Chapter 19
Risk and Uncertainty Management for Sustainable Supply Chains

Kirstin Scholten and Brian Fynes

19.1 Introduction

Supply chains are the backbone of the global economy as well as a major influence on the social and natural business environment (van der Vegt et al. 2015). In today's globalized world, every organization is part of at least one supply chain. Furthermore, the majority of everyday transactions - withdrawing money, eating in a restaurant, shopping for food or clothes, ordering something online - involves participation in a supply chain. As such, supply chains are the channels via which resources, services, and information flow from the originating supplier to the end user. A company's relationships across their supply chains combined with increasing globalization have facilitated worldwide operations, better communication, and the ability to integrate enlarged product variety and greater consumer choice. Simultaneously, the emergence of longer and more complex supply chains and relationships, shorter product lifecycles, increased competitive pressure, and environmental uncertainty (Mentzer et al. 2001) have exposed every business to the risk of unexpected disturbances that can lead to financial losses and in some cases firm closures (Skipper and Hanna 2009). Our world is increasingly uncertain (Tang 2006) and our supply chains more vulnerable than ever (Wagner and Bode 2008).

Vulnerability in the supply chain centers around the disruption of information, product, service, knowledge, control coordination, or monetary flows between organizations (Jüttner 2005; Narasimhan and Talluri 2009) and as a result exposes organizations to risks (Craighead et al. 2007). On a daily basis, newspaper headlines

K. Scholten (✉)
Faculty of Economics and Business, University of Groningen, Groningen, The Netherlands
e-mail: k.scholten@rug.nl

B. Fynes
Smurfit School of Business, University College Dublin, Belfield, Dublin, Ireland
e-mail: brian.fynes@ucd.ie

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highlight the consequences of risks: Toyota's product recalls in 2012, the horse meat scandal in 2013, industrial action at airports in France, Germany, and Belgium in 2014, the Rana Plaza factory collapse in Bangladesh in 2012, the volcanic ash eruption in Iceland in 2010 are only some of many examples that caused disruptions to supply chains globally. Each year 75 % of companies experience at least one supply chain disruption adding up to more than €1 M in costs for a single incident for 21 % of them; causes range from workforce strikes to adverse weather conditions, currency exchange rates, energy scarcity, service provision failures, and IT breakdowns (Business Continuity Institute 2013). Even a relatively minor problem within a supply chain can have significant consequences: a late delivery of raw materials can affect operations, with knock-on effects to company reputation, perception of brands, ability to win orders, quality, prices, profit margins, and lead times (Waters 2011). At worst, these contingencies can threaten the continuity and hence sustainability of organizations as has been shown in the past (van der Vegt et al. 2015). Hendricks and Singhal (2005) found that companies facing supply chain disruptions experience 33–40 % lower stock returns relative to their industry benchmarks over a 3-year period (one year before and two years after the disruption announcement date). At the same time, this might affect society as a downturn in financial performance often results in labor redundancies. Other disruptions have impacted severely on the environment e.g., the Deep Water Horizon Spill in the Gulf of Mexico in 2010 with subsequent long-term consequences for society in terms of water cleanness and the oil and gas industry in terms of policies. As the examples above illustrate, disruptions can affect any of the three dimensions of sustainability.

While the possibility of a disruption to a single facility or supplier may be relatively small, the probability in the end-to-end collective supply chain is much greater (Knemeyer et al. 2009). The network architecture of a supply chain is structured around a chain of decision nodes, where each node plays a role in adding value to final products and/or services. At the same time, each node also contributes to the risk profile in a positive or negative way (Ritchie and Brindley 2007a). For those reasons, firms are required to pay attention to factors such as labor conditions (social), financial stability (economic), and emissions (environmental) of their supply chain members. Yet, organizations frequently overlook such critical exposure to risk along their supply chains (Jüttner et al. 2003). Customers, however, are less concerned about why or where a disruption occurred; they expect the final product or service to be available to them at the right time and price (Elkins et al. 2005). Therefore, managers must delicately balance inventory, capacity, and other elements at appropriate levels across the entire supply chain in a dynamic, fast-changing environment (Chopra and Sodhi 2004).

Supply chain risk management and supply chain uncertainty management via resilience are the managerial counterparts of the concept of supply chain vulnerability (Jüttner 2005). This relationship is depicted in Fig. 19.1. The ultimate objective is to ensure that supply chains continue to work as planned, with smooth and uninterrupted flows of materials, information, and money from initial suppliers through to the final customers (Waters 2011). Hence, risk and uncertainty management contribute to business survival by limiting vulnerabilities and are therefore recognized

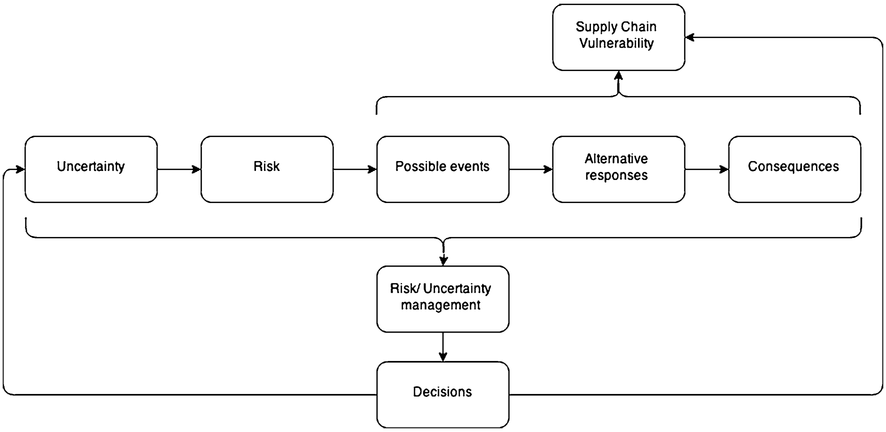

Fig. 19.1 Relationship uncertainty, risk, and vulnerability (adapted from Waters 2011)

by many organizations as an essential contributor to sustainable operations (Carter and Rogers 2008). While risk and uncertainty are intimately linked, they are not the same: risk is something measurable in the sense that estimates can be made of the probabilities of outcomes; uncertainty is not quantifiable and hence probabilities of possible outcomes are unknown (Khan and Burnes 2007). As such, risk is the expected outcome of an uncertain event (Manuj and Mentzer 2008b), whereas vulnerability is the exposure to serious disturbance arising from supply chain risks (Jüttner 2005).

