

# State of the art in supply chain risk management research: empirical and conceptual findings and a roadmap for the implementation in practice

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**Abstract** With regard to success and survival of a company, risk management is essentially important. Numerous insolvencies and financial crises have brought this complex issue to the attention of managers and scientists to a greater extent. There have already been rudimentary conceptual and empirical approaches to Supply Chain Risk Management. From analyzing conceptual papers and empirical studies, an integrative summary of the previous research is developed in order to identify the main principles of Supply Chain Risk Management and evolutionary steps for its implementation. This approach provides a framework for further analysis and exploration of Supply Chain Risk Management.

**Keywords** Supply chain risks ·  
Supply chain risk management · State of the art ·  
Principles · Roadmap

## 1 Management challenges from a turbulent global economy

The globalization of economic interchange, rising volatility of markets, trends towards out- and single sourcing, as well as just-in-time concepts are making today's supply chains ever more complex [1, 2]: Flows of goods, information, financial resources, rights, and multiple interfaces have to be integrated, increasing their vulnerability [3].

This is exacerbated by numerous events of the previous decade. Supply chains are often triggered by disturbances

on both the supply- and the demand side, e.g., terrorist attacks [4], natural disasters, changes in consumer behaviour, technological crises, or bankruptcy.

The trend to designing lean supply networks which are tightly coupled and operated at minimum levels of time and material's buffers makes them vulnerable to local disturbances. These can be an existential threat to global or networked supply chains and may have negative effects on costs, quality, flexibility, and reliability on image and ultimately the valuation of all the participants in the network. Cross-company Supply Chain Risk Management therefore becomes a critical success factor.

There has been a fundamental consensus emerging—in research as well as in business practice—that systematic risk management is required to deal with these challenges. However, there are different opinions on the necessary elements of successful Supply Chain Risk Management. Research on the process of Supply Chain Risk Management implementation has been lacking entirely.

The goal of this article is to first provide an overview of existing publications and studies concerning Supply Chain Risk Management and then to deduce principles and recommendations for its implementation.

The paper is organized as follows. Risk is a term which is often used, but not defined consistently in literature and practice. Therefore, in Sect. 2 common definitions of supply chain risk and risk-related terminology will be explained followed by an analysis of supply chain risk drivers. Section 3 defines Supply Chain Risk Management and provides theoretical insights into risk management before we give an overview about the state of the art in empirical and conceptual works on Supply Chain Risk Management. Based on the analysis, we summarize basic principles of Supply Chain Risk Management and provide evolutionary steps for its implementation in Sect. 4.

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Finally, Sect. 5 presents the conclusion and future directions.

## 2 Terminological and conceptual foundations

### 2.1 Defining supply chain risks

Risk can be defined in two ways. If related to the *causes* of risk, focus is on the deficits of information by a decision-making unit concerning prospective situations and events [5]. A decision under risk is one where there is objective or subjective uncertainty with regard to the outcomes of a chosen path of action.

A risk definition related to *effects* centres on the consequences of a decision. Risk can be understood as an endangerment that arises due to a wrong decision [6] or as “variation in the distribution of possible outcomes, their likelihoods and their subjective values” [7]. This definition allows considering risks as a speculative component of corporate actions.

Taking risks is not automatically negative. It may also offer opportunities and chances that might be of benefit for the company. While the approach related to effects interprets the risk as not making the goal, chance can be more specifically defined as the possibility to make that goal. A more comprehensive perception considers chance as a positive miss of the goal. The goal is over fulfilled [8].

In this paper, we refer to risk scenarios that arise along a supply chain. Jüttner, Peck and Christopher define supply chain risks relative to the integrity of the flow of the supply chain and conceive them accordingly, “...any risks for the information, material and product flows from original supplier to the delivery of the final product for the end user” [13].

Gaonkar and Viswandaham define supply chain risks according to the definition of risk by March and Shapira [7] as “...distribution of the loss resulting from the variation in possible supply chain outcomes, their likelihood, and their subjective values” [14].

