3
Supply Chain Risk Management (SCRM)

This chapter is divided in four main sections. First SCRM and constructs are defined, as it is crucial for any study dealing with risk to define the term appropriately (Wagner & Bode, 2006). Then advances on SCRM are presented based on key contributions in the field, what provides a basis for synthesizing the concept and to support the empirical studies regarding risk in SCs. Subsequently, previous contributions on SCRM are discussed, and gaps in the current context are highlighted.

3.1.
Supply Chain Risk Management Concept

The term 'risk' is normally associated with uncertainty (Zsidisin, 2003b; Jüttner et al., 2003) and can be defined as the expected outcome of an uncertain episode, i.e., uncertainty leads to the existence of risks (Manuj & Mentzer, 2008). The term risk is an elusive construct with a variety of meanings, measurements, and interpretations depending on the field of research (Wagner & Bode, 2006). At an academic level, a growing body of research on risk has emerged from a number of different fields, such as accounting, finance, economics, marketing, business, logistics, and psychology (Zsidisin, 2003b, Jüttner, 2005; Wagner & Bode, 2006).

The present study is focused on the SC field. From this perspective, risk refers to the possibility and effects of a mismatch between supply and demand that create a SC interruption (Tang & Musa, 2011), embracing the information, material, and product flows from the original supplier to the delivery of the final product to the end-user (Jüttner et al., 2003).

Main SCRM definitions are depicted in Table 3. The first column displays the considered references, while the second presents the definitions themselves

and the third provides the other papers that have adopted the mentioned definition in their work.

Reference	Definition of SCRM	Papers that adopted the definition
Jüttner et al. (2003)	SCRM is defined as the identification and management of risks for the supply chain, through a co-ordinated approach amongst supply chain members to reduce supply chain vulnerability as a whole.	Jüttner (2005); Gaudenzi & Borghese (2006); Williams et al. (2008); Khan & Pillania (2008); Ponomarov & Holcomb (2009); Yu et al. (2009); Colicchia et al. (2010), Jia & Rutherford (2010), Jüttner & Maklan (2011); Thun & Hoenig (2011); Zhang et al., (2011) Yang, (2011;) Vilko & Hallikas (2011); Colicchia et al. (2011); Lavastre et al. (2012); Colicchia & Strozzi (2012).
Norrman & Lindroth (2002)	SCRM is to [collaborate] with partners in a supply chain risk management process tools to deal with risks and uncertainties caused by, or impacting on, logistics related activities or resources.	Norrman & Jansson (2004); Faisal et al. (2006).
Tang, C. S (2006)	SCRM is defined as The management of supply chain risk through coordination or collaboration among the supply chain partners so as to ensure profitability and continuity"	Cheng, S. & Kam (2008); Blos et al. (2009); Micheli et al. (2008); Yu et al. (2009); Schmitt & Snyder (2012); Sun et al. (2012)
Norrman & Jansson (2004)	The focus of SC risk management is to understand, and try to avoid, the devastating effects that disasters or even minor business disruptions can have in a SC. The aim of SC risk management is to reduce the probability of risk events occurring and to increase resilience, that is, the capability to recover from a disruption.	Ponomarov & Holcomb (2009); Pujawan & Geraldin (2009)
Giunipero & Eltantawy (2004)	SCRM is a formal process that involves identifying potential losses, understanding the likelihood of potential losses, and assigning significance to	Lockamy & McCormack (2012)

	these losses	
Supply chain Concil (2008)	SCRM is the systematic identification, assessment and mitigation of potential disruptions in logistics networks with the objective to reduce their negative impact on the logistics network's performance	Reniersa et al. (2012)
Manuj & Mentzer (2008)	Global SCRM is the identification and evaluation of risks and consequent losses in the global supply chain, and implementation of appropriate strategies through a coordinated approach among supply chain members with the objective of reducing one or more of the following – losses, risk probability, speed of event, speed of losses, the time for detection of the events, frequency, or exposure – for supply chain outcomes that in turn lead to close matching of actual cost savings and profitability with those desired.	Ponomarov & Holcomb (2009); Christopher et al. (2011)
Goh et al. (2007)	SCRM is defined as the identification and management of risks within the supply network and externally through a co-ordinated approach amongst supply chain members to reduce supply chain vulnerability as a whole.	
Lavastre et al. (2012)	SCRM refers to risks that can modify or prevent part of the movement and efficient flow of information, materials and products between the actors of a supply chain within an organization, or among actors in a global supply chain (from the supplier's supplier to the customer's customer). SCRM can be seen as the capacity to be agile, as it is viewed as a risk management initiative that enables a firm to respond rapidly to market changes, as well as to potential	

	and actual disruptions in the supply chain.	
Tummala & Schoenherr (2011)	SCRM process is a tool to provide management with useful and strategic information concerning the SC risk profiles associated with a given situation. This is in contrast to the traditional approach based on single point estimates. The SCRM process ensures SC managers adopt strategic thinking and strategic decision making in evaluating options to improve supply chain performance.	

Table 1- Main SCRM definitions

One of the first definitions of SCRM was offered in Jüttner et al. (2003). The authors defined SCRM as the identification and management of risks for the SC through a coordinated approach amongst SC members in order to reduce SC vulnerability as a whole; however, the literature offers other definitions. As presented in table 3, many of the literature definitions embrace the concepts of vulnerability and resilience, where the first is understood as the susceptibility of the SC to the likelihood and consequences of disruptions (Blos et al., 2009) and the second as the adaptive capability of the SC to prepare for unexpected events, respond to disruptions, and recover from them by maintaining the continuity of operations at the desired level of connectedness and control over structure and function (Ponomarov & Holcomb, 2009).