This chapter sets out to examine how supply chain risk and uncertainty management practices support organizations and their supply chains in achieving long-term sustainability, whether it is in relation to economic, environmental, or societal factors. Firstly, we examine the process of *supply chain risk management* including *risk identification*, *risk assessment, and analysis* as well as *risk management strategies* and how these enable decisions; we then show how *uncertainty management* extends traditional supply chain risk management and how supply chain resilience enables organizations and their supply chains to also deal with unforeseeable events. Furthermore, we will discuss *disaster management* from a humanitarian perspective as a source of learning for uncertainty management in commercial supply chains. We conclude with a summary and a reflection.

19.2 Supply Chain Risk Management

While a crisis in a supply chain may be unpredictable, it may not be unexpected. To deal with and reduce the impact of global supply chain risk, existing theory suggests that businesses follow a course of action from risk identification to strategies specifically aimed at managing risk (Manuj and Mentzer 2008a). Effective supply chain risk management tries to do exactly that: identifying and managing risks in the supply chain through a synchronized approach among supply chain members, to lessen supply chain vulnerability as a whole (Faisal et al. 2006; Jüttner 2005). Proactively identifying where and when vulnerability is present creates the potential to avoid risks, prevent them from actually happening and reduce or mitigate their impact (Waters 2011). Stages in the risk management processes (labels differ among authors although the steps are similar see e.g., Manuj and Mentzer (2008a) or Jüttner et al. (2003)) include risk identification (or estimation), risk assessment (or analysis), evaluation to make a choice between strategies to manage risk as well as ongoing monitoring (Norrman and Jansson 2004). To be able to conduct the risk management process effectively, top management support is required so that a shared, supply chain-wide understanding and awareness of risks is created (Chopra and Sodhi 2004; Sheffi and Rice 2005). Only then can ongoing monitoring and control be conducted successfully as an essential part of the risk management processes. The stages of the risk management process will be further outlined in the following sections.

19.3 Risk Identification

The identification of risk sources is an important step in the risk management process as decision-makers become aware of events that may cause disturbances (Norrman and Jansson 2004). It encompasses a comprehensive and structured determination of potential supply chain risks (Tummala and Schoenherr 2011). Risks to the supply chain consist of anything that may interrupt the normal flows of the chain and as a consequence expose organizations within the supply chain to economic, environmental, and societal consequences (Craighead et al. 2007). Hence, there are a huge number of possible risks that can appear in almost endless variety (Waters 2011): sources of risk can be organizational, supply chain or environmental-related factors that affect the supply chain performance (Faisal et al. 2006; Peck et al. 2003; Jüttner 2005) - see Fig. 19.2. Taken together these risks define the vulnerability of a supply chain (Waters 2011).

- *Organizational risk sources:* Organizational sources of risk affect the operational side of an organization (Manuj and Mentzer 2008a). Hence, they are internal to any organization and relate to processes and controls (Peck et al. 2003; Jüttner 2005). Processes facilitate the management and production of value in an organization in the form of products and services for the end consumer (Christopher 1998). Risk inherent in processes can relate to accidents, the reliability of equipment, loss of an information technology system and quality issues (Waters 2011). Variability in processes can be managed via controls, which are assumptions, rules, systems, and procedures such as order quantities, batch sizes, and safety stocks (Christopher and Peck 2004). Therefore, risks in relation to controls arise more directly from human decision making via the application or misapplication of these assumptions, rules, systems, or procedures (Peck et al. 2003).

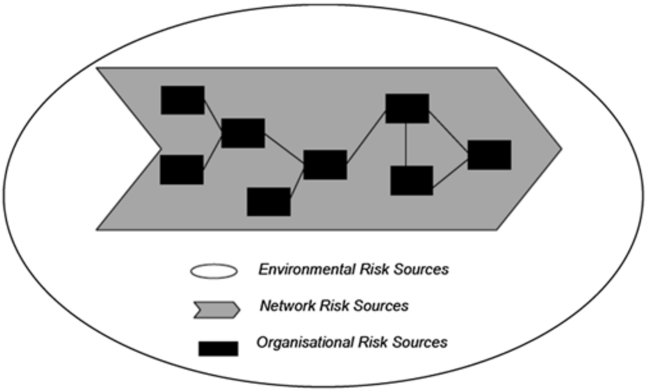

Fig. 19.2 Risk sources in supply chains (Jüttner et al. 2003)

- *Network risk sources:* Network risks are internal to the supply network but external to an organization (Jüttner et al. 2003). As such, these sources are prone to affect a number of interdependent parties in a supply chain (Jüttner 2005). Network risk sources refer to the possibility and impact of a mismatch between supply and demand (Jüttner et al. 2003). Therefore, network risks have been categorized as originating from the demand or the supply side. Demand and supply risks occur from the interactions between members of the supply chain and are often caused by inadequate coordination between members and lack of visibility (Waters 2011).