For the purposes of this discussion, a definition will be chosen that includes a reference to flow disruptions as well as outcome deviations, and aligns itself with the network levels of a supply chain.

Supply chain risks involve risks that can be attributed to disturbance of flow within the goods-, information-, and financial network, as well as the social and institutional network. They might have negative effects on the goal achievement of single companies and the whole supply chain, respectively, with regard to end customer value, costs, time, or quality.

### 2.2 Categorizing supply chain risks

Not only the definition of supply chain risk is a difficult endeavour, but also the categorization of various kinds of supply chain risks [15]. One attempt to categorize is considering three types of risks: Risks within a focal company, risks outside of this company and within the supply chain, and risks outside of the supply chain that affect the focal company from their respective place of origin [16].

Risks that originate within a focal company can be defined as either process risks or control risks. *Process risks* specify disturbance within a company’s activities with regard to increase in value, e.g., production delay or failing operating resources. Consequently, the desired performance cannot be created. *Control risks* emerge from disturbance in management systems or due to imprecise or wrong decision rules, which an organization uses to coordinate their own, and supplier’s and consumer’s processes. Badly planned batch sizes and even missing or not feasible work assignments for employees are counted among those [10].

Risks outside of the company and within the supply chain are distinguished between supply risk and demand risk [17]. *Supply risks* are based on disturbance of flow on behalf of the supplier. The breakdown of a key supplier is an example for supply risks. *Demand risks* involve disturbance on behalf of the consumer. Demand risks indicate e.g., fashionable or seasonal fluctuations in demand.

Risks outside of the supply chain are described as *environmental risks*. They include e.g., natural disasters, terrorist attacks, or changes in legal regulations.

### 2.3 Risk-related terminology

To complete the discussion of the terminological foundations of supply chain risk, a short overview of closely related terms follows:

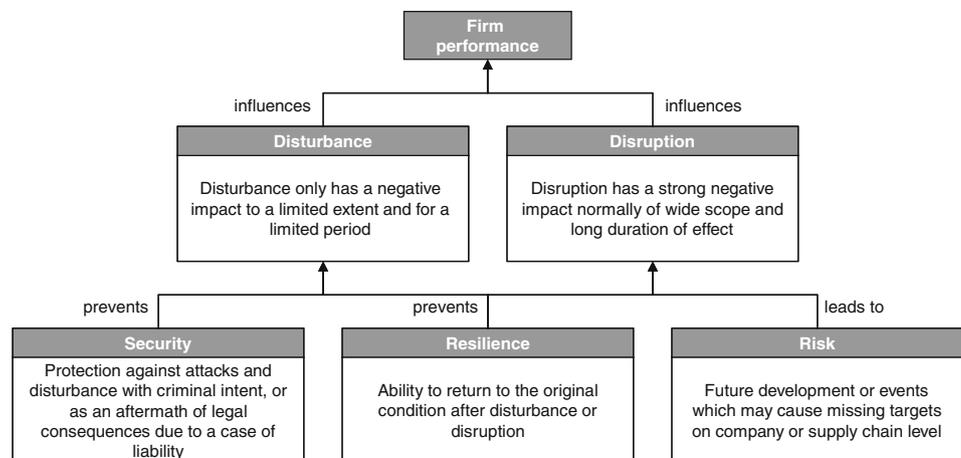
- *Disturbance*: Risks might lead to disturbance within the supply chain. Literally, disturbance can be defined as “the interruption and breaking up of tranquillity, peace, rest, or settled condition” [9]. Those might manifest themselves by fluctuation in demand, default of delivery, or quality changes. They usually lead to negative impacts for a limited period and parameter only and can be prevented by measures such as buffers.
- *Disruption*: Literally, disruption is defined as “the action of rending or bursting asunder; violent dissolution of continuity; forcible severance.” [9]. Sphere of action and duration of effect are graver than in the case of disturbance. Examples are strikes at key positions of international trade, alterations of political circumstances,

or natural disasters, which are interconnected with considerable financial damage.

