights that short-term financial pressure is detrimental to risk management, which is a long-term activity whose effects cannot necessarily be perceived immediately. More disruptions lead to a decreased operational efficiency, therefore less profits and more short-term financial pressure from Wall Street and the management. In other words, practical incentives tend to be aligned with short-term pressure and over time the organization loses its strategic focus on risk. This results in supply chain decisions that don't appropriately account for risk, and therefore result in even more disruptions over time.

### **7.2.4. Cost vs. Supply tradeoff loop**

This loop illustrates the choices that often need to be made between cost reductions and service levels, and how pressure to reduce cost can ultimately lead to increase in manufacturing cost primarily on account of increased disruptions. Exogenous factors (competition, inflation, state of the economy) as well as increased manufacturing costs are drivers of managerial pressure to cut costs. This leads to less slack in manufacturing processes and therefore higher sensitivity even to small disruptions, which in turn hurt operational efficiency. Consequently, there is pressure to supply the market to protect market share through expediting and firefighting. These are costly measures that ultimately increase manufacturing cost.

### 7.2.5. Spending oscillations loop

This loop highlights an issue that has been witnessed previously in other industries and a consequence of long time delays and the lack of institutional learning that surround risk management decisions. Intel was faced with a vexing problem as their trucks full of processors were getting hijacked in Southeast Asia. To control such incidents it hired gunmen to protect the shipments. After some time, the hijackings stopped completely and situation returned to normalcy. Later on, a new management team that was looking at opportunities to reduce costs concluded that the money spent on hiring gunmen was useless since no hijacking had happened in the past several years. Gunmen were fired and hijackings restarted.

## 7.3. Maturity Levels in Risk Management

A commonly used approach to improve a company's performance around risk management is to assess its maturity level. In the "Supply Chain Response to Terrorism" project at MIT-CTL, Rice classified the response in 4 levels, based on "anecdotal data from 20 firms interviewed": Basic, Reactive, Proactive and Advanced.

The International Association for Contract & Commercial Management (IACCM) has developed the Business Risk Management Maturity Model (BRM3). It identifies four levels of organizational competence in the area of business risk management (Novice, Competent, Proficient and Expert) against four attributes (Culture, Process, Experience, Application). Table 4 shows the high-level organizational maturity characteristics.

Attribute:	Level of Maturity			
	Novice	Competent	Proficient	Expert
<b>CULTURE</b>	Risk averse Lacking awareness / understanding Lacking strategy Lacking commitment	Patchy, inconsistent Some understanding / awareness Cautious approach, reactive	Prepared to take appropriate risks Good understanding of benefits across most of organisation Strategy mapped into process implementation	Proactive Intuitive understanding Belief, full commitment to be the best
<b>PROCESS</b>	Where present tend to be inefficient informal, ad-hoc	Inconsistent No learning from experience Standard approach / generic.	Consistent approach but scalable Tailored to specific needs	Adaptive Proactively Developed Fit for purpose Best of Breed
<b>EXPERIENCE</b>	None; nothing relevant	Basic competence	Proficient Formal qualifications	Extensive experience Leading qualifications  Externally recognised high competence
<b>APPLICATION</b>	Not Used	Inconsistent – major projects only Process driven Inadequately resourced	Consistently applied Adequately resourced	Proactively resourced Across entire business Flexible Measured for improvement

**Table 4 – BRM3 High-Level Organizational Maturity Characteristics**

An important caveat associated with this approach is that there is limited value in identifying and implementing an ideal “state of the art” (Level 4) solution. Although different levels can be described quite clearly, they are progressive in nature. Specifically, an organization that has not yet reached Level 3 will have a hard time implementing Level 4 practices. Instead, it is more effective to go up the ladder of maturity levels one step at a time so that the attributes of each level are gained and accepted all throughout the organization before moving forward.

## 7.4. Sensors in the ground

Sensors-in-the-ground is a concept promoted by the MIT Supply Chain 2020 project in the context of Scenario Planning. Sensors are based on the idea that when a company should be constantly looking for signposts that may indicate that how the future is unfolding.