  Demand risk relates to vulnerabilities associated with the outbound logistics flows and product demand (Jüttner 2005). It can be any potential or actual disturbance within the network to the supply chain flows downstream (Christopher and Peck 2004) such as variable demand, payments, problem with order processing, or customized requirements (Waters 2011). Demand risks vary with the nature of the product, with functional products generally less exposed to risks than innovative products (Fisher 1997; Manuj and Mentzer 2008a). Similarly, on the supply side, risks are associated with possible events that may affect the inbound flows (Manuj and Mentzer 2008a). Hence, supply risks are related to supplier actions or supplier relationships (Jüttner 2005). Consequently, the risk manifests itself upstream in potential or actual supply chain disturbances (Peck et al. 2003) caused by variability in the availability of materials, lead times, delivery problems, industrial action, or reliability of a supplier (Waters 2011).
- *Environmental risk sources:* As environmental risk is associated with disruption external to the focal organization and supply chain network (Jüttner 2005; Peck et al. 2003; Christopher and Peck 2004), it represents a level of risk that is often beyond the direct control of supply chain operators (Peck 2005). Factors influencing the level of environmental risk can be summarized as political, environmental, social, technological, economic, or legal aspects (PESTEL).

Table 19.1 Examples of classifications of risk sources in literature

Author (Year)	Risk sources
Mason-Jones and Towill (1998)	Environmental risk
	Demand and supply risk
	Process risk
	Control risk
Jüttner et al. (2003)	Environmental risk
	Organizational risk
	Network risk
Chopra and Sodhi (2004)	Disruption risk
	Delay risk
	System risk
	Forecast risk
	Intellectual property risk
	Procurement risk
	Receivables risk
	Inventory risk
	Capacity risk
Christopher and Lee (2004)	Financial risk
	Chaos risk
	Decision risk
	Market risk
Wagner and Bode (2006)	Demand side risk
	Supply side risk
	Catastrophic risk
Manuj and Mentzer (2008a)	Supply risk
	Operational risk
	Demand risk
	Security risk
Wagner and Bode (2008)	Demand side risk
	Supply side risk
	Regulatory, legal, and bureaucratic risk
	Infrastructure risk
	Catastrophic risk
Rao and Goldsby (2009)	Environmental risk
	Industry risk
	Organizational risk
	Problem-specific risk
	Decision-maker risk

Other categorizations of sources of risk, rather than organizational, network, and environmental are also reported in the literature (see Table 19.1). Whatever categorization one prefers, identifying risks related to such categories is critical so that consequences can be understood and assessed (Tummala and Schoenherr 2011).

There are many methods for the identification of specific risks (Norrman and Jansson 2004). "Five whys," cause-and-effect diagrams, Pareto analysis, checklists, interviews, process charts and controls supply chain even management and supply chain risk mapping (for further details see Waters 2011), are only some of the methods that can be used by managers to identify possible risk sources. Care needs to be taken in the identification as risk sources can never be seen in isolation: they are linked to each other in complex patterns with one risk source leading to another, or influencing the outcome of other risks (Manuj and Mentzer 2008b; Miller 1992) e.g., environmental risks can cause supply or demand risks (Jüttner 2005; Manuj and Mentzer 2008a). Furthermore, as a result of complex supply chain designs, there is the risk of additional chaos resulting from overreactions, unnecessary interventions, second guessing, mistrust, and distorted information throughout the supply chain (Christopher and Lee 2004) which could potentially lead to e.g., the bullwhip effect (for further details see Lee et al. 1997).

Irrespective of the source of the risk, the profile and nature of risk can be highly divergent: the financial default of a supplier (network risk) and a natural disaster destroying production capacity (environmental risk) are situations with completely different attributes in terms of incubation period, probability, predictability, and severity (Wagner and Bode 2006). As such, classifying risks into categories simply indicates the source of the risks and does not indicate the nature, scale, or manageability (Ritchie and Brindley 2007b). Hence, the identification and classification of risk sources on its own is meaningless as each risk effects the supply chain differently; at the same time, risk identification is of great importance (Jüttner et al. 2003) providing the basis for risk quantification, assessment, and evaluation that can be used in deriving risk mitigation strategies (Narasimhan and Talluri 2009). This will be further discussed in the following section.

19.4 Risk Assessment and Analysis

The main focus of supply chain risk assessment is to recognize and analyze future uncertainties to enable proactive management of risk-related issues (Norrman and Jansson 2004). This involves the determination of the consequences of all identified, potential supply chain risks, together with their magnitudes of impact (Tummala and Schoenherr 2011). Impact refers to the significance of the loss to the organization and/or supply chain(s) (Zsidisin et al. 2004). Adverse risk consequences can become manifested in any outcome measure such as loss of or damage to assets, income, service levels, or schedules. Supply chain design characteristics such as density, complexity, and node critically have been shown to increase the severity of possible risks (Craighead et al. 2007). Some further examples have been given in the introduction already. Accordingly, supply chain risk assessment should be a formal part of the decision-making process at every level from product design to component availability and lead time determination (Christopher and Peck 2004).

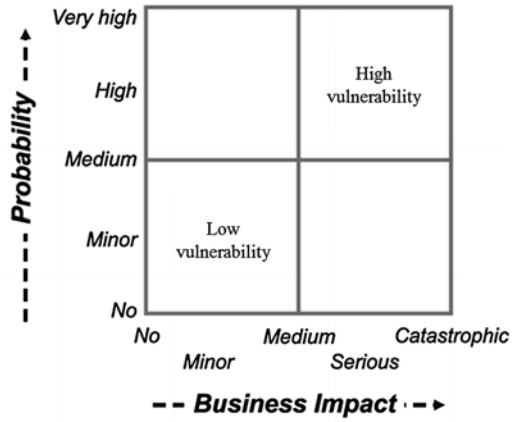

Fig. 19.3 Risk matrix (adapted from Norrman and Jansson 2004)

Nonetheless, the consequences of risk do not necessarily need to be negative as the essence of risk-taking is the potential opportunity to produce positive outcomes (Ritchie and Brindley 2007a) although in the context of this chapter, we define risk outcomes as negative.