- **Security:** Security emphasizes the security of companies, systems, and the public sector with regard to maintaining a desired condition. In the context of a supply chain, customs clearance of ocean freight, completion of coverage contracts to secure liquidity in the case of liability, or ongoing ability to deliver after terrorist attacks are to be mentioned in this context. Supply chain security can therefore be characterized as the protection of the supply chain against attacks and disturbance with a criminal intent, or as an aftermath of juridical consequences in the case of liability and perpetuation of the companies under those kinds of circumstances.
- **Safety:** In contrast, literally, *safety* is defined as “the state of being safe; exemption from hurt or injury; freedom from danger” [9]. In this context, it is more about the personal safety of a person or unit against a distinct threat in the sense of operating safety. Examples refer to process safety, environment and health, or emergency stocks. With regard to transport, transport safety in the sense of “safety” can be characterized as protection against threats that originate from transport itself and affect transported goods, means of transport, as well as the environment.
- **Resilience:** Resilience refers to the ability of an organization to quickly go back to a functioning initial state after disturbance [10], namely the ability “to bounce back from hardship” [11]. This behaviour can be seen as an analogy to the behaviour of elastic material exposed to extreme pressure. In order to give utterance to the necessary term of flexibility that is implied by resilient [12], the term will be understood as synonymous to agile at the same time.

Figure 1 shows the terms listed, their relationships, and their effect on firm performance.

**Fig. 1** Risk-related terminology



## 2.4 Drivers of supply chain risk

The literature on Supply Chain Risk identifies a number of trends that affect the degree of risk and can be seen as drivers of supply chain risk levels that need to be considered for a systematic supply chain risk management:

- **Globalization:** Cost pressure has motivated many companies to partially or completely outsource their production to low cost countries, as well as procuring internationally. Furthermore, the internationalization of sales market advances. However, resulting worldwide supply chains contain further risks due to higher coordination expenses, extended routes of transportation, as well as problems based on cultural differences [18–21].
- **Outsourcing:** The trend towards decreasing the degree of company-internal value-added due to transferring processes to suppliers, consumers, or service providers, leads to a fragmentation of supply chains [19]. Thus, outsourcing goes hand in hand with more complex business relations. Consequences might be indistinct responsibilities and insufficient control potential [13].
- **Centralization:** Increasing cost pressure advances to further focusing on few production and distribution locations. At the same time, the number of suppliers is reduced and inventory levels are decreased. This is meant to achieve scale effects and reduce costs [18]. Even so, important resources depend on single companies and divisions. The risk of downtimes in production, as well as the risk of increasing costs, opportunism, and lack of willingness to compete increases [22, 23].
- **Lean processes:** Lean production and just-in-time approaches were introduced in order to reduce waste within the supply chain. Decoupling inventory, capacity buffers, and time buffers, which used to absorb the effects of disturbance and delays on the company, were

abolished [24]. However, the risk situation of involved companies might thus decrease. Even in case of small delays, missing buffer stocks might represent a huge risk.

- *Complex products and service*: Increasing demand of more efficient and more comprehensive products and services lead to a rise of complexity in production and services [1, 16, 25]. The trend towards concentrating on core competences leads to cross-company production and product development [26]. The thereby growing number of actors and interfaces, and herewith potential failures, increases the risk potential within the supply chain. Moreover, product life cycles in many branches were shortened. It is therefore getting more and more difficult to precisely forecast the demand of goods [19, 27].
- *IT-dependence*: Internal as well as cross-company processes in the range of flow of goods, finances, and information are closely interrelated nowadays. They can only work properly with an extensive IT-support. A failure of the IT infrastructure within or between companies might cause considerable damage.
- *Deficits of information*: The more interwoven and comprehensive the relation between processes within the own company and upstream or downstream supply chain partners, the more difficult it becomes to obtain a comprehensive and detailed knowledge about the latter [26]. Moreover, an active flow of information between companies and cross-company management of risk become harder to implement, and many risks simply do not even get discovered.

