

## 2 The Genesis of Supply Chain Risk

*“When anyone asks me how I can best describe my experiences in nearly 40 years at sea, I merely say, uneventful. Of course, there have been winter gales, and storms and fog and the like, but in all my experience I have never been in any accident of any sort worth speaking about. [...] I never saw a wreck and have never been wrecked, nor was I ever in any predicament that threatened to end in disaster of any sort.”*

Edward John Smith  
Captain in command of the RMS Titanic

Supply chain officers may feel with Edward Smith. After years of *uneventful* supply chain management and after years of striving after more efficient processes, unexpected and sometimes even devastating events have derogated supply chains. A series of major disruptions like Hurricane Katrina, piracy attacks offshore Somalia, global financial crisis, flooding in Thailand, European ash-cloud, Japanese earthquake and tsunami among others have revealed a missing preparedness within today's supply and distribution networks [248]. Thus, the management of so-called supply chain risks became an issue.

This chapter briefly summarizes the genesis of supply chain risk. It starts with explaining the trends that revealed the sensitivity of mod-

ern supply chains, it revises different classes of disruptive triggers and it traces the path from the consideration of disruptions to supply chain risk management and the need for quantification.

## 2.1 Logistics Innovations – A Blessing and a Curse

The strategic influence of supply chain management on business performance – including not only overall logistics costs, but also customer satisfaction – is well confirmed by companies of almost all industries. Domestic firms can offer products worldwide, and hence, they compete not only with local companies on the domestic market, but also with international competitors they encounter on the world market. In order to remain competitive, while benefiting from logistics potentials, companies strive for improving and streamlining their operational processes [329, 334]. As revealed by Computer Science Corporation in 2004, companies availed themselves of the implementation of efficiency-increasing logistics innovations. While 52% of the considered companies registered an increase in their revenues, 72% stated to benefit from the new developments implemented in their supply chains. Besides the positive effects American AMR among others concluded that these new trends and strategies have a negative counterpart, which is highlighted by the increasing number of disrupted supply chains [66, 129, 149, 334, 348]. Highly efficient operations [329] expose supply chains to an environmental crossfire of different volatile influences. While disruptions do not occur everyday, supply chain strategies – also called *risk drivers* – that lead to disruptions do. When a firm takes a pure cost minimization approach in order to increase overall efficiency, it reduces excess capacity and inventory, which could make up for production losses caused by disruptions. Formerly isolated events within the supply chain can today “escalate to wide scale network disruptions” [71].

Innovation	Trend	Opportunity		Threat
Globaliza- tion	LCCS	20% to 30% lower ma- terial and labor costs		longer lead times
		supply closer to man- ufacturing and cus- tomer sites in emerg- ing markets		increased risk of sup- ply disruption and transportation capac- ity and performance issues
				exposure to new po- litical, security, regu- latory, tariff, and cur- rency risk
	Outsourcing	improve operating performance and service levels		limited visibility or control of service lev- els or selection and performance of sub- tier suppliers
		lower operating costs		
Informa- tion Availability	VMI	improves spend lever- age		limits ability to di- rectly manage visibil- ity, quality, and per- formance
		improve service and fill levels		
	Integrated Supply	reduce management burdens		increased reliance on single supplier for broader range of materials and services
		access "one-stop shop"		
Lean Man- agement	JIT/JIS	reduce costs	inventory	little, if any, buffer stock or time

	streamline operations	opera-	increase stockouts due to delivery glitches	risk and manu- facturing disruptions due to supply or delivery glitches
Supply Base Rational- ization	improve age	spend lever-	increased fewer or source suppliers	reliance on even sole-
	reduce burdens	management	links financial and operational health of sup- plier	performance to and opera- tional health of sup- plier
	improve supply	strategic relationships	increased likelihood of dual- or sole-sourced suppliers relying on single sub-tier sup- plier	

**Table 2.1:** Opportunities and risks of prevailing logistic best practices [see also 2, 63, 249, 329].

Popular logistics improvements, which can be derived from three main sources: globalization, lean management principles, and increased information availability, are presented in Table 2.1 [2, 63, 249, 329].