In addition to the severity and impact, organizations need to understand that supply chain disruptions can be frequent or infrequent and short- or long-term (Chopra and Sodhi 2004). Risk is perceived to exist if there is a relatively high likelihood that an event occurs and that the event has a significant associated impact or cost (Zsidisin et al. 2004). Therefore, as some risks will have severe consequences and others not, it is important for organization to assess the probability of the risk occurrences alongside the possible impact (Cohen and Kunreuther 2007). The likelihood of occurrence, typically expressed as a probability, can be articulated in objective (absolute values) or subjective terms (ranges) (Ritchie and Brindley 2007a). In this context, probability is a measure of the likelihood of occurrence of a negative event.

Combining the assessment of impact (consequences) and probability allows organizations to classify their supply chain vulnerability as shown in Fig. 19.3. This is calculated by multiplying the value of the impact of risk by its probability of occurrence (giving the expected value of the impact) or by Monte Carlo simulation, scenario analysis, failure modes, and effects analysis or network models (Waters 2011). The most important consideration for a risk manager is to have an advanced plan that indicates a suitable response to any possible event (Spekman and Davis 2004) that has first been identified and then quantified as shown in the section via considerations of impact and probability (vulnerability). Hence, following these steps in the risk management process, different possible risk management strategies need to be considered to derive at a decision of what to do. Consequently, in the next section, we will describe possible risk management strategies.

19.5 Risk Management Strategies

While it is impossible to completely eliminate risks and consequent vulnerabilities from a supply chain, they can be reduced if an organization is proactive and prepared (Faisal et al. 2006). Risk management is the process in which decisions are made to accept a known or assessed risk and strategies are developed that reduce the probabilities and impact of negative events and/or their consequences in case they occur (Cohen and Kunreuther 2007; Manuj and Mentzer 2008b). Depending on the assessment of risks, different strategies can be deployed to manage the risks: risk reduction or mitigation, risk avoidance, risk-taking or acceptance and risk sharing or transfer (Norrman and Jansson 2004) (see Fig. 19.4). There is no one best strategy for protecting supply chains against risks, instead, managers need to know which strategy works best against which given risk (Chopra and Sodhi 2004).

Notwithstanding the level of vulnerability, managers have two choices, either they can ignore (or accept) the risk and do nothing, or they can respond and do something (Waters 2011). Since it is not feasible nor practical to develop mitigation and sharing/transfer strategies for every risk identified, risk management begins with the examination of the costs required to implement each preventative action to contain and manage the identified supply chain risks (Tummala and Schoenherr 2011). Often a cost-benefit analysis of low-probability low-impact risks shows that the cost to mitigate the risk is higher than the cost to bear the risk; e.g., in the case of a stationery supply chain for a food processing company, the risk to the stationery supply chain can be accepted without further action, but needs to be monitored closely to ensure that the impact remains low in case the risk should manifest itself in a disruption.

Companies typically focus on managing risks with the greatest impact and the greatest probability. Accordingly, Kleindorfer and Saad (2005) suggest that *risk avoidance*, the strategy used for high-probability high-impact risks, should precede risk reduction and mitigation. An avoidance strategy is used when the risks

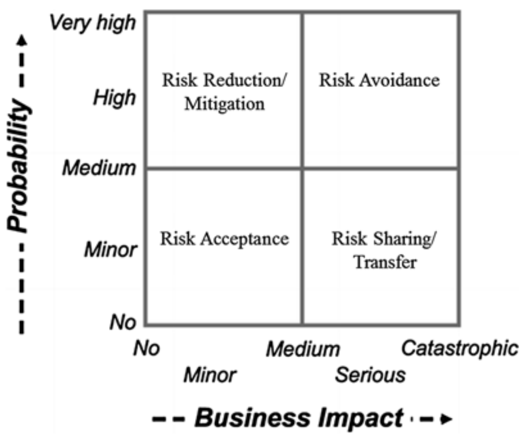

Fig. 19.4 Risk management matrix (adapted from Norrman and Jansson 2004)

Table 19.2 Supply chain risk mitigation strategies (Tang 2006)

Risk mitigation strategy	Benefit(s) under normal circumstances	Benefits after a major disruption
Strategic stock	Improves capability to manage supply	Enables a firm to respond to market demand quickly during a major disruption
Postponement	Improves capability to manage supply	Enables a firm to change the configurations of different products quickly
Flexible supply base	Improves capability to manage supply	Enables a firm to shift production among suppliers promptly
Make and buy	Improves capability to manage supply	Enables a firm to shift production between in-house production facility and suppliers rapidly
Economic supply incentives	Improves capability to manage supply	Enables a firm to adjust order quantities quickly
Flexible transportation	Improves capability to manage supply	Enables a firm to change the mode of transportation rapidly
Revenue management	Improves capability to manage demand	Enables a firm to influence the customer product selection dynamically
Assortment planning	Improves capability to manage demand	Enables a firm to influence the demands of different products quickly
Silent product rollover	Improves capability to manage supply and demand	Enables a firm to manage the demands of different products swiftly

associated with operating in a given market (environmental risk) or working with particular suppliers or customers (network risk) is considered unacceptable (Manuj and Mentzer 2008a). To avoid is to eliminate the types of event that could trigger the risk by either driving overall probabilities associated with risk events to zero or by reducing the frequency and probability of a risk (Manuj and Mentzer 2008b). Being attacked by pirates for example is a high risk for cargo ship operators in some parts of the world; to reduce the risk other routes that avoid the most dangerous seas that can be used (Waters 2011). Another option for an organization is to drop specific products, suppliers, or geographical markets if supply is seen to be highly vulnerable (Jüttner et al. 2003).