The same concept can be applied to disruption recognition. In risk management, as in Business Continuity Planning, early recognition is a key to avoidance and faster recovery. For example, sensors will play a critical role in isolating supplier prone to financial difficulties. However, early recognition can only be possible if the signposts have been

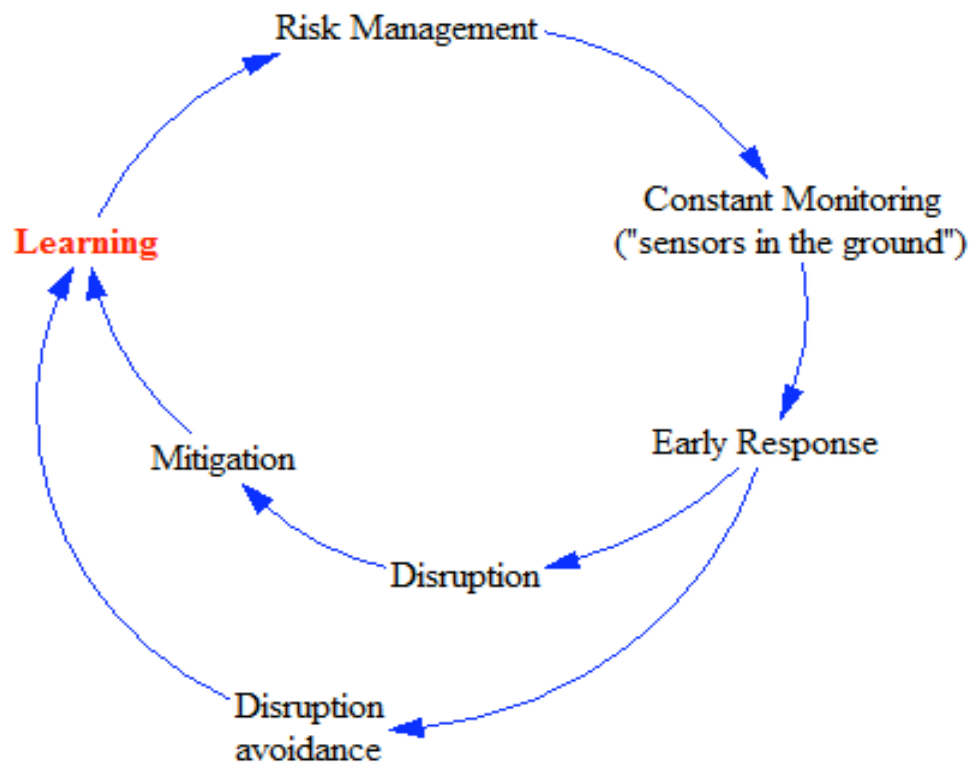
identified ahead of time. In our example, one signpost could be social unrest among the supplier's workforce. Another key aspect of the concept is that sensors are useless without proper monitoring processes. Following our example again, this could mean monitoring the local newspaper at the supplier's location on a weekly basis for any trace of financial difficulty, something that may take half an hour a week at most, but it can help avoid trouble, should anything were to happen. There are numerous instances in the literature when companies learned about their suppliers' issues very late prompting emergency response even though appropriate sensors could have provided early warning. In many organizations unfortunately, early warning processing is done purely in an informal manner.

## 7.5. A Path to Effective Risk Management

In this thesis, we have highlighted in an objective manner, what we believe are typical strengths of the supply chain in large successful organizations, from a risk management perspective. We have also identified specific areas where improvements can be driven to make the supply chain even more resilient. We have looked extensively at the literature and drawn conclusions by comparing the state-of-the-art of what is being done in other industries with what we have learned during our case study at a large CPG organization. Some specific recommendations for that organization have been underlined in the case study as "possible actions" and "takeaways". These are the first steps towards improving the overall supply chain risk management practice.

But the core point of our recommendation is aimed at the highest level of the organization. Executives in business units are typically spending relatively small fraction of their time dealing with risks and crises, and that too in a rather informal manner. As a result, in addition to less effective risk informed decisions, opportunities to learn from past disruptions are lost. We strongly believe that a piecemeal approach to enhance supply chain resilience is a risky proposition. Just like manufacturing, risk management is an *evolutionary* process as illustrated in Figure 7 below. The key is in becoming a "learning

organization”<sup>35</sup> with respect to risk management, continuously enhancing its capabilities based on the dynamic external and internal environment.



**Figure 7 – Evolutionary Risk Management Cycle**

To pay due attention to supply chain risk, it should be assigned to a corporate level risk management group and supply chain decision-making process should be redesigned to involve this group. This group should be the formal and central organization that deals with supply chain risks on a full-time basis. We are not advocating that the business units be relieved of this responsibility since operational executives are the ones with the local knowledge of risks and most affected by it. But one team should have the ownership and a holistic view of the system wide supply chain risk that is integrated with other aspects of organizational risk. This organization should be the owner of key processes in order to enable cross-fertilization of ideas between business units and functions to foster faster learning.