3.1.1.
Synthesis for the definition

Based on Table 3, SCRM can be synthesised as the management of risks for a SC through a coordinated approach amongst SC members to reduce SC vulnerability overall (Jüttner et al., 2003; Jüttner, 2005; Tang, 2006; Gaudenzi & Borghese, 2006; Goh et al., 2007; Williams et al., 2008; Micheli et al., 2008;

Khan & Pillania, 2008; Manuj & Mentzer, 2008; Blos et al. 2009, Ponomarov & Holcomb, 2009; Colicchia et al., 2010; Jia & Rutherford, 2010; Christopher et al., 2011; Jüttner & Maklan, 2011; Thun & Hoenig, 2011; Vilko & Hallikas, 2011; Colicchia et al. 2011; Zhang et al., 2011; Yang, 2011; Colicchia & Strozzi, 2012; Lavastre et al., 2012; Schmitt & Snyder, 2012; Sun et al., 2012) and to increase resilience (Norrman & Jansson, 2004; Faisal et al., 2006; Khan & Pillania, 2008; Ponomarov & Holcomb, 2008; Pujawan & Geraldin, 2009). SCRM seeks to minimise, monitor, and control the probability and impacts of uncertain disruptive events (Pujawan & Geraldin, 2009; Lockamy III & McCormack, 2012) and to ensure performance (Manuj & Mentzer, 2008; Christopher et al., 2011; Tummala & Schoenherr 2011; Reniersa et al. 2012), profitability, and continuity (Tang, 2006; Manuj & Mentzer, 2008; Micheli et al., 2008; Cheng & Kam, 2008; Yu et al., 2009; Blos et al., 2009; Christopher et al., 2011).

3.2.
Supply Chain Risk Management Main Constructs

According to Jüttner et al. (2003) and Gaonkar & Viswanadham (2007), four main constructs constitute SC risk: risk drivers, risk sources, risk consequences, and risk-mitigation strategies. These risk constructs will be discussed in turn. It is important to notice that, within a SC, a risk consequence of one company can be a risk source for another at the same time, such that the constructs can propagate and 'multi-tier cause-and-effect chains' can occur. Therefore, the classification of risk constructs is always subject to perspective, but is important to notice the influence between them, as proposed by Jüttner et al. (2003), once drives impact on the sources that can promote undesired consequences that need to be mitigated. With the intention of effectively treating risks, it is essential to understand the relationships between the constructs, usually done during the identification phase, to apply the correct mitigation strategies.

3.2.1.
Supply Chain Risk Drivers

Some developments have forced companies to change their way of doing business in order to maintain the competitiveness of their supply chain (Thun & Hoenig, 2011), in this sense this research follows Jüttner et al. (2003) and Wagner & Bode (2006) defining risk drivers as how certain trends in a contemporary SCM that are responses to competitive pressures might increase or decrease the vulnerability of the SC. These trends provide the conditions upon which successful companies base their competitive advantages and distinctiveness (Pfohl et al., 2010). Drivers are recognized as competitive pressures with risk source implications, where risk drivers impact the probabilities of risk sources (Ritchie & Brindley, 2007). Examples of risk drivers from the literature are listed in Table 4.

Risk Drivers	References
Globalization	Huchzermeier & Cohen (1996); Cohen & Huchzermeier (1999); Novaes (2000); Harland et al. (2003); Novaes & Souza (2005); Jüttner et al. (2003); Norrman & Jansson (2004); Jüttner (2005); Tang (2006); Pfohl et al. (2010); Thun & Hoenig (2011); Thun et al. (2011); Lavastre et al. (2012).
Product variants	Harland et al. (2003); Pfohl et al. (2010); Thun & Hoenig (2011); Thun et al. (2011).
Outsourcing	Harland et al. (2003); Jüttner et al. (2003); Norrman & Jansson (2004); Jüttner (2005); Wu & Olson (2008); Pfohl et al. (2010); Thun & Hoenig (2011); Thun et al. (2011); Lavastre et al. (2012).
Global sourcing	Wagner & Bode (2006); Zsidisin (2003a); Chopra & Sodhi (2004); Wagner & Neshat (2012).
Reduction of the supplier base / supplier concentration	Jüttner et al. (2003); Norrman & Jansson (2004); Jüttner (2005); Wagner & Bode (2006); Thun & Hoenig (2011); Thun et al. (2011); Wagner & Neshat (2012); Lavastre et al. (2012).
Focus on efficiency	Norrman & Jansson (2004); Sheffi (2005); Jüttner (2005); Tang (2006); Pfohl et al. (2010); Thun & Hoenig (2011); Thun et al. 2011; Lavastre et al. (2012); Wagner & Neshat (2012).
Partnerships and other close relationships	Jüttner et al. (2003); Zsidisin et al. (2004).
Centralized distribution	Jüttner et al. (2003); Jüttner (2005); Pfohl et al. (2010); Thun & Hoenig (2011); Thun et al. (2011): Lavastre et al. (2012).

Centralized production	Jüttner (2005); Pfohl et al. (2010); Thun & Hoenig (2011); Thun et al. (2011); Lavastre et al. (2012).
Supplier dependence	Giunipero & Eltantawy (2004); Jüttner (2005); Spekman & Davis (2004); Svensson (2004) Wagner & Bode (2006); Khan et al. (2008); Wagner & Neshat (2012); Grötsch et al. (2013).
Customer dependence	Hallikas et al. (2005); Svensson (2004) Wagner & Bode (2006) Wagner & Neshat (2012).

Table 2- Risk Drivers

3.2.2.
Supply Chain Risk Sources

Risk sources are any variables that cannot be predicted with certainty and from which disruptions can emerge that affect the SC outcome variables (Jüttner et al., 2003; Faisal et al., 2006). The literature offers many different categories into which risk sources can be grouped. The typology adopted herein is based on Miller (1992), Jüttner et al. (2003), Ritchie & Brindley (2007), and Rao & Goldsby (2009) and groups risk sources into organizational (inside the firm), network related (beyond the frontiers of the firm including its SC), industrial, and environmental risks. They are presented in Tables 5, 6, 7 and 8 together with examples of risk sources.