Similarly, *risk reduction and mitigation*, aim to reduce both the probability and consequence of the possible risk event (Manuj and Mentzer 2008b). Mitigation tactics are those by which an organization takes some action in advance of a disruption (Tomlin 2006) with the aim of achieving robustness. Table 19.2 gives an overview of risk management strategies that aim to achieve robustness for supply network risks rather than organizational risks only (for further details on each strategy see Tang 2006). Furthermore, information sharing, aligning incentives, risk sharing, and corporate social responsibility are required to successfully implement risk mitigation strategies (Chopra and Sodhi 2004; Faisal et al. 2006; Spekman and Davis 2004).

As illustrated in Table 19.2, supply chain risk mitigation strategies can be beneficial under normal circumstances as well as during a major disruption (Tang 2006).

However, at the same time, they can create challenges: every decision that mitigates one risk can end up intensifying another (Chopra and Sodhi 2004). As slack is taken out of supply chains with the aim to reduce costs, the chance that events in one link will affect other links considerably increases. Hence, typical supply chain risk management solutions such as the maintenance of buffer stocks, built in slack in delivery lead times, excess profit margins to cover returns are becoming less viable in a world of outsourcing, just in time (JIT) and materials requirement planning (MRP). As a result, trade-offs between the robustness (benefit) of a supply chain to disruptions and the overall efficiency (cost) of the supply chain under normal operations have to be made. (Kleindorfer and Saad 2005). For example, having additional inventory that might buffer a supply failure can at the same time significantly increase inventory holding costs and in some cases risk of obsolescence.

Risk sharing or transfer move some of the risks from one organization in the supply chain to another (typically more able or willing to handle it) (Waters 2011) via outsourcing, offshoring, or contracting (Manuj and Mentzer 2008a). Risk could for example be transferred to insurance companies or supply chain partners by moving inventory liability, changing delivery times of suppliers (just-in-time deliveries), dealing with customer uncertainty (make-to-order manufacturing), or by deciding to move a part of the production to an outside party (Manuj and Mentzer 2008b). However, sharing or transferring risk neither eliminates nor reduces the probability or impact of a possible risk event. So while insurance can cover the costs of disruption, the disruption nonetheless can occur.

Generally, organizations take decisions and plan to protect themselves against recurrent, low-impact risks in their supply chains by making use of one of the strategies above but ignore high-impact, low-likelihood ones (Faisal et al. 2006) simply because of the low probability of occurrence (Waters 2011). Yet the exacerbating frequency, magnitude, and impact of disasters present an increasing threat to the sustainability of communities, supply chains, businesses, and their resources. The impact of local or regional events can transcend globally: for example, the earthquake in Japan 2012 not only affected the Japanese and Asian economies but led to shortages in the automobile and technology industry globally. However, such low probability supply chain disruptions are hard to identify, hence cannot be assessed and analyzed which limits the possibilities of deriving risk management strategies and decisions. Hence, they cannot be managed via the risk management process so far; they have to be managed in a different way. In the following section, we examine how to manage the unknown: supply chain uncertainty. We will do so by reflecting on practices from an extreme case context: humanitarian disaster management.

19.6 Supply Chain Uncertainty Management via Resilience

Uncertainty management is no longer about if, but when a disruption is going to happen. In its extreme form, uncertainty relates to the situation in which there is a total absence of information, knowledge, understanding, or awareness of a potential event occurrence (Ritchie and Brindley 2007a). Hence, it is difficult if not impossible to follow the risk management process from risk identification to risk assessment and management. By accepting that not all risks can be foreseen, controlled, or eliminated (Jüttner and Maklan 2011) supply chain resilience enhances the traditional risk management process as it enables an organization to deal with uncertain factors that can only be identified and predicted to a limited extent (Scholten and Schilder 2015). Whereas risk management tries to decrease the vulnerability (probability and impact) of a certain risk, resilience focuses on the ability to absorb the impact of a disturbance that might stem from any risk by enabling the supply chain to return to stable conditions faster (Peck 2005). The aim is not to analyze risks and find the best strategy to respond, but to consider each part of the supply chain, see what happens when the part is disrupted and set up mechanisms that enable quick recovery of operations (Waters 2011).

Resilience has been defined in supply chain terms as "the adaptive capability of the supply chain to prepare for unexpected events, respond to disruption and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structures and function" (Ponomarov and Holcomb 2009:131). An often-cited example in the context of supply chain resilience is a fire at a Philips Electronics plant in Albuquerque, New Mexico in March 2000 which simultaneously affected Nokia and Ericsson (see e.g., Norrman and Jansson 2004; Sheffi and Rice 2005), who accounted for 40 % of the plant's shipments (Mukherjee 2008). Both competitors were solely dependent on Philips for the chips they produced (Sheffi and Rice 2005). The two companies reacted differently to the supply chain disruptions. Nokia was better able to deal with the disruption than Ericsson, displaying the adaptive capabilities that allowed the organization to quickly discover and efficiently recover from the disruptive event (Blackhurst et al. 2011; Pettit et al. 2010). Ericsson on the other hand, had to quit the mobile-phone business as a result of the disruption, leaving Nokia to reinforce its position as the European market leader. But what made the adaptive capability of Nokia better than the one of Ericsson?

While there are few conceptual differences in how supply chain resilience is defined (see e.g., Brandon-Jones et al. 2014; Peck et al. 2003; Ponomarov and Holcomb 2009; Sheffi and Rice 2005) the formative elements needed to secure the adaptive capability of resilience are presented with significant disparity in literature (Jüttner and Maklan 2011; Scholten et al. 2014). Formative elements of the adaptive capabilities of a supply chain have, for example, been conceptualized as collaboration, supply chain design principles, risk awareness, visibility, flexibility, security and velocity (Blackhurst et al. 2011; Christopher and Peck 2004; Jüttner and Maklan 2011; Sheffi and Rice 2005) - see Table 19.3 for an overview. On their own, all of these elements display good SCM practices based on integrating and coordinating resources (Jüttner and Maklan 2011). The example of Nokia and Ericsson further illustrates this: Nokia acted quickly after hearing about the fire and moved to tie up spare capacity at other Philips plants and every other supplier they could find (Mukherjee 2008). The company sent 30 employees to work with Philips and other suppliers to restore supply (Sheffi and Rice 2005). Furthermore, they