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<sup>35</sup> Peter Senge, *The Fifth Discipline: The Art and Practice of The Learning Organization*

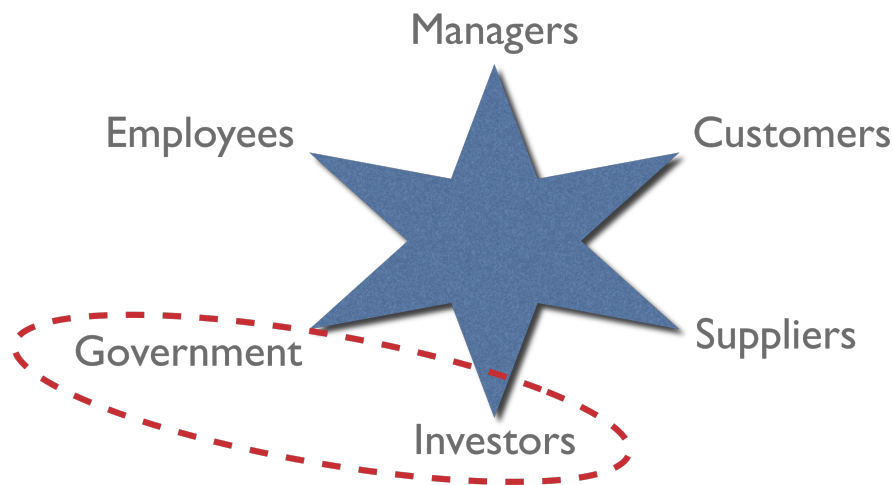
To be successful, a corporate group would require sponsorship from the top management, in addition to active support from the business units, who need to be on board with the new approach to risk management. We are aware that this is a high level idea that could not be achieved overnight in any organization. Above all, it requires a strong cultural shift in addition to the process shift to be effective. However, we strongly believe that this will treat supply chain risk as a part of the sales and supply chain design process, as part of a revenue-generation opportunity rather than a cost center.

Finally, the following table summarizes the ten key elements in supply chain risk management that are part of the change required to achieve the paradigm shift outlined in this thesis.

<b>Before</b>	<b>After</b>
Operational	Strategic
Reactive	Proactive
Anecdotal	Cultural
Isolated	Holistic
Silos	Integrated
Ad hoc	Formalized
Rooted	Evolutionary
Risk Mitigation	Risk Optimization
Risk Avoidance	Risk Portfolio Development
Risk as Cost Burden	Potential for Reward

**Table 5 – Ten Key Elements for Supply Chain Risk Management Evolution**

## 7.6. Bridging the Information Asymmetry Challenge



**Figure 8 – Risk-oriented stakeholder analysis of a company**

Another observation driven by a risk-oriented stakeholder analysis of a company (see Figure 8) is the asymmetry of information between those who own the ultimate responsibility for a company's actions, namely investors and governments, and those who make decisions about risks. Investors and governments are essentially unaware of the risks borne by a company. The reporting requirements that are in place in most developed nations concern essentially financial data, which reflects essentially the near-past performance of a company.

By contrast, there are very little or no requirements regarding the reporting of risks, which affect the future performance of a company. We believe that managers, who take decisions involving risks, should be held accountable for them beyond short-term financial performance. While firms today can find it convenient to be discreet about the risks they are bearing, market or regulations could make "risk reporting" a competitive advantage or even a requirement, something firms should be ready for. Those who take a leadership position in this area may certainly be rewarded for their initial efforts, and we believe it to be an additional motivation for this pursuing further research.



In addition and with a more general goal, we hope that this research will draw interest to the topic of risk in the supply chain and the current lack of accountability, transparency, and information around it. We hope that, over time, along with the traditional financial performance data, risk metrics will also be reported, inside organizations and ultimately outside, leading to information symmetry between stakeholders. While financial information reflects past and present performance, assessing the present risks borne by an organization gives a certain level of information on its *future* performance.