Global sourcing enables companies to follow strategies like low-cost country sourcing (LCCS), or outsourcing and off-shoring, all of which enable companies to implement cost reduction actions and to focus on their core activities. Stretched lead times, limited visibility, and difficult communications can, however, decrease flexibility and response time in case of supply chain failures. Lean management principles like Just-in-Time or Just-in-Sequence and supply base rationalization allow companies to synchronize supply with production

demand more efficiently. When efficiency is the sole objective, there is very little buffer to enable recovery after a supply chain disruption has occurred. New technologies like e-business, vehicle telematics, inter-modal systems, tracking systems, and automated handling have improved information availability as well as facilitated purchasing activities for both consumers and procurement managers. However, these developments increased customer expectations. Nowadays, consumers buy more products from websites rather than visiting shops [334]. Furthermore, they want immediate gratification. Late orders caused by supply chain disruptions often result in lost customers. Additionally, information technology provides transparent and consistent support in planning, monitoring and controlling material as well as financial and information flows. As companies in the meantime rely on planning and monitoring tools, a small IT-failure could have a tremendous and immediate impact on the whole supply chain performance [249].

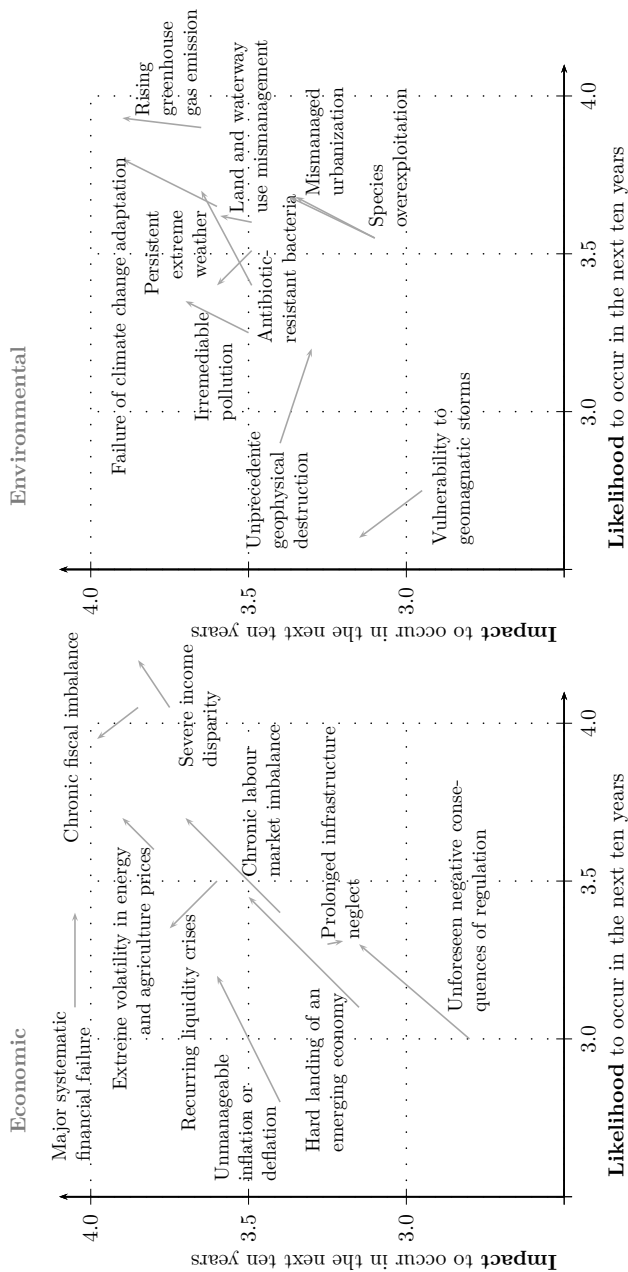
Logistics innovations have shifted supply and distribution processes from more or less straight chains to globally acting, complex and highly interrelated networks, most-often operating beyond consecutive company boundaries. Supply chains consequently operate in a volatile environment and are exposed to different types of potential disruptive triggers.