Table 19.3 Supply chain resilience overview (Excerpt from Scholten et al. 2014)

System level resilience capabilities	Resilience elements	Christopher and Peck (2004)	Sheffi (2005), Sheffi and Rice (2005)	Ponomarov and Holcomb (2009)	Pettit et al. (2010, 2013)	Zsidisin and Wagner (2010)	Jüttner and Maklan (2011)	Wieland and Wallenburg (2012, 2013)
Supply chain (re-)engineering:		**X**	**X**	**X**	**X**			
The conceptualization, design, implementation, operation, and re-engineering of the supply chain (Naim et al. 2000)	*Efficiency:* The ability to produce outputs with minimum resource requirements (Pettit et al. 2010)	X	X	X	X			
	Redundancy: Limiting or mitigating the negative consequences of change by keeping resources in reserve, such as having safety stock, maintaining multiple supplier and running operations at a low-capacity utilization rates (Blackhurst et al. 2005; Sheffi and Rice 2005)	X	X	X	X	X		
	Robustness: The ability of a supply chain to resist change without adapting its initial stable configuration (Wieland and Wallenburg 2012)							X

(continued)

Table 19.3 (continued)

System level resilience capabilities	Resilience elements	Christopher and Peck (2004)	Sheffi (2005), Sheffi and Rice (2005)	Ponomarov and Holcomb (2009)	Pettit et al. (2010, 2013)	Zsidisin and Wagner (2010)	Jüttner and Maklan (2011)	Wieland and Wallenburg (2012, 2013)
Collaboration:		**X**	**X**	**X**	**X**	**X**	**X**	**X**
The level of joined decision making and working together at a tactical, operational, or strategic level between two or more supply chain members (horizontal or vertical). Scalable through the magnitude of relationship strength, quality, and closeness. (Jüttner and Maklan 2011)	*Visibility*: The identity, location, and status of entities transiting the supply chain, captured in timely messages about events, along with the planned and actual dates/times for these events (Francis 2008)	X	X	X	X		X	X
Agility (Flexibility):		**X**	**X**	**X**	**X**	**X**	**X**	**X**
The ability to rapidly respond to change by adapting its initial stable configuration (Wieland and Wallenburg 2012)	*Velocity*: The speed in which a supply chain can react to changes in demand, upwards or downwards (Christopher and Peck 2004)	X	X	X	X	X	X	X
	Visibility: see above	X	X	X	X		X	X
Risk Awareness: Making supply chain risk assessment a formal part of the decision making process at every level (Christopher and Peck 2004)		**X**	**X**	**X**	**X**			
Knowledge Management: Knowledge and understanding of supply chain structures—both physical and informational and its ability to learn from changes (Adapted from Ponomarov and Holcomb 2009)		**X**	**X**	**X**	**X**			

changed some of the product specifications so that they could take chips from other Japanese and American suppliers (Mukherjee 2008). The company's culture (risk awareness) together with the deep relationships with suppliers (collaboration) enabled the company to recognize the severity of the situation quickly (visibility and velocity), disseminate the news and take immediate action at various levels of the organization (agility and knowledge management) (Sheffi and Rice 2005). Hence, they displayed all system level adaptive supply chain resilience capabilities: supply chain re-engineering, collaboration, agility, risk awareness and knowledge management. Therefore, Nokia had the adaptive capabilities that supported its supply chain to overcome the disruption by continually adapting and altering itself to meet required changes, that would let the company deal with the situation (Scholten et al. 2014).

Ericsson on the other hand was not proactive and did not realize the seriousness of the disruption until weeks later (Sheffi and Rice 2005). It took too long before higher management was aware of the incident and the company had neither alternative sources of supply nor was it prepared for this kind of accident (Mukherjee 2008). In fact, by the time Ericsson took action for recovery, the worldwide supply of the chips in question, was committed to Nokia (Sheffi and Rice 2005). Ericsson employed sharing and transfer of risk via insurance: business interruption costs were calculated and compensated as approximately $200 million (Norrman and Jansson 2004). However, the insurance was not able to eliminate the consequences of the manifested risk. As Waters (2011) argues, low probability high-impact risks should not be managed with regular supply chain risk management tools and strategies. Instead, holistic mechanisms considering the system level adaptive supply chain resilience capabilities of supply chain re-engineering, collaboration, agility, risk awareness and knowledge management need to be put in place. Hence, the incident made Ericsson realize the importance of not only understanding and managing risks internally—but also trying to manage *uncertainty* along the supply chain (Norrman and Jansson 2004) in a way that operations can continue during any emergency.

While the importance of uncertainty management is evident in both theory and practice, the literature has moved little beyond basic conceptual frameworks to assess the resilience of a *supply chain* rather than a single organization (Blackhurst et al. 2011; Jüttner and Maklan 2011; Pettit et al. 2013). Hence, there is hardly any management guidance on the implementation and operationalization of the concept of supply chain resilience (Scholten et al. 2014). Recent supply chain studies suggest that commercial supply chain operations can benefit from research into disaster SCM (Christopher and Tatham 2011) especially in relation to risk and uncertainty management practices (Day et al. 2012): private sector businesses can learn about vulnerability assessment, preparation, and response to disasters from humanitarian organizations (Van Wassenhove 2006). As breakdowns and interruptions in material and information flow (Blecken 2010) occur frequently in emergency situations, organizations that are active in disaster management are experts in working with uncertainty and risk - for them experiencing unpredictability is the norm (Scholten et al. 2014). As such, the disaster management sector has the potential to create a hothouse of information for risk and uncertainty management practices in addition to the traditional practices described in this chapter so far, thereby providing critical insights applicable to private sector SCM. This has been shown by recent research from Scholten et al. (2014) and will be further outlined in the following section.