Organizational Risk Sources	**References**
Operating uncertainties: labor uncertainty (labor unrest, strikes, and employee safety), input supply uncertainty (raw material shortages, quality changes, and spare parts restrictions); IT system uncertainties; and production uncertainty (machine failures).	Ghoshal, 1987; Miller (1992); Novaes (2000); Jüttner et al. (2003); Chopra & Sodhi (2004); Christopher & Peck (2004); Jüttner (2005); Zeng et al. (2005); Wagner & Bode (2006); Cucchiella & Gastaldi (2006); Wu et al. (2006); Manuj & Mentzer (2008); Rao & Goldsby (2009); Thun & Hoenig (2011); Sofyalıoğlu & Kartal (2012).
Liability uncertainties: unanticipated harmful effects due to the production or consumption of a company's product (product liability, emission of pollutants).	Miller (1992); Rao & Goldsby (2009).
R&D uncertainty: uncertain results from R&D activities.	Miller (1992); Blos et al. (2009).

Credit uncertainty: problems with collectibles. Default by clients on their debts to a firm can be a direct cause of variations in the firm's income stream. These can delay payments to the other SC members, creating a cycle that is difficult to resolve.	Miller (1992); Rao & Goldsby (2009); Blos et al. (2009).
Behavioural uncertainty: managerial or employee self-interested behaviour.	Miller (1992); Manuj & Mentzer (2008); Rao & Goldsby (2009); Thun & Hoenig (2011).

Table 3- Organizational Risk Sources

Network Related Risk Sources	**References**
Lack of ownership: results from blurring boundaries between buyers and suppliers in the chain.	Jüttner et al. (2003).
Chaos or well-known bullwhip effect: increasing fluctuations of order patterns from downstream to upstream SCs.	Jüttner et al. (2003).
Inertia: a general lack of responsiveness to changing environmental conditions and market signals.	Jüttner et al. (2003).
Supply risks: various events that affect the continuity of the supplier and result in the temporary or permanent perturbation or termination of the buyer-supplier relationship, i.e., the transpiration of significant and/or disappointing failures with inbound goods and services	Cohen & Huchzermeier (1999); Novaes (2000); Jüttner (2005); Cucchiella & Gastaldi (2006); Wagner & Bode (2006); Manuj & Mentzer (2008); Blos et al. (2009); Thun & Hoenig (2011); Lavastre et al. (2012); Sofyalıoğlu & Kartal (2012).
Demand risk: risk associated with the outbound logistics flows and product demand, which can be caused either by inbound disruptions or,e.g.,volatility of fads, new product adoptions or short product life cycles.	Cohen & Huchzermeier (1999); Novaes (2000); Novaes & Souza (2005); Jüttner (2005); Wagner & Bode (2006); Manuj & Mentzer (2008); Thun & Hoenig (2011); Lavastre et al. (2012); Sofyalıoğlu & Kartal (2012).

Table 4- Network Related Risk Sources

Industry Risk Sources	**References**
Input market uncertainty: industry-level uncertainties surrounding the acquisition of	Miller (1992); Zsidisin (2003a); Rao & Goldsby (2009); Thun & Hoenig (2011).

adequate quantities and qualities of inputs into the production process.	
Product market uncertainty: unexpected changes in the demand for an industry's output due to, e.g., changes in consumer tastes, availability of substitute goods, and scarcity of complementary goods.	Miller (1992); Chopra & Sodhi (2004); Jüttner (2005) Wagner & Bode (2006); Wu, et al. (2006); Manuj & Mentzer (2008); Rao & Goldsby (2009); Thun & Hoenig (2011).
Competitive uncertainty: uncertainties associated with rivalry among existing firms, potential entrants into the industry, and technological uncertainty in product and process innovations.	Miller (1992); Cohen & Huchzermeier (1999); Chen & Paulraj (2004); Li & Lin (2006); Cucchiella & Gastaldi (2006); Rao & Goldsby (2009); Blos et al. (2009).

Table 5- Industry Risk Sources

Environmental Risk Sources	**References**
Political uncertainties: context of major changes in political regimes (war, revolution, democratic changes in government, or other political turmoil).	Miller (1992); Jüttner et al. (2003); Chopra & Sodhi (2004); Christopher & Peck (2004); Jüttner (2005); Zeng et al. (2005); Wagner & Bode (2006); Wu et al. (2006); Manuj & Mentzer (2008); Rao & Goldsby (2009); Thun & Hoenig (2011); Sofyalıoğlu & Kartal (2012).
Government policy uncertainties: government policy changes that impact the business community (fiscal and monetary reforms, price controls, trade restrictions, nationalization, government regulation, or barriers to earnings repatriation).	Miller (1992); Cohen & Huchzermeier (1999); Novaes (2000); Christopher & Peck (2004); Cucchiella & Gastaldi (2006); Rao & Goldsby (2009); Thun & Hoenig (2011).
Macroeconomic uncertainties: fluctuations in the level of economic activity and prices (inflation, changes in relative prices, foreign exchange rates, interest rates, or terms of trade).	Miller (1992); Huchzermeier & Cohen (1994); Cohen & Huchzermeier (1999). Novaes (2000); Chopra & Sodhi (2004); Christopher & Peck (2004); Zeng et al. (2005); Novaes & Souza (2005); Cucchiella & Gastaldi (2006); Rao & Goldsby (2009); Trkman & McCormack (2009); Blos et al. (2009); Sofyalıoğlu & Kartal (2012).
Social uncertainties: occurs when the beliefs, values, and attitudes of the population are not reflected in the current government policy or business practice (changing social concerns,	Miller (1992); Jüttner et al. (2003); Chopra & Sodhi (2004); Christopher & Peck (2004); Jüttner (2005); Wagner & Bode (2006); Rao & Goldsby (2009); Trkman & McCormack

social unrest, demonstrations, terrorist attacks).	(2009); Blos et al. (2009); Thun & Hoenig (2011); Sofyalıoğlu & Kartal (2012).
Natural uncertainties: various phenomena that could impair business functions and decrease the productive capacity of firms operating in the affected region (variations in rainfall, floods, fire, extreme weather, hurricanes, earthquakes, other natural disasters).	Miller (1992); Jüttner et al. (2003); Chopra & Sodhi (2004); Christopher & Peck (2004); Zeng et al. (2005); Jüttner (2005); Wagner & Bode (2006); Wu et al. (2006) Rao & Goldsby (2009); Blos et al. (2009); Thun & Hoenig (2011); Sofyalıoğlu & Kartal (2012).