## 2.2 Supply Chain Disruptions

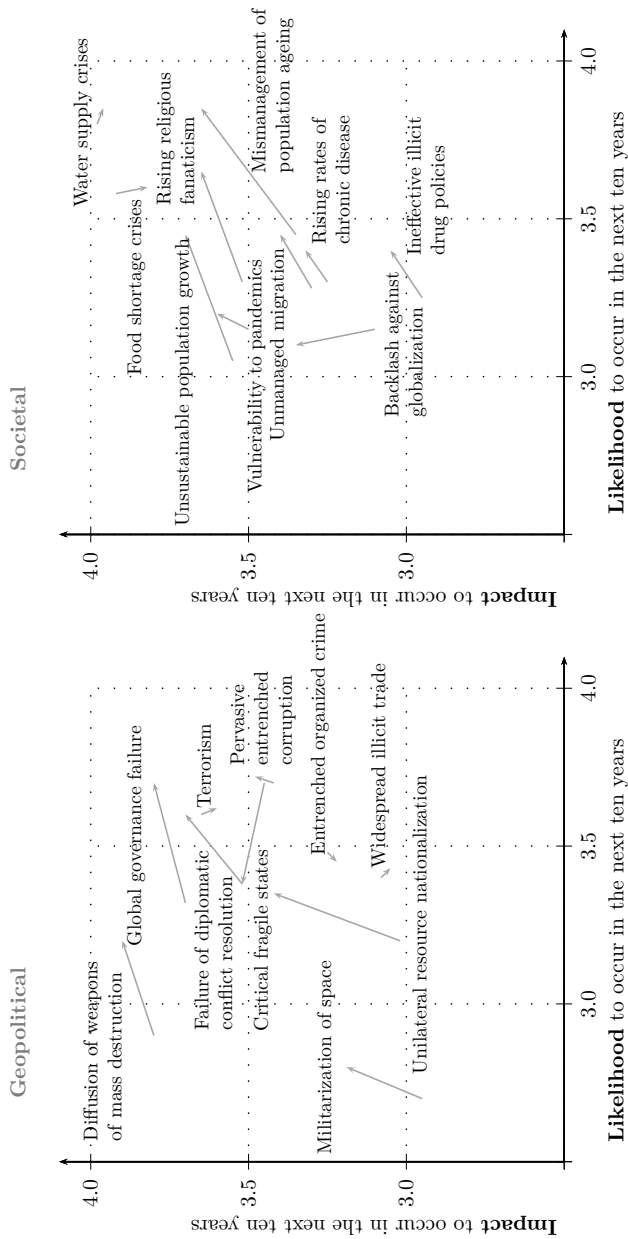
Disruptions like power outages, labor strikes, supplier glitches, epidemic or terrorist attacks were always considered as geographically isolated events, which executives heard about in news, but did not need to manage in their own companies nor within logistics operations. However, due to increased complexity of world-wide spread supply chains, a medical crisis in Asia became a problem for the producer of high-tech goods in the middle east. A labor strike in harbor facilities of the US affected exports coming from South Korea. The

hurricane Katrina hit oil refineries in New Mexico, but oil prices increased all over the world [78]. The nature of disruption triggers varies among economic, environmental, geopolitical (as well as societal) and technological categories. Due to the ongoing change of the risk landscape all over the world, the number of triggers resulting in disruptions especially for supply networks increases and evolves constantly. Figure 2.1 presents the global risk landscape changes from 2012 to 2013 including aspects especially valid for supply chains.

According to the Supply Chain Risk Initiative of the World Economic Forum the top five external triggers among these categories in 2012 were natural disasters, extreme weather conditions, conflict and political unrest, terrorism as well as sudden demand shocks [249]. Although not yet top-ranked, IT-disruptions like IT-failure or cyber attacks can be regarded as an emerging trigger, which needs more attention. A study of the University of Minnesota concluded that 90% of companies encountering a ten day lasting IT-breakdown had to declare bankruptcy after two years at the latest. In the following paragraphs main types of disruptive triggers are further discussed. Additionally, Table 2.2 provides an overview of prominent supply chain disruptions and their impact on supply chains. For a more detailed discussion of historical disruptions and their business impacts, we refer to Punter [239].

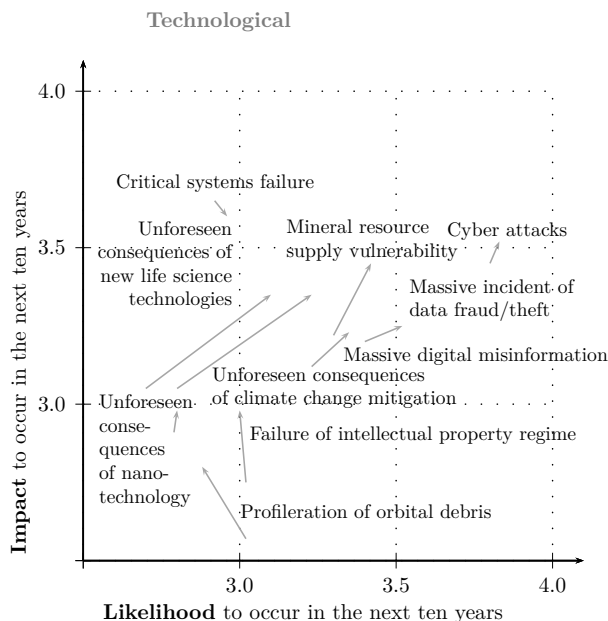


(a) Economic and Environmental



(b) Geopolitical and Societal





(c) Technological

**Figure 2.1:** Global risks landscape – movements from 2012 to 2013. Assessed on a scale between 1 and 5 [250].

Name	Incident	Description	Year
Great East Japan earthquake	seaquake and tsunami	An undersea earthquake off the Pacific coast of Tohoku occurred in March 2011. The earthquake triggered tsunami waves that reached heights of up to 40.5 meters and which flooded inland up to 10 km. Several industries such as high-tech and automotive suffered from enormous production shortages.	2011