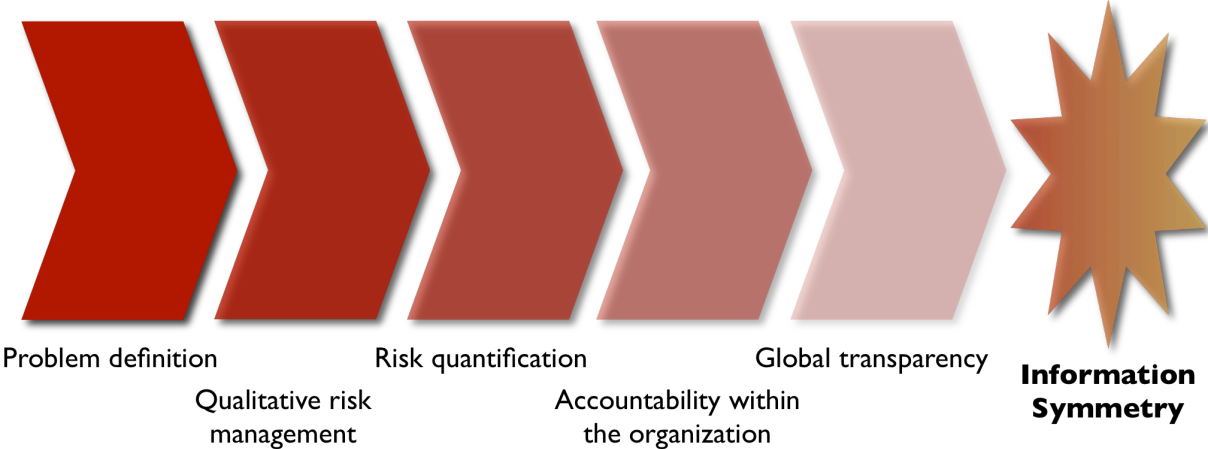


Figure 9 - Research ultimate objective

## Chapter 8. Conclusion and Future Research

Our findings corroborate the general understanding that, although supply chain risk management is gaining significant momentum, few organizations have managed to “walk the talk”, and too often underestimate the value of a formal approach to supply chain risk management.

The research drew from fields outside the normal realm of supply chain risk management. A policy perspective was taken to isolate important drivers of risk that lie beyond the direct control of organizations, such as political uncertainty and regulations. The objective is to promote a more proactive outlook in organizations to anticipate and exploit the uncertainty in the business environment. Similarly, a market perspective was used to articulate a novel way to uncover information asymmetry in the domain of risk management. Instead of simply pointing to asymmetry as an undesirable fact of business world, we proposed two approaches that could be used for developing creative solutions. Specifically, we discuss how prediction markets and credit derivatives concepts can be deployed to level the playing field in the domain of supply chain risk.

We surveyed the state-of-the-art of supply chain risk management by exploring both the qualitative and quantitative sides of risk management in this thesis. We studied, in detail, the reasons why risk is often neglected in organizations, and learned from several conceptual frameworks that have been proposed in the literature. On the more quantitative side, we presented tools that have been used or could be used for supply chain risk management, such as Decision Analysis or Real Options.

We applied our proposed supply chain risk management framework to the case company, focusing primarily on qualitative methods. Data for the analysis was collected by way of semi-structured interviews with business executives and relevant company documents. The results were presented to shed light on the current risk management practices at the company by highlighting their strengths and potential weaknesses.

In conclusion, we argue that *evolutionary risk management processes accompanied by a radical shift in business risk culture are required to achieve competitive advantage through supply chain risk management.*

Future research on this extremely important topic is necessary to promote a disciplined approach to supply chain risk management. The development of a balanced approach integrating qualitative and quantitative models is best suited for the domain of risk management. Another key aspect for the future research effort would be to find ways to promote risk considerations to the strategy level.