Table 6- Environmental Risk Sources

These sources are represented in a SC as risk events that impact the entire SC (Leão et al., 2011; Cagliano et al., 2012; Xanthopoulos et al., 2012), in which risk events can be defined as the manifestations of uncertainties that pose the threat of interrupting SC operation (Huang et al., 2009; Leão et al., 2011).

3.2.3. Risk Consequences

Risk consequences are the focused SC objectives, such as costs or quality, which are the different forms in which the objectives may be manifested (Jüttner et al., 2003). They have an effect on a SC's ability to continue operations, get finished goods to market or provide critical services to customers (Jüttner, 2005). They affect the ability of the focal firm to meet customer demands (in terms of both quantity and quality) within anticipated costs and time or may cause threats to customer lives and safety (Manuj & Mentzer, 2008). The literature identifies different consequences, ranging from financial consequences through reputation damage to delays in customer deliveries, as presented in Table 9.

Risk Consequences	**References**
Sales losses	Jüttner et al. (2003); Zsidisin (2003b).
Cost increases	Jüttner et al. (2003); Schmitt & Snyder (2012).
Financial losses	Goldberg et al. (1999); Harland et al. (2003); Jüttner et al. (2003); Zsidisin (2003b); Ritchie & Brindley (2007).
Product quality reduction / losses	Jüttner et al. (2003); Zsidisin (2003b).
Social losses	Harland et al. (2003).

Threats to customer life and safety	Goldberg et al. (1999); Harland et al. (2003); Jüttner et al. (2003); Zsidisin (2003b); Manuj & Mentzer (2008).
Negative corporate image or reputation damage	Goldberg et al. (1999); Harland et al. (2003); Jüttner et al. (2003).
Delays in customer deliveries	Harland et al. (2003); Wu et al. (2006); Manuj & Mentzer (2008); Blos et al. **(**2009**).**

Table 7- Risk Consequences

3.2.4.
Risk Mitigation Strategies

These strategies are actions that deliberately move organisations to mitigate the uncertainties identified from the various risk sources (Miller, 1992). These strategies can be grouped into six different categories (based on Miller, 1992): Financial Risk Management; Avoidance, when the risks associated with operating in a given product market or geographical area considered unacceptable; Control; Cooperation, involving joint agreements rather than unilateral control as a means of reducing uncertainty; Imitation, following competitors' strategies as a means of coping with uncertainty; and Flexibility. Table 10 summarises the main strategies.

Category	**Risk mitigation strategies**	**References**
Financial Risk Management	Insurance	Miller (1992).
	Forward of futures contracts	Miller (1992).
	Real options approach	Huchzermeier & Cohen (1996); Cohen & Huchzermeier (1999); Novaes (2000); Novaes & Souza (2005); Cucchiella & Gastaldi (2006).
Avoidance	Dropping specific products / geographical markets / supplier or customer organisations	Huchzermeier & Cohen (1996); Cohen & Huchzermeier (1999); Novaes (2000); Novaes & Souza (2005); Jüttner et al. (2003); Thun & Hoenig (2011); Thun et al. (2011); Sofyalıoğlu & Kartal (2012).
	Delay new market entry	Miller (1992); Sofyalıoğlu & Kartal (2012).
	Vendor selection methodologies	Wu & Olson (2008); Sawik (2011).

Control	Vertical integration	Miller (1992); Jüttner et al. (2003); Sofyalıoğlu & Kartal (2012).
	Horizontal mergers and acquisitions	Miller (1992).
	Inventory system: increased stockpiling and the use of buffer inventory	Jüttner et al. (2003); Chopra & Sodhi (2004); Byrne (2005); Sheffi & Rice (2005); Tomlin (2006); Thun & Hoenig (2011); Thun et al. (2011); Lavastre et al. (2012); Schmitt & Snyder (2012).
	Maintaining excess capacity in productions, storage, handling and / or transport	Huchzermeier & Cohen (1996); Cohen & Huchzermeier (1999); Novaes (2000); Novaes & Souza (2005); Jüttner et al. (2003); Chopra & Sodhi (2004); Byrne (2005); Sheffi & Rice (2005); Thun et al. (2011).
	Imposing contractual obligations on suppliers and customers	Jüttner et al. (2003); Lavastre et al. (2012).
	Gain market power	Miller (1992).
	Long-term contractual agreements and commitments with suppliers and customers	Miller (1992); Swink & Zsidisin (2006); Lavastre et al. (2012); Sofyalıoğlu & Kartal (2012); Grötsch et al. (2013).
Cooperation	Collaborative relationship management (e.g., partnerships, alliances or joint-ventures)	Miller (1992); Giunipero & Eltantawy (2004); Faisal et al. (2006); Ritchie & Brindley (2007); Trkman & McCormack (2009).
	Joint efforts to improve visibility, transparency, information transmission / sharing, and understanding within SC	Jüttner et al. (2003); Speckman & Davis (2004); Byrne (2005); Sheffi & Rice (2005); Faisal et al., (2006); Ritchie & Brindley (2007); Thun et al. (2011); Lavastre et al. (2012).
	Risk sharing	Jüttner et al. (2003); Speckman & Davis (2004); Faisal et al., (2006).
	Aligning incentives and revenue sharing policies in a SC	Speckman & Davis (2004) Faisal et al., (2006).
	Joint efforts to prepare SC continuity plans	Jüttner et al. (2003); Tomlin (2006). Lavastre et al. (2012).
Imitation	Imitation of product and process technologies	Miller (1992).