Thailand flooding	flooding	The Thailand flooding in 2011 affected production capacity and inventory stock-out and price increase, similarly. As Thailand is the world's second major exporter of hard disk drives (HDD), an entire industrial sector was hit by the flood. According to the e-commerce tracking site Dynamite Data the price of HDD increased by 50% to 150% shortly after the flooding until 300% in the weeks afterwards.	2011
Eyjafjalla- jökull	volcanic eruption	On 14 April 2010 the eruption of the Icelandic volcano Eyjafjallajökull affected European supply chains. Due the leashed ash-cloud air travel was extensively affected by the closure of airspace over many countries. Companies such as BMW had to interrupt production in Munich, Dingolfing and Regensburg.	2010
West Coast Port Lock- out	labor strike	After weeks of negotiations between the international longshore and warehouse Union and the pacific maritime association, workers of all ports of the US West Coast went on strike for 10 days.	2002
9/11	terroristic attacks	The safety measures after the attacks of September 11 led to excessive delays in delivery within the US and abroad, and consequently to production bottlenecks at affected companies.	2001
Nokia- Philips- Ericsson	lightening bolt	A lightning bolt struck a high-voltage electricity line in New Mexico. The power fluctuation caused a fire in a Philips factory in Albuquerque. The factory produced semiconductors for mobile phones. The fire and the sprinkler destroyed around 1 million semiconductors. Nokia and Ericsson were the principle customers of Philips' semiconductors.	2000

Dell-Apple	earthquake	After an earthquake heavily affected production capacities of Taiwan's high-tech industry. Apple and Dell encountered enormous difficulties in procuring semiconductors.	1999
Toyota-Aisin	short circuit	A short circuit provoked a fire at a factory of Toyota's major p-valve supplier Aisin. P-valves are a low priced product, but essential for the production. Production was expected to halt for several weeks. Alternative valve suppliers were not immediately available and Toyota faced an increased demand, which already has led production levels reaching 115%.	1997

**Table 2.2:** Major disruptions from 1997 – 2011.

### 2.2.1 Environmental Disruptions

The recent series of natural and epidemic catastrophes affecting companies worldwide – like the Kobe earthquake in Japan in 1995, SARS in South-East Asia in 2003, the Hurricanes Katrina, Rita and Wilma in the US in 2005, the Wenchuan earthquake in China in 2008, the volcanic eruptions in Iceland 2010 and 2011, E coli outbreak in 2011 and the earthquake in Japan 2011 – are “violent reminders” [329, p. 307] that globally wide-spread supply networks are sensitive towards changes in their environment. The Chūetsu earthquake in Japan in 2004 resulted in an estimated economic loss of US\$ 28 billion, 2005 Hurricanes Katrina, Rita and Wilma totaled US\$ 155,3 billion, the earthquake in the Wenchuan Region in China is estimated with US\$ 85 billion and the tsunami in Japan with US\$ 210 billion economical loss [75].