## References

- American Society for Quality, *Failure modes and Effect Analysis*, (excerpt from Tague, The Quality Toolbox, 2004), <http://www.asq.org/learn-about-quality/process-analysis-tools/overview/fmea.html> (retrieved December 2007)
- AXA Corporate Solutions, Ernst&Young, *Risk management Practices in 2006: Are you ready for change?*, FERMA survey & seminar, Oct 2006
- Max H. Bazerman and Michael D. Watkins, *Predictable surprises: the disasters you should have seen coming, and how to prevent them*, Harvard Business School Publishing, 2004
- Abby S. Benson, *The Role of Organizational Culture in Creating Secure and Resilient Supply Chains*, 2005 (MST & MLOG)
- Kadi Bouti, *A state-of-the-art review of FMEA/FMECA*, International Journal of Reliability, Quality and Safety Engineering; 1994, 1, 4
- Marion A. Brach, *Real Options in practice*, Wiley, 2003
- Robert T. Clemen, *Making Hard Decisions: An Introduction to Decision Analysis*, Duxbury Press, 1996
- Diane L. Coudu, *How Resilience Works*, Harvard Business Review, May 2002
- Federica Cucchiella and Massimo Gastaldi, *Risk management in supply chain: a real option approach*, Journal of Manufacturing Technology Management, Vol.17 No.6, 2006
- Richard de Neufville, Stephan Scholtes and Tao Wang, *Valuing Options by Spreadsheet: Parking Garage Case Example*, ASCE Journal of Infrastructure Systems, Vol.12 No.2, 2006
- Renée Dye, *The promise of prediction markets: A roundtable*, The McKinsey Quarterly, 2008 No.2
- Edward Erickson: Presentation on Cisco's Supply Chain Risk Management practices, MIT Center for Transportation and Logistics, Supply Chain Frontiers, 2006
- FM Global, *The New Supply Chain Challenge: Risk Management in a Global Economy*, 2006
- Warren Gilchrist, *Modelling failure modes and effects analysis*, International Journal of Quality & Reliability Management, 1993

- Kevin B. Hendricks, *An Empirical Analysis of the Effect of Supply Chain Disruptions on Long-Run Stock Price Performance and Equity Risk of the Firm*, Production and Operations Management Society, Spring 2005
- Kevin B. Hendricks and Vinod R. Singhal, *The effect of supply chain glitches on shareholder wealth*, Journal of Operations Management, Vol.21 No.5, December 2003
- Kevin B. Hendricks and Vinod R. Singhal, *Association Between Supply Chain Glitches and Operating Performance*, Management Science, Vol.51 No.5, May 2005
- KPMG, *Enterprise Risk Management: An emerging model for building shareholder value*, 2001
- Howard C. Kunreuther and Erwann O. Michel-Kerjan, *Climate Change, Insurability of Large Scale Disasters, and the Emerging Liability Challenge*, University of Pennsylvania Law review, Vol.155:1795, 2007
- Garrett J. Lee and Zen-Lee M. Chang, *Supply Chain Disruptions: Managing Risks vs. Managing Crises*, MLOG Thesis, MIT, June 2006
- International Association of Contract and Commercial Managers (IACCM), *Business Risk Management Maturity Model*, 2003
- Kmenta, Fitch, and Ishii, *Advanced Failure Modes and Effects Analysis of Complex Processes*, 1999 ASME Design Engineering Technical Conferences
- Timothy A. Luehrman, *Investment Opportunities as Real Options: Getting Started on the Numbers*, Harvard Business Review, July-August 1998
- Timothy A. Luehrman, *Strategy as a Portfolio of Real Options*, Harvard Business Review, September-October 1998
- Timothy A. Luehrman, *What's It Worth: A General Manager's Guide to Valuation*, Harvard Business Review, May-June 1997
- McKinsey Quarterly, *Understanding Supply Chain Risk: A McKinsey Global Survey*, 2006
- Andreas Norrman and Ulf Jansson, *Ericsson's proactive supply chain risk management approach after a serious sub-supplier accident*, International Journal of Physical Distribution & Logistics Management, Vol.34 No.5, 2004
- Roberto Pinto, *Supply Chain Risk Management: an Introduction*, Risk Central, April 2007

- Charles R. Plott and Kay-Yut Chen, *Information Aggregation Mechanisms: Concept, Design and Implementation for a Sales Forecasting Problem*, California Institute of Technology Social Science Working Paper 1131, March 2002
- Sophie Pochard, *Managing Risks of Supply-Chain Disruptions: Dual Sourcing as a Real Option*, TPP Thesis, MIT, August 2003
- James B. Rice, Jr., *Supply Chain Response to Terrorism: Creating Resilient and Secure Supply Chains*, Supply Chain Response to Terrorism Project, MIT Center for Transportation and Logistics, August 2003
- D.H. Stamatis, *Failure Mode and Effect Analysis: FMEA from Theory to Execution*, American Society for Quality, 2003
- Jeff Tew and Debra Elkins, *Managing Enterprise Risks in Global Automotive Manufacturing Operations*, Government-University-Industry Research Roundtable Meeting, National Academies, Feb 2006
- Anisya Thomas and Lynn Fritz, *Disaster Relief, Inc.*, Harvard Business Review, November 2006
- Goran Svensson, *A conceptual framework for the analysis of vulnerability in supply chains*, International Journal of Physical Distribution & Logistics Management, 2000
- S. Venkatesh and Jayashankar M. Swaminathan, *Managing Product Variety through Postponement: Concept and Applications*, September 2001
- World Economic Forum, *Global Risks 2007: A Global Risk Network Report*, 2007
- Yossi Sheffi, *The resilient enterprise: overcoming vulnerability for competitive advantage*, MIT Press, 2005
- Yossi Sheffi and James B. Rice Jr, *A Supply Chain View of the Resilient Enterprise*, MIT Sloan Management Review, Vol.47 No.1, Fall 2005
- Justin Wolfers and Eric Zitzewitz, *Prediction Markets*, Journal of Economic Perspectives, Spring 2004, Vol.18 No.2
- George A. Zsidisin, Lisa Ellram, Joseph Carter and Joseph Cavinato, *An analysis of supply risk assessment techniques*, International Journal of Physical Distribution & Logistics Management, 2004