	Follow other firms in moving into new markets	Miller (1992).
Flexibility	Product diversification	Miller (1992); Huchzermeier & Cohen (1996).
	Geographic diversification	Miller (1992); Huchzermeier & Cohen (1996); Cohen & Huchzermeier (1999); Novaes (2000).
	Increase overall flexibility	Chopra & Sodhi (2004); Byrne (2005); Sheffi & Rice (2005).
	Flexible input sourcing (e.g., dual sourcing and multiple sourcing)	Miller (1992); Miller (1992); Huchzermeier & Cohen (1996); Cohen & Huchzermeier (1999); Novaes (2000); Jüttner et al. (2003); Chopra & Sodhi (2004); Byrne (2005); Sheffi & Rice (2005); Tomlin & Wang (2005); Tang & Tomlin (2008); Thun & Hoenig (2011); Thun et al. (2011); Lavastre et al. (2012); Sofyalıoğlu & Kartal (2012).
	Back-up supplier	Tomlin (2006); Chopra et al. (2007).
	Localized sourcing	Jüttner et al. (2003).
	Flexible work force size and skills, plants and equipment	Miller (1992); Huchzermeier & Cohen (1996); Cohen & Huchzermeier (1999); Novaes (2000).
	Multinational production	Miller (1992).
	Postponement	Miller (1992); Cohen & Huchzermeier (1999); Novaes (2000); Novaes & Souza (2005); Jüttner (2005); Sofyalıoğlu & Kartal (2012).
	Flexible supply contracts	Jüttner et al. (2003); Tang & Tomlin (2008).
	Flexible manufacturing	Huchzermeier & Cohen (1996); Cohen & Huchzermeier (1999); Novaes (2000); Tang & Tomlin (2008).
	Flexible distribution	Huchzermeier & Cohen (1996); Cohen & Huchzermeier (1999), Novaes (2000).

Table 8- Risk Mitigation Strategies

3.3. Advances on Supply Chain Risk Management

The literature review presents several different frameworks and tools to manage risk in SCs. This section presents an overview of the different phases and tools used in order to implement the SCRM. Table 11 summarizes the main phases presented by the literature, as well as in the last column the industry sector used in the application of the respective study (whenever there were any application). Each phase will be discussed in turn.

References	Context analysis	Identification	Assessment	Selection and Implementation of Risk Treatment Strategy	Control	Monitoring	Studied Industry
Hallikas et al. (2002)		x	x				Electronic and metal
Harland et al. (2003)	X	x	x	x			Electronic
Hallikas et al. (2004)		x	x	x		x	
Norrman & Jansson (2004)	X	x	x	x	x	x	Telecom
Kleindorfer & Saad (2005)		x	x	x			Chemical
Cucchiella & Gastaldi (2006)	X	x	x	x			
Ritchie & Brindley (2007)		x	x	x			Agricultural/construction
Manuj & Mentzer (2008)	X	x	x	x			
Adhitya et al.(2008)	X	x	x	x		x	Refinery
Pujawan & Geraldin (2009)	X	x	x			x	Government-owned fertilizer company
Oehnen (2009)	X	x	x	x	x	x	Manufacturer of precision instruments, manufacturer of precision electromechanical devices, engineering and sourcing services
Tuncel & Alpan (2010)		x	x	x		x	Food
Giannakis & Louis (2011)		x	x	x		x	
Blome & Schoenherr (2011)		x	x	x		x	Banking, logistics, insurance, automotive
Tummala & Schoenherr (2011)	X	x	x	x	x	x	
Kern et al. (2012)		x	x	x	x	x	Mid-sized manufacturing companies
Ghadge, et al. (2013)		x	x	x			Aerospace and Defense organization in the UK
Hachicha & Elmsalmi (2013)		x	x	x		x	Food industry
Elleuch et al. (2014)		x	x	x		x	Hospital pharmaceutical

Table 9- SCRM phases and applied industry

3.3.1.
Context Analysis

The supply network context analysis is defined by the problem or concern. This analysis involves the understanding of who owns what, and what are the key measures currently in place. During the SCRM process, only those members with a significant potential loss to any member in the network should be considered (Harland et al., 2003). Oehnen et al. (2009) define in this phase the delimitation of the scope, regarding causes and consequences among the SC members. The context analysis is finalized to an examination of the network structure, to define the most suitable performance measure and to delaine the responsibility inside the structure (Cucchiella & Gastaldi, 2006).

The literature suggests during this phase the creation of the diagrammatical representation of the supply network enriched with appropriate data, through a SC Risk Map (Harland et al., 2003; Norrman & Jansson, 2004; Adhitya et al., 2008; Manuj & Mentzer, 2008; Oehnen et al., 2009; Pujawan & Geraldin, 2009). According to Tummala & Schoenherr, (2011) SC mapping is an approach in which the SC and its flow of goods, information and money is visually depicted, from upstream suppliers, throughout the focal firm, to downstream customers.

There is no consensus on the literature on where to insert the SC mapping. Although, many authors do include it in the context analysis, others describe the mapping of the SC as part of the risk identification process (Norrman & Jansson, 2004; Pujawan & Geraldin, 2009). The first authors are focused only upstream, while the second ones are focused in the process instead of members.