Beyond the trends and developments which increase a supply chain's vulnerability [28, 29], additional influences from a supply chain's environment call for consideration:

- *External threats*: Due to their global alignment, supply chains are usually also exposed to extreme external threats, such as natural disasters, epidemics, or terrorist attacks, which negatively affect logistics systems [17].
- *Required resources of growing economics*: Existing raw materials and energy run short due to the persistent growth and the high level of required resources, especially in Asian economics. This might lead to a poor delivery reliability and ability to deliver, and therefore negatively affect the cost structure of companies and supply chains.

The trends and influences listed above are drivers of supply chain risk. But—at the same time—they provide the conditions upon which successful companies base their competitive advantages and distinctiveness. They increase chances for differentiation and excellence. In order to exploit these chances and maintain control over associated

risks in a balanced way [19], a systematic Supply Chain Risk Management is required.

### 3 Supply chain risk management

#### 3.1 Defining supply chain risk management

Supply chains tend to increase in complexity, as the previous discussion showed. The fact that numerous suppliers, service providers, and end consumers may be involved in a network of relationships causes risks and vulnerability for everyone. It is not sufficient to just analyse the risks with regard to one focal company, but potential domino effects upon all partners and relations have to be examined.

Companies in the supply chain differ in risk attendance and risk acceptance level. It is therefore necessary to aim for mutual goal setting and planning across the entire supply chain network. With regard to Supply Chain Risk Management, this means mutually identifying and communicating problems in order to abolish information asymmetries and prevent negative effects on firm performance. Systematic risk management may be conceptualized as a process that consists of risk identification, risk assessment, risk mitigation strategies and risk control [30].

For the following arguments, consequently, a definition of Supply Chain Risk Management is applied as suggested by Kajüter: “Supply Chain Risk Management is a collaborative and structured approach to risk management, embedded in the planning and control processes of the supply chain, to handle risks that might adversely affect the achievement of supply chain goals” [30].

A subcomponent of Supply Chain Risk Management is Supply Chain Security Management [31]. Supply Chain Security Management can be defined as “the application of policies, procedures, and technology to protect supply chain assets from theft, damage, or terrorism and to prevent the introduction or unauthorized contraband, people or weapons of mass destruction into the supply chain” [32].

#### 3.2 Theoretical bases of supply chain risk management

Two familiar sets of theories are useful in providing a theoretical basis for systematic considerations of Supply Chain Risk Management [33]:

*Capital market theory* assumes perfect markets with equal conditions for all agents, perfect information, and no transaction costs. A distinction is made between systematic risks and non-systematic risks [34]. All market participants are equally exposed to systematic risks. They depend on external factors and cannot be prevented by internal risk management [35]. Non-systematic risks are different for

every single company. Due to the assumption of a perfect competition, non-systematic risks might be entirely eliminated by diversification [36]. Systematic risk can be shifted to some extent to third parties through the utilization of appropriate financial instruments. In perfect competition, risk management on company and supply chain level therefore becomes irrelevant, since investors are able to control risks on their own [33]. However, risk management by implication becomes reasonable in real-life conditions of an imperfect market with altered assumptions, such as taxes and subsidies [35], [37].

*New institutional economics* does not act on idealized assumptions. It assumes that companies act rationally only in a restricted manner, as soon as information asymmetries and transaction costs occur on the market. The relation between company's management and its shareholders is consistent with a principal-agent-situation. Information is distributed unequally. The management is the agent. It holds more information on the risky situation than the shareholders. The latter are not involved in immediate business processes. The shareholders act as principals. This situation might lead to advantages for the management due to profiting from investments that the shareholders would distance themselves from if they knew about the risky situation to a larger extent [36]. On the other hand, the management depends on success and consistency of the company and is not able to diversify its own risk. It therefore tends to make opportune decisions and to handle investments in a more risk averse way than the shareholders want them to [35]. A risk management system may serve to reduce deficits of information by a reporting in order to increase the faith in an investment. Besides, a concrete decision scope can be applied, concerning which risk position the company aims at and how it deals with risks [33]. *New institutional economics* can also be applied to supply risks where the purchasing organization refers to a principal and the supplier as an agent [22].