19.7 Disaster Management

The disaster management context represents an ideal opportunity to examine supply chain risk and uncertainty given the exacerbating frequency, magnitude, and impact of disasters threatening the sustainability of communities, businesses, and their resources around the globe (Scholten et al. 2014). Disasters seriously disrupt the functioning of society, and cause widespread human, material, or environmental loss or damage, which is often of such magnitude that the affected areas cannot rely just on their own resources to manage their situations (United Nations 1992). Hence, they test the resilience of affected local supply networks which integrate government agencies, non-governmental organizations, for-profit organizations, the military and community organizations into relief efforts (Day 2014). The aim of humanitarian relief is to quickly provide assistance and alleviate suffering either long term or during and after a disaster in affected areas with the aim of saving and sustaining lives as well as (re)creating self-sufficiency (Thévenaz and Resodihardjo 2010). According to van Wassenhove (2006) SCM is a crucial function in disaster management for the following reasons:

- The performance of relief operations in terms of effectiveness and speed of current and future operations and programs.
- Serving as a bridge between disaster preparedness and response, between procurement and distribution and between headquarters and the field.
- Providing a rich source of data in terms of tracking of goods, which could be used to analyze post-event effectiveness.
- Representing 80 % of relief operations (and their costs) and therefore being the element that can make the difference between a successful or failed operation.

Both private sector and disaster, not-for-profit SCM not only have a lot in common (Ernst 2003), but humanitarian supply chains may be somewhat commercial in the way that private sector companies might undertake production and some of the transport and logistical activities (Jahre et al. 2009). However, at the same time disaster relief chain management differs on various levels (Beamon and Balcik 2008) as shown in Table 19.4. As a result of the unpredictability and uncertainties around disasters, humanitarian relief operations are faced with unique characteristics: zero lead times affecting inventory, procurement and distribution, high stakes at risk, unreliable supply and transportation information (Beamon 2004).

While nobody can identify exactly when or where a low-probability high-impact disaster, such as an earthquake or tsunami, is going to happen, identifying vulnerable areas that are at risk (Peck 2005, 2006) creates opportunities to put in place

Table 19.4 Comparison of private sector vs. humanitarian logistics (Mizushima 2008)

	Private sector	Humanitarian
Situations	Fairly predictable	Unpredictable: emergencies
		Fairly predictable: development
Execution time	Varies due to market conditions	Extremely compressed
Demand	Relatively stable, predictable	Determined by random events, relatively unpredictable location/type/size
Distribution network configuration	Methodology to determine structure and locations	Challenging; Location/type/size unknown
Universal language	English	Depends on location
Technology	State-of-the-art systems, well-defined processes	Lack of standardized systems, Information unreliable, incomplete or non-existent
Strategic objectives	Maximize profit; Improve shareholder value	Save lives, alleviate suffering
Personnel	Skilled, specific logistics education	Little or no education in logistics
Stakes	Customer satisfaction, profitability	Human life
Infrastructure	Modern, well-maintained	Primitive, poor, sometimes totally destroyed
Environment	Stable, conducive to business, and transportation	Problematic, often extremely dangerous

practices and resources that minimize the impact of disasters before they occur (Dilley 2006; Scholten et al. 2014). This echoes similarities to the traditional risk management process described earlier. However, sustainable relief operations and their management involve a continuum of interlinked activities (Pettit and Beresford 2005) across the four disaster phases: preparedness, immediate response, recovery, and mitigation. The disaster management cycle depicted in Fig. 19.5 indicates that effective and efficient disaster management is about the application of a strategic focus to the processes of making *proactive* decisions to lessen disaster impact (during mitigation and preparation) and *reactive* decisions in overcoming the impact (during response and recovery) (Natarajarathinam et al. 2009) comparable to definitions of supply chain resilience in academic research:

- *Mitigation* concerns the application of measures that will either prevent the onset of a disaster or reduce the impact should one occur (Altay and Green 2006; Tomlin 2006).
- *Preparedness* includes activities that prepare for an effective and efficient response (Altay and Green 2006; Tomlin 2006).
- *Response* processes include the employment of resources to preserve life, property, the environment, and the social, economic, and political structures (Altay and Green 2006).

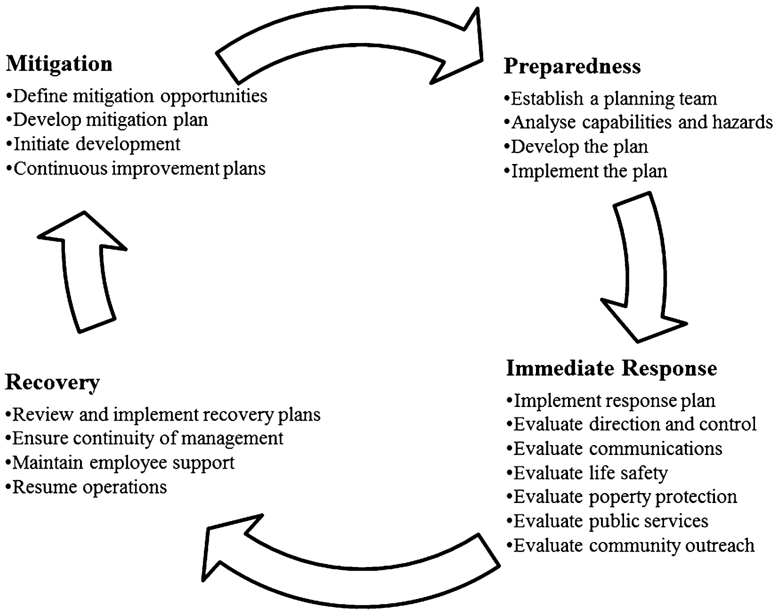

Fig. 19.5 Disaster management processes (adapted from Helferich and Cook 2003)

- During *recovery*, actions are taken in the long term after the immediate impact has passed to stabilize and restore some semblance of normalcy in structures (Altay and Green 2006).