3.3.2.
Risk Identification

Risk Identification is the fundamental phase of the entire risk management process, where risks, that the studied SC is exposed to, are identified (Hallikas et al., 2002; Harland et al. 2003; Norrman & Jansson, 2004; Kleindorfer & Saad, 2005; Cucchiella & Gastaldi, 2006; Ritchie & Brindley, 2007; Adhitya et al., 2008, Pujawan & Geraldin, 2009; Oehnen et al., 2009; Giannakis & Louis, 2011; Blome & Schoenherr, 2011; Kern et al., 2012; Ghadge et al., 2013; Hachicha &

Elmsalmi, 2013; Elleuch et al., 2014). Risk identification helps to develop a common understanding of the future uncertainties surrounding the SC, thus recognizing the potential risks in order to manage these scenarios effectively. (Hallikas et al., 2002; Norrman & Jansson, 2004; Hallikas et al., 2004; Tuncel & Alpan, 2010).

The objective is to create what can be referred to as a "profile" for each of the risks identified (Manuj & Mentzer, 2008; Ghadge et al., 2013).

Some authors as Norrman & Jansson (2004), Cucchiella & Gastaldi (2006), Tuncel & Alpan (2010) and Elleuch et al. (2014) consider the determination of the probabilities and impacts of all potential SC risks, as part of the risk identification process.

The literature proposes different tools to identify risk. Hallikas et al. (2002) and Hallikas et al. (2004) propose the interview process based on in a hierarchical form of risks, since many causes and effects relationships consist of hierarchical chains. Afterwards a closer inspection of some risks can be done by influence diagram, in order to structuring and analyzing the qualitative information. According to Harland et al. (2003) and Oehnen et al. (2009) the risk identification should be done, through brainstorming with other actors in the supply network.

The brainstorm findings are used to build a Risk Cause/ Effect matrix (Oehnen et al., 2009). Norrman & Jansson (2004) suggest a risk mapping, identifying the risk sources and thereby understanding their potential consequences. The authors point out two techniques for representing of the sequences of failures that may propagate through a complex system, the "fault tree analysis" (FTA) and the "event tree analysis" (ETA). FTA examines all potential events leading up to the critical event and it is a graphical diagram that shows how a system can fail, while ETA focuses on events that could occur after a critical event and identifies and quantifies possible outcomes following initiating events by looking at potential consequences. For Adhitya et al. (2008), risk identification can be employed through the Hazard and Operability (HAZOP) analysis. Pujawan & Geraldin (2009) propose the use of the SC map as a way to identify risk. Tuncel & Alpan (2010) indicate the construction of the failure mode, effect and criticality analysis (FMECA), based on interviews to identify risks. Elleuch et al. (2014) corroborate Tuncel & Alpan (2010), indicating FMECA based on a brainstorming process. Tummala & Schoenherr (2011) point out the

following approaches that can help in the identification of potential SC risks: SC mapping, checklists or check sheets, event tree analysis, fault tree analysis, failure mode and effect analysis (FMEA) and Ishikawa cause and effect analysis (CEA). Giannakis & Louis (2011) suggest that the backbone of the risk identification is based upon the monitoring of various key performance indicators (KPIs) related to the performance of SC partners. These authors assert that KPIs can be used to identify an abnormal situation that may involve a potential risk. Ghadge et al. (2013) propose the hexagonal model developed for process improvement, POLDAT (Process, Organization and Location, Data, Applications and Technology). The use of process improvement model for risk classification is expected to provide the systematic approach for capturing the risk behavior within the SC network. The findings are validated through a Delphi group. At last, Hachicha & Elmsalmi (2013) promote the use of risk analysis group to identify risk and build reachability matrix and identify the relationship among the risks, named Structural Self Interaction Matrix (SSIM).

3.3.3. Risk Assessment

Risk assessment focuses on the prioritization of the risks that will affect the vulnerability of the SC, as consequence contributes with the selection process of suitable corrective management actions for the identified risk in the risk identification phase (Harland et al., 2003; Hallikas et al., 2004; Norrman & Jansson, 2004; Adhitya et al., 2008; Oehnen et al., 2009; Giannakis & Louis, 2011; Blome & Schoenherr, 2011; Tummala & Schoenherr, 2011; Elleuch et al., 2014; Hachicha & Elmsalmi, 2013). This phase provides the understanding of the relationship between the risks (Oehnen et al., 2009) and aims the evaluating and understanding of each risk in detail for its relevancy (Kern et al., 2012).

Concerning risk assessment, almost every definition in the literature includes an evaluation of the likelihood of occurrence and an estimation of the possible impact in case the risk event unfolds (Hallikas et al., 2002; Harland et al., 2003; Hallikas et al., 2002; Norrman & Jansson, 2004; Kleindorfer & Saad, 2005; Manuj & Mentzer, 2008; Ritchie & Brindley, 2007; Adhitya et al., 2008; Oehnen et al., 2009; Tuncel & Alpan, 2010; Giannakis & Louis, 2011; Blome &

Schoenherr, 2011; Tummala & Schoenherr, 2011; Kern et al., 2012; Ghadge et al., 2013).

Although, most of authors have the similar definition of risk assessment, the object of the assessment can change. Differently of the others authors, that assess the probability and consequences of the risk event, Pujawan & Geraldin (2009) assign the probability to the risk source and the severity to the risk event, promoting the understanding the relationship between both.