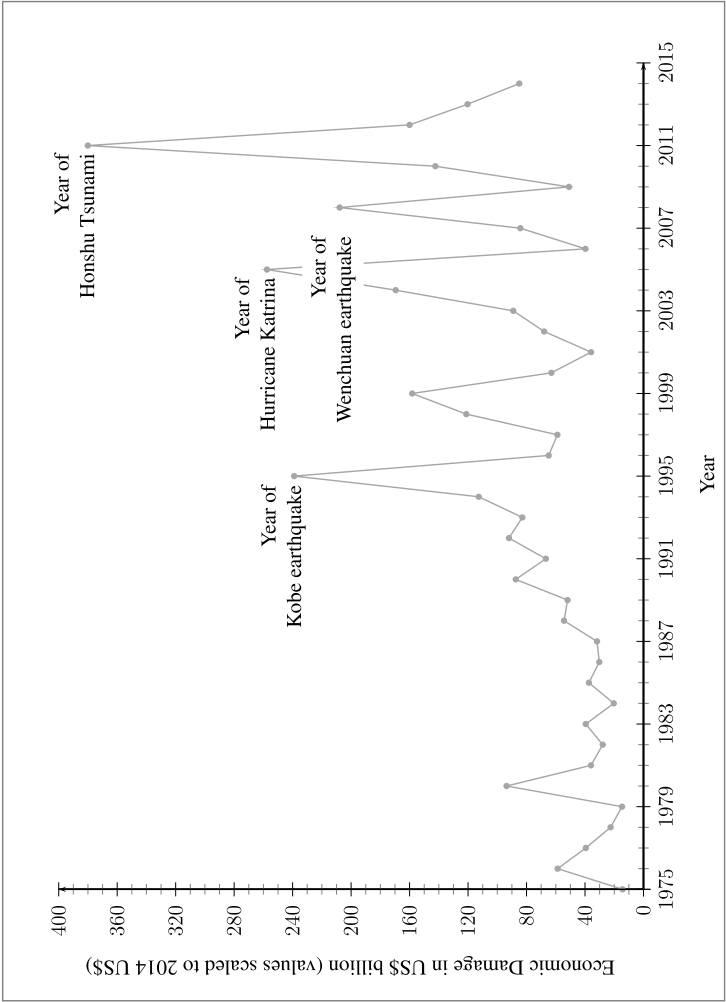
Unfortunately, the aforementioned examples of natural and epidemic disasters are not rare events with anecdotal value. According to the International Disaster Database (EM-DAT) from the Center of Research on Epidemiology of Disasters (CRED) the long-term upward trend of frequency and economic magnitude of worldwide disasters started in 1950 and has aggravated ever since [59, 71, 75, 217, 218] see Figure 2.2. Certainly, population growth, the spread of valuable assets and improved reporting influenced this development. The exponential growth of frequency and magnitude, however, cannot be explained solely by these factors [59]. The outlook on the future of supply networks is evident: supply chains remain exposed to deviations evoked by natural and epidemic disruptions.

### 2.2.2 Economic Disruptions

Currency exchange rate fluctuations, commodity price volatility, global financial crises, sudden demand shocks, supplier glitches and export/import restrictions are examples of economic disruptions.

Globally-spread supply chains connect companies among diverse countries, belonging to different currency areas. Fluctuations in currency rates between procurement, production and distribution locations potentially offset margins. Competitive devaluation – sometimes referred to as *currency war* – like for example in 2010 has a great impact on supply chain profitability when procurement or distributions are concentrated overseas [248].

Additionally, cross-border movements are vulnerable to export and import restrictions or border delays evoked by customs regimes, tariff and non-tariff barriers, quota systems, security concerns and infrastructure bottlenecks [248]. According to the Supply Chain Risk Initiative of the World Economic Forum sudden new restrictions pose the main disruption trigger for cross-border material flows within supply and distributions networks [248].



**Figure 2.2:** Economic damage in US\$ billion caused by reported natural disaster (1975-2014) ©EM-DAT [75].

Whereas in the past fluctuations in crude oil prices and consecutively in transportation costs [276] could be solely referred to international turmoils (Gulf war I and II, OPEC embargo), today, increased investment fund activities and disruptions affecting oil production companies lead to an increase of daily crude oil price volatility. Especially the fluctuations in the years 2007 to 2009 have shown that forecasting changes and level shifts are difficult.<sup>1</sup> Thus crude oil prices should be assumed to remain highly volatile.

Most supply chain innovations are build on the assumption of cheap oil where lower wages embedded in a stable economy justify long transportation routes. However, at a certain point, where increased transportation costs offset benefits from outsourcing or off-shoring. Over the last decade some developing countries evolved to emerging economies, whose gross domestic product increased constantly. While the annual percentage change of real GDP growth in high-income countries declined from 4% in 2000 to 2% in 2010, it increased in developing countries from 4% in 2000 to 6% in 2010. The wage inflation of the last decade, coupled with a weaker dollar, further aggravated the cost-efficiency of sourcing from low-cost countries. According to Goel et al. a Chinese plant worker, made \$1740 a year in 2003 and earned \$4140 in 2008 [105]. The annual wage inflation in China has averaged 19 percent since 2003, contrary to that the US wage inflation has averaged only 3 percent [105]. Thus, besides volatile oil prices increased wages yield to offset the benefits of LCCS.

---

<sup>1</sup> In 1999, the World Bank was forecasting the nominal crude oil price to level off at US\$ 18/barrel for 2005 and US\$ 19/barrel for 2010. This perception reflected the one of most analysts, who assumed real prices to average between US\$ 15/barrel and US\$ 20/barrel in the long run [15]. When in January 15, 2002, WTI futures contract were first introduced the December 2008 futures contract opened at US\$ 18.88. The average crude oil price of 2008, however, was US\$ 97/barrel [15]. Although a number of regulations to financial markets are now being introduced, the effectiveness of these reforms towards excessive speculations has to be seen [110].

Economic system shifts or disruptions are difficult to predict but unfortunately remain influencing globally-spread supply chains as well.