As with the Ponomarov and Holcomb's (2009) definition of supply chain resilience, resilience in the context of humanitarian aid has been defined as "a process linking a set of adaptive capabilities to a positive trajectory of functioning and adaptation after a disturbance" (Norris et al. 2008:130). In an empirical study, Scholten et al. (2014) establish a link between the conceptual supply chain resilience adaptive capabilities and practical disaster management processes part of the disaster management cycle (Fig. 19.5). The results depicted in Fig. 19.6 show that mitigation processes are of paramount importance as they are the antecedents to building supply chain resilience capabilities which in turn enable the execution of the necessary processes during preparedness, response, and recovery. The authors emphasize that there is no "one-size-fits-all" model for supply chain resilience as each organization will have idiosyncratic requirements (van Vactor 2011) in terms of time, human, physical, and organizational resources. Christopher and Peck (2004) highlight that determining the appropriate practices to manage supply chain vulnerabilities and risk appears to be context-specific, dependent amongst other things on the supply chain's response to the need for operational excellence. Hence, the framework by Scholten et al. (2014) depicted in Fig. 19.6 is not to be seen as a specific defined route to supply chain resilience but more as a road map that can guide individual,

Disaster Management Processes		Supply Chain Resilience Capabilities				
		Horizontal & Vertical Collaboration	*Supply Chain (Re-) engineering*	*Agility*	*Risk Awareness*	*Knowledge Management*
Mitigation	Establish a cross-functional planning team	√	√		√	√
	Analyze supply chain capabilities and hazards	√			√	√
	Develop and communicate plan for preparedness, response and recovery	√	√		√	√
	Agree measurements and metrics for preparedness, response and recovery	√	√		√	√
	Develop continuous improvement and supply chain risk mitigation plans	√	(√)		**√**	**√**
Preparedness	Implement preparedness plan: Translate strategic agreements into operational matters	√	(√)	(√)		√
	Evaluate based on measurements and metrics	√		(√)		√
	Establish routines through training and simulation	√	√	(√)		√
Response	Implement response plan, measurements and metrics	√	(√)	√		√
	Evaluate direction and control	√		(√)		(√)
	Evaluate communications throughout the supply chain	√		(√)		(√)
	Evaluate supply chain disruption outreach	√	(√)	√		(√)
Recovery	Review and implement recovery plans	√	(√)			√
	Ensure continuity of risk and resilience management	√			√	
	Maintain employee support	√			√	
	Resume operations	√		(√)		√

(√) = possibly required
√ = required

Fig. 19.6 Integrative framework for building supply chain resilience (Scholten et al. 2014)

context-specific supply chains (commercial and disaster management businesses) in improving and building their supply chain resilience and disruption management capabilities. Furthermore, their framework contributes to the development of an awareness of the value of the strategic capabilities involved in the different disruption phases and of how they interact with each other through specific processes.

However, supply chain resilience is only one aspect contributing to sustainability in the humanitarian context. Often humanitarian organizations are still years behind their private sector counterparts who realized the importance of using efficient supply chains at an earlier stage. Academic literature has highlighted the lack of recognition for the supply chain function within humanitarian organizations (see e.g., Pettit and Beresford 2005; Van Wassenhove 2006). Modest progress is evidenced as some of the bigger humanitarian organizations' senior management has recognized the importance of SCM to the performance of relief operations. Nevertheless, things are often different in the field. Even where proven SCM practices and strategies are used, acceptable response and recovery performance has remained elusive (Day 2014). The pipeline of publications in general SCM journals on humanitarian aid, and the establishment of a specialized journal demonstrate the growing acknowledgement of the value, importance, and potential of this research field. Nevertheless, advancements in humanitarian SCM remain necessary for the prompt alleviation of a disaster's impact and overall sustainable operations: "What is lacking, is a body of theory that can help explain why some approaches manage to create effective disaster supply chains, whereas so many disasters suffer the lack of effective disaster supply chains" (Boin et al. 2010:4). This highlights the possibilities for cross learning between commercial and disaster management organizations: commercial companies can learn about supply chain risk and resilience management from disaster management organizations (effectiveness) while at the same time passing on their general knowledge on supply chain management (effectiveness and efficiency). Balaisyte et al. (2017) discuss such cross-sector partnerships in more detail in Chap. 22.

19.8 Conclusion

Today more than ever, managers need to be aware of risk and uncertainty that might negatively impact the organizational sustainability due to suboptimal supply chain performance. Adopting supply chain risk management practices cannot only yield continuous improvement of supply chain operations (Elkins et al. 2005), but also be the key to business survival and sustainability. While there is a large body of knowledge and research on risk management and how to try and prevent supply chain disruptions via the supply, chain risk management process (identification, assessment and analysis, strategies and decisions), in today's global and complex world it is not a question of if a disruption is going to happen but when. Therefore, we need to know how they can be dealt with in an effective and efficient way. Yet, research on supply chain resilience, a concept that extends supply chain risk management to deal with uncertainties, is for a large part conceptual; more empirical research and practical insights, particularly beyond a single company perspective, are required to help organizations and their supply chains to become more sustainable.

One area for potential insights on supply chain resilience is the humanitarian aid sector. On the one hand, humanitarian SCM, while particularly rich and exciting, could be treated as just another research context for applying theories developed in the mainstream commercial SCM. On the other hand, this approach overlooks the potential opportunities for reverse learning as the dynamic and unpredictable environment of humanitarian SCM may provide unique insights for building mainstream theory. Humanitarian SCM shows many similarities and faces many of the challenges of commercial SCM, except in a more extreme context. Existing research on humanitarian SCM highlights the possibilities of cross learning and integration between humanitarian and commercial operations. However, more bridges need to be built for two-way learning.

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