In order to assess the risk the literature offers different tools. Hallikas et al. (2002) and Hallikas et al. (2004) based their assessment on the probability and severity, through the relationship between both. Norrman & Jansson (2004) combine impact and probability in a risk map/matrix, focusing on the financial impact. Manuj & Mentzer (2008) suggest the use of decision analysis, case study or perception based. These tools and frameworks are based primarily on one of the two major paradigms for risk assessment: probabilistic choice and risk analysis. According to Manuj & Mentzer (2008) probabilistic choice is based on the idea that undesired choice will be compensated with good events. Therefore, a solution can be evaluated based on its average behavior. However, there are cases where there is not enough repetition of events or situations, so probabilistic compensation of bad and good results cannot be assumed. In such cases, the risk analysis paradigm is more applicable. The risk analysis paradigm is based on the concept of minimizing regret. Regret is the difference between the cost of an optimal solution and the cost of the solution actually adopted. Therefore, depending on the type of risk events, a combination of risk analysis and probabilistic choice is a reasonable approach for global supply chain risk assessment. Pujawan & Geraldin (2009) suggest the determination of the Risk Potential Number (RPN) to assess the risk, based on three factors, probability of occurrence, severity of impacts, and detection, using the Failure Mode and Effect Analysis (FMEA) as input. The authors assign the probability to the risk agent (source) and the severity to the risk event and correlated them through the House of Risk Model, methodology created by the authors. Tuncel & Alpan (2010) and Elleuch et al. (2014) corroborate Pujawan & Geraldin (2009), assessing the risk through RPN, although the focus of the assessment is the risk event. Oehnen et al. (2009) propose the SC Risk Dynamics Model to understand the relationship between the identified risks. The impact and probabilities can be assessed through

FMEA and Monte Carlo simulations. Tummala & Schoenherr (2011) suggest that techniques such as the Delphi method or expert focus groups can aid in the derivation of probabilities. However, they point out that if objective information is not available, subjective information, beliefs and judgment can be used to approximate distributions. Other approaches proposed to determine the probability by the authors include: parameter estimation, five point estimation, probability encoding, or Monte Carlo simulation. Once defined the probability of the risks, Tummala & Schoenherr propose the determination of risk exposure values, for each identified SC risk, based on Risk Consequence Index x Risk Probability Index, in order to assess them. Alternatively, the risk exposure values may also be used to classify risks based on Pareto analysis. Giannakis & Louis (2011) propose the simulation to assess the risk, where the probability for the disruption to become reality is estimated through the use of FMEA and/or formal mathematical models that can utilize linear regression, time series regression models and stochastic models. Ghadge et al. (2013) suggest the risk modelling to capture the impact in terms of cost and time and the possible failure point due to disruption, using the statistical model to provide the input parameters. To capture the dynamic interactions of different risk attributes in a SC and assess them the authors apply System Dynamic Modelling, that is modelled using a simulation platform. In order to analyze the variation in the output of the mathematical model, influenced due to different variations in the inputs, the authors propose the sensitive analysis. At least, Hachicha & Elmsalmi (2013) propose the combination of two tools to assess risks, Interpretative Structuring Modeling (ISM) and *Matrice d'Impacts Croisés Multiplication Appliquée á un Classement* (MICMAC). ISM sets the risk sources in a hierarchical manner and shows the relationship between them. MICMAC identify all the risk variables (risk events) related to risk sources and allows a final hierarchical map that gives the key risk variables and their mutual relationship that would help them to propose effective risk mitigation strategies.

3.3.4.
Selection and implementation of Risk Treatment strategy

Selection and Implementation of Risk treatment Strategy includes the development and the evaluation of diverse treatment strategies in order to select appropriate strategies to manage the risk (Hallikas et al., 2004; Kleindorfer & Saad, 2005; Cucchiella & Gastaldi, 2006; Manuj & Mentzer, 2008; Pujawan & Geraldin, 2009; Oehnen et al., 2009; Giannakis & Louis, 2011; Tuncel & Alpan, 2010; Tummala & Schoenherr, 2011; Kern et al., 2012; Ghadge et al., 2013; Elleuch et al., 2014). The selection process needs to include the cost required to reach the desired performance, since the business impact of the strategy must justify the investments (Kleindorfer & Saad, 2005; Oehnen et al., 2009; Tuncel & Alpan, 2010; Tummala & Schoenherr, 2011; Ghadge et al., 2013).

During this phase the selected strategy is implemented, in order to treat the prioritized risks (Harland et al., 2003; Hallikas et al., 2004; Norrman & Jansson, 2004; Kleindorfer & Saad, 2005; Cucchiella & Gastaldi, 2006; Ritchie & Brindley, 2007; Adhitya et al., 2008, Manuj & Mentzer, 2008; Pujawan & Geraldin, 2009; Oehnen et al., 2009; Tuncel & Alpan, 2010; Giannakis & Louis, 2011; Blome & Schoenherr, 2011; Tummala & Schoenherr, 2011; Kern et al., 2012; Ghadge et al., 2013; Hachicha & Elmsalmi, 2013; Elleuch et al., 2014). Albeit, most of the retrieved papers emphasize the preventive strategies, some authors bring the reactive ones (Harland et al., 2003; Adhitya et al., 2008; Tuncel & Alpan, 2010, Kern et al., 2012; Ghadge et al., 2013).

Although, the literature points out the implementation of the strategies, the aim of this phase is not a consensus. There are three different focus observed. The first one assumes that this phase focuses on reducing the consequences if an adverse event is realized (Norrman & Jansson, 2004; Cucchiella & Gastaldi, 2006; Manuj & Mentzer, 2008). The second one considers that it initiates a process that intents to eliminate or reduce the prominent risk (Hallikas et al., 2004; Tummala & Schoenherr, 2011; Pujawan & Geraldin, 2009; Giannakis & Louis, 2011). At last, the third one presumes that this phase can remedy the causes (reducing the occurrence) or remedy the consequences (reducing the impact) or both (Harland et al. 2003; Oehnen et al., 2009; Tuncel & Alpan, 2010; Kern et al., 2012).