### 2.2.3 Socio-Geopolitical Disruptions

Geopolitical areas – where political stability is missing, where terrorism is prevalent or where law enforcement is restricted – impose a threat to supply chain performance [248]. Socio-political turmoils, like the “Arabic Spring” for example, decreased political stability in North Africa, increased the fear of interrupted oil supply and hence raised the volatility of oil prices. Similarly, the Iraq War impaired global transport flows: Singapore Airlines – flying over the Middle East – had to choose more southerly routes, which caused a decrease of their cargo capacity for products coming from Singapore [66]. Likewise, the Ukraine conflict forced air carriers to change routes. Terrorist attacks threaten democratic societies, western citizens as well as public institutions. Additionally, companies fear attacks on production and distributions hubs. Compared to physical attacks on infrastructure, legislative responses like the safety precautions after the 9/11 attacks are considered to be more realistic. Strong restrictions at the Mexican and Canadian border and the aircraft grounding lasting several days intercepted the continuous procurement of production companies. In the fourth quarter of 2001 Ford, for example, suffered from a decline in car production of almost 13% [198]. There is no reported evidence that indicates an upcoming world-wide, perseverative, political stability. With regard to the current unrest and warlike disturbances in Iraq, Syria, Gaza, and the Ukraine one may safely assume that the uncertainty originating from the socio-geopolitical environment will (unfortunately) continue to exist – also for globally-spread supply chains.

## 2.2.4 Technological Disruptions

Several surveys point out that technological disruptions induced by accidental Information Technology (IT) failure, cyber attacks or corporate espionage are increasingly threatening the efficient operation of supply chains [240, 249].

Innovations like automatic identification and data acquisition, mobile devices, and cloud computing resulted in new systems such as tracking and tracing, real-time control applications, or software-as-a-service. Supply chains, therefore, evolved into interdependent systems not only with respect to material, but also information and financial flows [249]. In the meantime, cyber criminals may utilize these technologies to attack different types of flows within a supply chain. Additionally, decision and analysis tools offer planning support for production, transportation, and supply networks. EDI systems are used for the exchange of documents between suppliers and manufacturers. Both systems are indispensable in daily supply chain operations. Systematic attacks on corporate IT infrastructures may introduce computer virus or cause blackouts, and thus have tremendous effects on overall business performance. Many high-tech companies as well as legislations of large economies have already responded to the increasing potential threat imposed by cyber attacks for supply chains. The United States for example established the national cyber security division within the US Department of Homeland Security. Germany set up a national cyber response center. Both institutions are designed to create countermeasures to cyber attacks. Additionally, corporate unions such as Boeing, Cisco, IBM, Microsoft, NASA and the US Department of Defense, published a security framework for reducing the supply chain attacks and ensuring the integrity of the network [310].

Despite concerns about air traffic or rail infrastructure control or even GPS systems being hacked and manipulated too [240] – a possibility that is discussed intensively [88] – accidental IT failures might be more realistic with quite similar effects. The pursuit of developing



physical secure technology should, therefore, be a major concern – especially in the light of reported traffic and logistics accidents like the mid-air collision of a passenger plane and a cargo aircraft over Überlingen in 2002, like the short circuit at British Telecom in 2004 [317], or like the collision of a carriage and a freight train in 2014 [43].

## 2.3 Coping with Risk

Innovations focusing on improving efficiency turned supply networks into globally operating, interrelated and complex systems, whose boundaries cross corporate entities. Formerly geographically isolated disruptions and volatilities became an issue. Both, scientific community [270, 274, 334, 349] and practitioners [129, 140] became aware of the increased number of perils that have the potential to disrupt a supply chain. The raise of decision makers' awareness, led to the application of a well-known (but not well-understood) concept: risk. The transition from disruptions to risks passed off quickly and apparently arbitrarily. Since then the management of supply chain risk is defined as one of the five fundamental challenges of supply chain management [140]. Quantitative tools are needed that support decision makers in managing those supply chain risks.