### 3.3 A survey of recent empirical studies

The study of inventory models can be seen as an early starting point of the empirical studies of supply chain risk [38, 39]. There has been an increasing number of broader empirical studies recently.

In order to learn what the insights and results of those efforts were, a literature survey has been undertaken of quantitative and qualitative empirical studies published in several leading international journals: *The International Journal of Logistics: Research and Applications*, *International Journal of Physical Distribution and Logistics Management*, *International Journal of Production Economics*, *Journal of Business Logistics*, *Journal of Purchasing and Supply Management*, *Supply Chain*

*Management Review*, *Supply Chain Management: An International Journal*, and *The International Journal of Logistics Management*. Publications were analysed for the period between 1998 and 2008 when they made apparent references to supply chain risk and supply chain risk management. In addition, relevant monographs of the last decade as well as contributions to compilations by relevant authors were also analysed, while adjacent topics like *Supply Chain Security Management* [31, 40] were not included in the survey.

Zsdisin and Ellram studied procurement risks [22]. Due to their findings, purchasing organizations increasingly become involved in behaviour-based management in response to threats of supply risk from the ability of suppliers to meet technological advances and quality standards. Another interesting result of their study was that buffers are build regardless of the extent of perceived supply risks.

Based on case studies, the authors came to the recommendation that purchasing organizations can assess supply risk with techniques that focus on addressing supplier quality issues, improving supplier processes, and reducing the likelihood of supply disruptions [41]. Risk assessment techniques facilitate the obtaining of information by purchasing organizations to verify supplier behaviours, promoting goal congruence between buying and selling firms, and reducing outcome uncertainty associated with inbound supply.

Another study focussing on the supply side is done by Svensson who analysed the inbound logistics flow of manufactures [28].

In a follow-up publication approach, Svensson qualitatively investigated key areas, causes, and contingency planning of corporate vulnerability in supply chains [42]. His conclusion is that dependencies on processes bear more risks than dependencies on other companies or on time. National, international, and global environmental risks influence those risks. Exchange of information takes place via direct connections between companies, not within the entire supply chain.

Kersten et al. [43] found that Supply Chain Risk Management has played a minor role only among a sample of companies they interviewed. Information is being exchanged between companies of the 1st und 2nd tier primarily, not really across a wider range of participants in multi-tier supply chains. However, these note that Supply Chain Management is perceived to become more and more relevant.

Jüttner and Peck [17] found in their study a strong interest in supply chain risks around the turn of the millennium, sensitized by the Y2K-Bug. They were able to demonstrate rippling effects of supply chain risks in their study. However, risk management systems on supply chain

level have not been installed quite often. Every company rather establishes its own risk management system. The study furthermore showed a strong demand for tools for Supply Chain Risk Management. Availability of information is essential at this point. The majority of interviewed companies never or only occasionally exchanges information on their exposure to specific risks. Based on the survey findings, issues of Supply Chain Risk Management were derived and structured along the conceptual levels philosophy, principles, and processes.

Hallikas, Virolainen and Tuominen [44] analysed risk management in partnerships. According to their study, strategic partnerships boost corporate learning, innovation, communication, and common risk management. Risks within supplier–consumer relations are also perceived as mutual if there are asymmetrical relations (“adhesion contracts”). Their empirical study showed that corporate control risk rates higher especially within companies with high risk than just risk aversion or risk reduction.