# Appendix 1: Interview Guide

## General Questions

- Can you describe briefly your position and responsibilities? What do you do on a day-to-day basis?
- What previous positions did you hold (at CPG Co or elsewhere)?
- Tell me of a specific disruption, relevant to your position, that you can recall in good detail.
  - What happened?
  - Where/When was this?
  - How and from whom did you learn about it?
  - Who did you tell first? To whom must you report disruptions?
  - Were there consequences in other parts of the supply chain, or for other divisions?
  - How did you resolve the problem? Who was involved in the solution, and who was making decisions?
  - What information was needed to solve the problem? Where did it come from, and how quickly?
  - What do you feel the impact of the disruption was?
  - What did you do once things were back in order?
  - What risk procedures are in place to tackle this kind of disruption? In particular, what are you personally required to do when it happens?
  - When the disruption occurred, what was the main thing you were trying to protect?
- If someone comes to you with a project to invest a substantial amount in order to reduce your risk exposure, even if it will not bring any immediate cost savings, how do you take a decision to invest or not?
- How is your activity related to risk and security? How much of your time is devoted to it?
- How has your role changed in the last few years?

*(Lower priority questions)*

- How does the introduction of a new product change your activity? Give me a concrete example from a recent product introduction
- What role does IP play in your position? Give me an example of a recent IP infringement.
- What role does environmental policy play in your position? Give me a recent example that you can recall.
- How sensitive are you to the geopolitical environment? Give me an example of when this mattered.
- How sensitive are you to the availability of natural resources? Give me an example of when scarcity was an issue.
- What are the areas where disruptions happen the most often? Where do you feel that there are some vulnerabilities or bottlenecks in the supply chain?
- We want to know how they perceive the risk procedures and the discrepancies between the procedures and their application.

**Management**

- Can you describe the organizational structure at CPG Co?
- What is the role of the “steering committee”? Who sits in it? What criteria do they take into account?
- What is the history of union relations?
- How is risk included in the discussions?

**Finance**

- Can you recall of an incident where the foreign exchange rate or financial markets were an issue? In general, what do you feel is your vulnerability to financial markets or foreign exchange rates?
- How do you evaluate the financial impact of supply chain disruptions?
- Give me an example of a recent disruption or near-miss that you had to evaluate.
- What insurance coverage do you have? How do you manage it? Who is responsible for it?



*(Lower priority)*

- How much do you feel that the fluctuation in finances can be attributed to external factors (e.g. unexpected changes in markets) even if they did not result in an actual disruption?

## **Operations**

### **Procurement**

- How many suppliers do you have per item?
- How do you qualify your suppliers? Tell me about the last time you qualified a supplier.
  - How does that change between items that are sole-sources, single-sourced or dual-sourced?
  - How does your supplier relationship change depending on the type of supplier?
  - How do you monitor the activity and the financial health of your supplier?
  - How do you evaluate the risks borne by your suppliers?
- How much did it cost the last time you brought a new supplier or switched suppliers?
- Are you using any special raw materials that mean specific constraints?
- Can some parts be substituted to each other?
- Tell me about quality problems that you had in the past.

### **Manufacturing / Packaging**

- Tell me about your manufacturing / packaging locations and the flows of products?
- How do you allocate production between the facilities?
- What is the flexibility between products on various lines?
- What does it take to modify part of the process?
- Tell me about a recent accident in a facility. What safety programs and safety issues do you have?
- Tell me about a recent maintenance issue.
- Tell me about the last time you had an IT problem or you changed anything in your IT systems.