In order to select the appropriated strategy the literature presents different tools. Cucchiella & Gastaldi (2006) suggest the real options theory to select the treatment strategy. Pujawan & Geraldin (2009) propose the House of Risk Model to give priority of the treatment actions considered effective, but considering reasonable money and resource commitments. Oehnen et al. (2009) propose the SC Risk Dynamics Model to help the selection of the treatment strategy. Tuncel & Alpan (2010) propose the use of Petri nets (PN), a graphical technique for specification and design of discrete event dynamic systems, to be used in commercial simulator to evaluate the performance of the SC network under risk factors, in order to help the decisions concerning the treatment of the risk. Giannakis & Louis (2011) propose the use of simulation to help the selection of the strategy. Tummala & Schoenherr (2011) suggest the Hazard Totem Pole (HTP) analysis to help the selection of the optimal strategy, based on probability, severity and cost of risks. Ghadge et al. (2013) propose the use of the risk modeling results to help managers decide their strategies for the set of risk attributes instead of dealing with each risk independently. At least Elleuch et al. (2014) suggest the Analytic Hierarchy Process (AHP) to evaluate risk treatment scenarios and Desirability Function Approach (DFA) to measure the efficiency of the selected treatment strategy. It also is important to reference the work of Saaty & Vargas (2006). These authors propose the Analytic Network Process (ANP) in order to select of the optimal strategy in response to risk. The ANP can be seen as an evolution of the AHP.

3.3.5. Risk Control

A few numbers of papers bring the control aspect of the SCRM. This phase consists on examining of the progress made regarding the implemented risk treatment strategies and corrective actions can be taken if deviations occur in achieving the desired SC performance (Norrman & Jansson, 2004; Oehnen et al., 2009; Tummala & Schoenherr, 2011; Kern et al., 2012).

Although, Giannakis & Louis (2011) suggest the use of KPI and Tummala & Schoenherr (2011) the use of Data Management System to control the treatment strategy applied, risk treatment is not enough explored in the literature review.

3.3.6.
Risk Monitoring

As the SC structure and operation changes regularly, new risks should be continually monitored (Hallikas et al., 2004; Adhitya et al., 2008 and Kern et al., 2012). In this sense the risk monitoring consists in supervision of the SC to detect risks when they occur, identifying the potential increasing trends and their respective probability or consequences (Norrman & Jansson, 2004; Hallikas et al., 2004; Oehnen et al., 2009; Adhitya et al., 2008; Tuncel & Alpan, 2010; Pujawan & Geraldin, 2009; Blome & Schoenherr, 2011; Tummala & Schoenherr, 2011; Kern et al., 2012; Elleuch et al., 2014).

This phase is concerned to monitor the SC to detect new possible risks and identified ones as well (Norrman & Jansson, 2004; Hallikas et al., 2004; Adhitya et al., 2008; Tuncel & Alpan, 2010; Pujawan & Geraldin, 2009; Blome & Schoenherr, 2011; Tummala & Schoenherr, 2011; Kern et al., 2012; Elleuch et al., 2014).

Despite Oehnen et al. (2009) cover all the phases proposed in this framework, it is important to highlight that during the risk monitoring their focus is on identified risks, instead of new ones. In spite of Adhitya et al. (2008) propose the use of KPI to control the system as a tool, the literature doesn't present enough explanation about this topic.

3.4.Empirical Studies on SCRM

In spite of the increasing importance of this topic, the relevant literature offers few empirical studies. Most of the available empirical studies analyze SCRM from the perspective of a single firm. Khan et al. (2008) developed a case study of a major UK retailer. They discovered that the fact that supplier relationships were close made it difficult for the retailer to regulate its suppliers and assess their performance. Their over-reliance and over-dependence on suppliers increased the uncertainty in their business transactions.

Thun & Hoenig (2011) and Thun et al. (2011) conducted a survey of 67 manufacturing plants in the German automotive industry. Thun & Hoenig (2011) identified product variants and a reduction in the supplier base as two of the main

risk drivers. Therefore it increases SC vulnerability and promotes the risk sources: increasing raw material prices, customer demand changes, and delivery chain disruptions. They concluded that the instruments of SCRM in the German automotive industry are predominantly implemented only at a low level. Thun et al. (2011) contributed to the understanding of the reactive instruments of SCRM used by large-scale enterprises.

Wagner & Neshat (2012) considered other industries beyond automotive, such as food, consumer goods, and logistics providers. They measured and compared SC vulnerability for various categories of firms by conducting a survey of a broad range of German firms and identified important drivers. Sofyalıoğlu & Kartal (2012) conducted an empirical study in Turkey with a company operating in the iron and steel industry. They identified supply risks, operational risks, and demand risks as the most relevant risk sources. In terms of SC strategies to mitigate risk, the authors found that flexible contracts and alliances are a viable way to share risks, especially in preventing operational risks related to production capacity problems, quality problems with supplier service, and the costs of holding inventory. Control and postponement were also indicated as mitigation strategies for reacting to demand volatility in their empirical study.

Lavastre et al. (2012) provided an understanding of SCRM by studying attitudes toward risk, the tools used to understand risk, and the ways in which decisions are made in a sample of French companies. They found that a lack of preparedness, either in terms of not detecting a risk or not having thought about solutions to potential problems, can have grave consequences. Although the findings of these empirical studies are relevant and that most of them consider many companies in their samples, none of them analyzed SCRM from a multi-tier point of view.

Blos et al. (2009) went beyond the single firm perspective by conducting a multi-tier pair (dyadic relationship) empirical study in the automotive and electronic industries in Brazil. They identified the main SC risks and highlighted the urgency of the implementation of SCRM. The authors concluded that the investigated industries need to implement SCRM because of increasing sources of SC risk.

Jüttner (2005) sought to understand the business requirements for SCRM from a practitioner's perspective based on the findings from an exploratory quantitative survey and qualitative focus group discussions with SC managers from different

tiers. The author concluded that there is a lack of mutual knowledge about individual companies' risk management planning activities and that there is little evidence of risk management applied at the SC level.

Although Jüttner (2005) and Blos et al. (2009) included firms from different SC tiers, they did not focus on interconnected firms within the same SC as occurs in reality.