### 2.3.1 Enterprise Risk

Contrary to targeted holistic supply chain risk management, the treatment of perils that impede the efficient execution of atomic (logistics) sub-systems is well-established. For example, on the level of small-scale operations such as production tasks, risk is perceived as technical failures or human errors. In this context, event-related deviations from expected parameter levels are addressed by the means of scheduling systems. Scheduling tools work on an operational planning level and are executed whenever the decision maker wants to

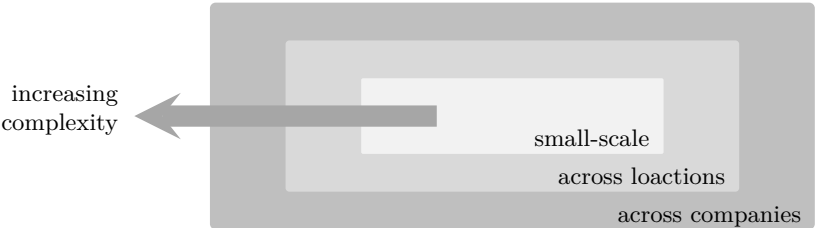
integrate new information. Managerial techniques such as Failure Mode Event Analysis (FMEA) [161, 257], Event Tree Analysis (ETA) [76] or Fault Tree Analysis (FTA) [156, 161] support decision makers in identifying potential triggering events and their related consequences. These techniques are also used for larger logistics systems crossing single locations. However, interruptions within these systems, for example in distribution networks, are quantified by frequency and estimated damage.

On an enterprise level risk management tools became necessary and were established, after major corporate and accounting scandals in the US resulted in economic crises. In the 1990, for example, companies like Enron or Tyco were struck by accounting scandals which led the US government to enact the so called Sarbanes-Oxley Act (SOX) [242]. SOX asks for the integration of risk management in a proposed Internal Control System (ICS). The Committee of Sponsoring Organizations of the Tradeway Commission (COSO) developed an Enterprise Risk Management Integrated Framework including risk elements like event identification, risk evaluation and risk reaction. In accordance with the situation in the United States the European Union enacted several EU Directives (EU Directive 4., 7. and 8.), which hold for the implementation and control of corporate ICS [175] and led to extensions of national laws, e.g. the German Accounting Law Modernization Act (BilMoG). The compliance with these regulations impose challenges to enterprises. The occurrence of disruptive triggers is regarded as a threat that affects logistics figures which in turn influence overall corporate financial figures and need to be governed appropriately.

Today, the management of perils is even more difficult, because enterprises are parts of complex and interrelated supply chains. Disruptions occurring upstream the supply chain may affect product quality or reputation of supply chain partners downstream. Along with the growing complexity of modern supply chains, the impact of any willful action or unintended change have become hard or even impossible to predict. Figure 2.3 summarizes the aforementioned

Logistics Systems	Characteristics		Risk Perception	Tools
production tasks	small-scale		technical failure & human error	scheduling
distribution processes	across locations		relationship between frequency and damage	FMEA, ETA, FTA, ICS
supply chain	across companies		?	?

(a) Characteristics, risk perception, and tools of different logistics systems



(b) Increasing complexity of logistics systems

**Figure 2.3:** Risk perception and complexity of different logistics systems.

thoughts and visualizes the increasing complexity of logistics system from small-scale operations over subsystems crossing single locations and business units up to the concept of a supply chain and their related perception of risk.

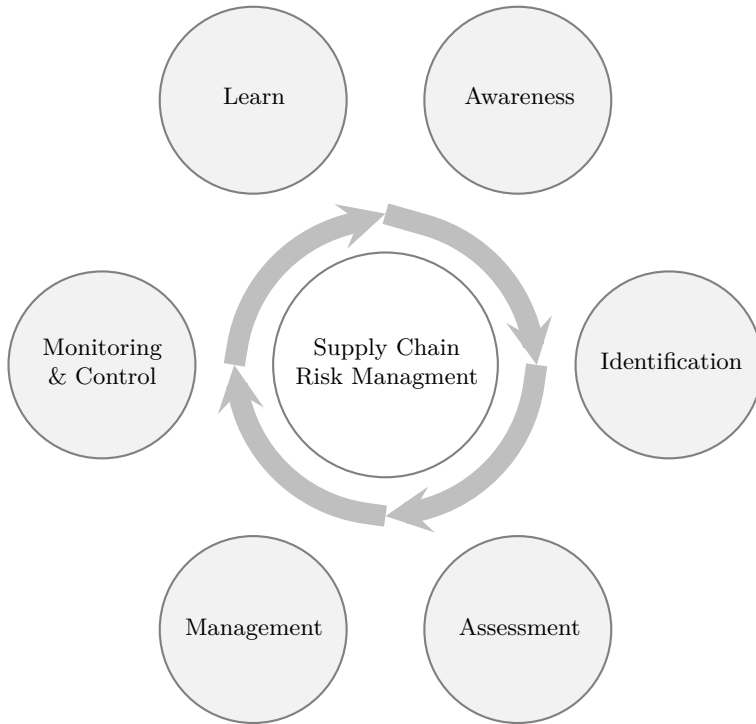
2.3.2 Following the footsteps of Management

Out of the literature of supply chain risk management, different streams of interest and focus developed concentrating on managing and reducing supply chain risk. Much attention has been devoted to the management of supply chain disruptions, which is referred to

as *supply chain disruption risk management* [28]. Supply chain disruption management subsumes approaches that identify and assess short-term alternatives that limit the exposure to disruptive triggers and/or return supply chain execution back to a normal and/or acceptable status. The relatedness between supply chain disruption management and supply chain risk management is well elaborated by several authors [28, 66, 192, 204, 266, 282].