- What do you outsource and what would you outsource?
- What would you never outsource?

### **Distribution**

- Do you have an internal fleet or do you use 3PL?
- How do you qualify transporters?
- Do you track on-time delivery? How? If not, what made you take that decision?
- Why are you using different kinds of transporters in different regions? What drives this decision?
- How do you handle theft or shrinkage? Tell me about the last time there was such an issue.
- How about counterfeiting? Tell me about the last time this issue came up.
- How do customs and border crossings in general contribute to creating issues in your supply chain?

### **Network Design**

- What are the primary objectives of the supply chain?
  - How would you like it to be?
- What is the last thing that you added or changed to your supply chain?
  - How was the decision made?
  - Who makes such decisions?
- How and at what level do you monitor your supply chain's performance?
- What are your inventory policies? (for raw materials, finished inventory, etc.)

### **Research & Development**

- How often do you introduce new products or modify existing products?
- What changes does it bring to the supply chain?

### **Risk Management**

- What is the size of the risk management group? Who is involved?
- What are the current risk management processes and methods in place?
- Do you have a cross-divisional disruption or incident reporting system in place?
- What areas of CPG Co is risk management focusing on?
- What historical data do you have about disruptions?
- What is your insurance coverage strategy? How do you manage it? Who is responsible for it?
- Can you give us an example of recent decisions that were made to hedge against risks in the supply chain, and the key criteria that were used to evaluate the decision?
- How does risk management relate to business continuity planning?
  - Can you give me a specific example when BCP was helpful?
  - How do you measure the efficacy of BCP?
  - How do you update BCP processes?
  - What are the fire safety policies?
- How do you handle Sarbanes-Oxley compliance? What information must you retain and report regarding disruptions and the associated losses?

### **Customer Groups**

- Do customers have exceptional constraints or requests that impact the supply chain design?
- How do you forecast demand and with what accuracy?

### **Thanks / Closure**

- Is there anything that we left out or overlooked and that you think might be important for us to know for our research?
- Do you have any questions about the project?
- Thank you for your time, your patience and candidness in answering our questions.
- Would you mind answering a couple more questions, by e-mail or over the phone, if we find that we left something out?

## Appendix 2: Decision Analysis Example

Let us illustrate Decision Analysis approach by looking at a simplified investment decision faced by an entrepreneur. Let us assume that our entrepreneur has purchased land in an area of town that starts to develop commercially with the idea to build a parking garage.

The success of the commercial development in the area, however, is unsure. The entrepreneur wonders if he should build a small parking garage (4 floors) or a large one (8 floors). Each alternative comes with a specific cost and benefit profile along with associated uncertainty. Specific details of the two alternatives are as follows:

- The small garage requires a lower upfront investment, and lower yearly maintenance costs. If demand is low, then the net revenue will be limited because the initial investment is quite small. However, the revenues from a small garage are capped: even if demand for parking is high, there will only be so many spots that can be filled every day (and customers may become frustrated if the garage is consistently full).
- By contrast, the large garage requires a significantly larger upfront investment, and higher yearly maintenance costs. The large garage generates significantly higher revenue, provided the demand for parking is high. However, if demand is low, the entrepreneur will incur losses due to under utilization of the parking capacity.

At this point in time and with the available information, our entrepreneur estimates that there is a 40% chance of the demand for parking being low in this area in the future, and a 60% chance of demand being high.

These alternatives can be analyzed by developing a Decision Tree of the two investment opportunities. Assuming building costs and profit/loss figures under the two scenarios, we can build a Decision Tree as shown in Table 6 below.

In this simplified case, the first alternative (build small) has an expected value of:

$$\$20M * 0.6 - \$2M * 0.4 - \$8M = \$3.2M$$

The second alternative (build big) has an expected value of:

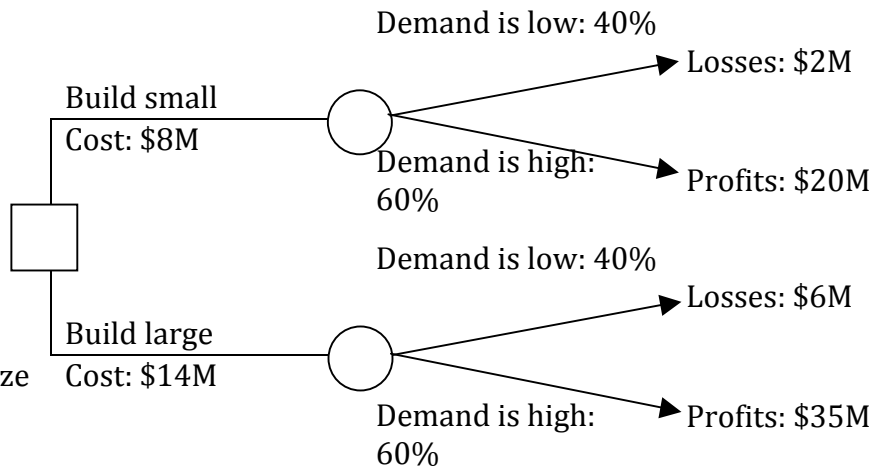
$$\$35M * 0.6 - \$6M * 0.4 - \$14M = \$0.6M$$

The solution maximizing the expected value in that case is therefore to build a small garage rather than a big one. Even though the profits of a large garage would be much higher if the demand is high, the risk borne with a large garage if demand is low is too high to be acceptable.

Decisions and Objectives	Alternatives	Probabilities	Consequences (present value)
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Decision: Build small or large parking garage?

Objective: Maximize the total future expected value



**Table 6 - Decision Tree**

## Appendix 3: Real Options Example

Let us revisit our entrepreneur's parking garage decision and use the Real Options approach. By thinking in terms of postponement of decision as much as possible without sacrificing the future, we can think of a new and intuitive alternative of option to extend along with the previous two alternatives. The logic of the new **option to extend** is as follows:

- build a small garage initially (4 floors), but with strong enough building foundations to support an additional 4 floors in the future, if needed
- a few years later, as the parking demand becomes clear based on the commercial development of the area, the entrepreneur can decide to:
  - **expand the garage** by building the additional 4 floors on top of the strong foundations, if demand is high;
  - **keep the garage as is**, incurring no additional costs, if demand is low.

Building a small garage with strong foundations is of course more expensive than just the small garage. We can assume that it costs \$10M. The additional initial cost of building the small garage (\$2M in our case) would be the options **premium**, i.e. the additional cost paid upfront that allows us to defer, therefore capturing the value of the flexibility of this strategy.

In the Real Options terms, the **underlying asset** on which we are buying an option is the garage expansion i.e. capacity. Finally, the **exercise price** of the option is the cost of expanding the garage, an assumed present value of \$4M.

Let us now look at the financial outcome of this option strategy, using similar figures as presented in the decision analysis example:

- if demand is low, then the building costs of the small garage with strong foundations will be \$10M, but the operating losses will only be \$2M as earlier, or a total net present loss of \$12M.

- if demand is high, then our entrepreneur will choose to expand the garage at the opportune time (once he is sure that demand will be high). The total present costs of construction are  $\$10\text{M} + \$4\text{M} = \$14\text{M}$ . The profits will be assumed to be  $\$33\text{M}$  (lower than our previous “build large” case, because we can reasonably assume that some sales are lost while the extension is being built). This brings a net present profit of  $\$33\text{M} - \$14\text{M} = \$19\text{M}$ .

If we make a similar expected value calculation, from today’s point of view (i.e. a 40% chance of a low demand and a 60% chance of a high demand), the expected value of our Real Option strategy is  $\$19\text{M} \times 0.6 - \$14\text{M} \times 0.4 = \mathbf{\$5.8\text{M}}$ . This is clearly higher than the expected values of both previous inflexible strategies (build large:  $\$0.6\text{M}$  profits; build small:  $\$3.2\text{M}$  profits).

The Real Options framework bring the best of both worlds: by having a flexible strategy, we are effectively reducing the risk of a very large loss, while keeping open the possibility to yield large profits when possible. This is the **value of flexibility**.

We should however note that expected value calculation, as it was made in the previous section for immediate decision-making with static strategies, is not an accurate and complete way to evaluate real options. Because we are looking at a decision that will be made in the future from today’s perspective, we are undervaluing flexibility. In reality, following our simple example, the decision to expand or not will be made in the future, using newly acquired information about the market, so that the chances of success of this strategy are much higher than if we were to take the decision immediately. In addition, we are not evaluating the possibility that the market may eventually be slower than expected and take a long time to grow. With the flexible strategy, we could imagine keeping the small design for ten or more years, and only then expand the garage when conditions become favorable: in this case, the option to expand has no limitation in time.