A generic managerial approach especially tailored for supply chain risk can be traced from diverse authors [28, 100, 109, 120, 133, 216, 334, 345, 349]. The approach is arranged as a process cycle, which encompasses the following core management steps intended to be applied for each potential disruptive trigger that evolves out of the aforementioned main types of disruption, see Figure 2.4:

- *Awareness.* The acknowledgment and establishment of a corporate risk culture is considered to be essential for the success of supply chain risk management implementations. Establishing culture implies creating risk awareness and information transparency over different business units, management levels, and supply chain partners [133, 149, 334].
- *Identification.* To install selective risk countermeasures it is indispensable to know about the threats in the environment of supply chains. Gathering and evaluating information about prospective trends or level shifts are the objectives of the identification step. Therein the supply chain, its boundaries, its processes, and its objectives are defined and described.
- *Assessment.* Then activities within the specified system are examined in order to identify potential points of weaknesses as well as threats [334]. Traditionally, the result of this step is a catalog of potential relevant threats [345]. Upon the predominant understanding of risk, identified supply chain risks are classified, assessed and ranked in accordance to their relevance. The relevance is usually quantified by the probability of a threat and its related impact.



**Figure 2.4:** Process cycle of supply chain risk management steps based on [28, 109, 120, 133, 216, 334, 345, 349].

- *Management.* For top-prioritized supply chains efficient counter-measures need to be identified, designed and implemented. Different types of typically mentioned risk mitigation options include, but are not limited to insurance, information sharing, relationship and partnership development, design of contractual mechanisms, regular reviews and supplier audits, and pro-active assessment and planning, like flexible supply base, flexible transportation, strategic stock, or postponement [251, 307]. Ritchie and Brindley [251] as well as before Kleindorfer and Saad [168] discovered the

development away from individualistic measures, such as insurance or supplier contracts, towards integrated and co-operative risk responses. While the application of the former puts external responsibilities in charge of financial and physical damages, the latter encourages risk sharing among supply chain partners.

- *Monitoring & Control.* The surveillance of relevant performance indicators, the continuous update of the relevance of identified risk, and of the developed activities for risk response are continuously executed actions and referred to as Monitoring and Control.
- *Learn.* It is emphasized by numerous authors that the course of supply chain risk management is an ongoing process, steps interact and new insights need to be considered for the execution.

Although this cycle provides a work flow of risk conduction, it lacks a quantitative treatment of risk that can be adjusted to any logistical subsystem within a supply chain, whether it is a production task or a corporate subnetwork.

### **2.3.3 Identification needs Quantification – Quantification needs Definition**

Besides logistics operations, the performance of related business units such as finance, sales, purchasing or IT affect and depend on an effective supply chain risk management. System-inherent uncertainties that can hardly be allocated to a specific event need to be identified as well. The delimitation of different types of risks is, however, vague and hinders an efficient execution of supply chain risk management. With the intention to enhance the supply network with the capability to appropriately respond to threats, supply chain risk management has to provide reliable instruments that support the understanding and mitigation of supply chain risks. These instruments include qualitative indicators and quantitative metrics. The expertise of supply chain officers or the evaluation of real cases are valuable with regard

to the understanding of risks. The need for quantitative instruments tailored for supply chains is even higher and continuously increasing, because it allows a systematic approach for risk consideration and surveillance. Consequently, the development of *risk quantification metrics* represents the most prioritized improvement need for supply chains [248]. It is due to the very nature of the term risk and the development of its understanding that results in diverse perceptions and definitions of supply chain risk and its management. As threats originate from diverse environmental categories, may affect various parts of the supply chain and have to be handled by different corporate units, this discipline attracts the attention from multiple domains and research fields. It follows that definitions of concepts related to supply chain risk depend on the methodological background and interest of research scientist as well as on cultural, industrial or geographical differences, rather than on what is actually needed or reliable.

In the following Chapter we work on the contemporary understanding of risk and re-define supply chain risk with the intention to provide the basis for what is needed most: supply chain risk quantification.

Towards Supply Chain Risk Analytics  
Fundamentals, Simulation, Optimization

Heckmann, I.

2016, XXII, 411 p. 83 illus., Hardcover

ISBN: 978-3-658-14869-0