In their extensive study, Pfohl, Gallus and Köhler [45] examined sources of supply chain risks. They found that demand risks are the most critical for service providers. In the future, the relevance of resource risks will increase. Supply risks are the highest risks for industrial and trading companies. The relevance of supply risks will further increase in the future. When dealing with supply chain risks, it became obvious that industrial and trading companies predominantly deal with supply chain risks proactively, whereas service providers deal with them in a reactive manner. Generally, many companies realized the importance of a structured risk management process. However, there is still potential for improvement with regard to its implementation. This applied especially for logistics service providers. Pfohl, Gallus and Köhler concluded that a cross-company Supply Chain Risk Management is a pragmatic concept for the future. However, it is hardly practiced nowadays. Obstacles can seldom be found within the company itself, but rather at interfaces with partners.

Straube and Pfohl [46] were able to prove the increasing effect of advancing risks and security requirements on logistics in their empirical study. Customer requirements and the demand for improvement of processes are the main drivers for activities in order to increase security and prevent risks. With regard to the future, the empirical results showed that the increased global security requirements and risk potentials will change logistics systems in industry, trade, and service. Reduced single and global sourcing, augmented redundancies due to storage, and higher inventory were expected. High potential is credited to efficient security and risks management in order to improve reliability. It also accounts for a strong driver in order to increase logistics costs.

Wagner and Bode [47] examined the influence of supply chain risks on the performance of a supply chain. According to their study, 6% of the supply chain performance’s variance can be attributed to supply chain risks. Supply-side risks, as well as demand-side risks significantly affect the supply chain performance. However, a negative effect of regulatory, legal and bureaucratic risks, infrastructure risks, and catastrophic risks on the supply chain performance could not be established.

In another study, Wagner and Bode [23] examined the correlation of supply chain vulnerability and supply chain risk. They found out that a company’s dependence on certain customers and suppliers, the degree of single sourcing, or reliance on global supply sources are relevant for a company’s exposure to supply chain risk. According to their findings, a strong customer dependence and a strong supplier dependence increase significantly demand-side risks. Moreover, supplier dependence, single sourcing, and global sourcing were identified as significant drivers of vulnerability on supply-side risks. Regarding catastrophic risks, only global sourcing is a significant factor that exposes firms to higher risk from catastrophes.

Papadakis [48] analysed the financial performance of supply chains after disruptions. He demonstrates the decrease in the company’s stock price as a reaction of supply chain risks [22].

Financial effects on supply chain risks were also studied by Hendricks and Singhal 2003 and 2005 [49, 50]. Due to their findings, firms suffering from supply chain disruptions experience between 33 and 40% lower stock returns relative to their benchmarks over a 3-years time period that starts 1 year before and ends 2 years after the disruption announcement date. Furthermore, a significant negative effect on profitability could be proved.

The analysed empirical papers prove the high importance of a supply chain wide risk management due to the effects of supply chain risks on firm and supply chain performance. Most companies are aware of that and more and more of them react by efforts in Supply Chain Risk Management. However, often this only includes first tier supply chain partners.

### 3.4 Towards more comprehensive conceptual contributions

The studies reviewed so far are important contributions to the foundation of a field of systematic research on Supply Chain Risk Management. However, they focus primarily on issues of problem definition and systematization of supply chain risks, or on the transfer of general insights to risk management to the specific context of supply chain management.

Comprehensive conceptualizations of Supply Chain Risk Management with broad practical applicability are found only at a preliminary stage of development [1]:

Cranfield University's "Self-Assessment Workbook" [51] offers an approach to managing supply chain risks. The underlying four stages of risk management include: Description of the supply chain, vulnerability self-assessment templates, evaluation of implications, and identification of actions. However, the workbook barely offers advice on cross-company exchange of information.

The latter is the main aspect in the Supply Network Risk Tools by Harland, Brenchley and Walker [1], which derives from various case studies. Their six-step process aims at the management of procurement risks: Map the supply network, identify risk and its current location, assess risk, manage risk, form collaborative supply risk strategy, and implement supply network risk strategy.

Hallikas, Virolainen, and Tuominen [44] developed a Supply Chain Risk Management concept which concentrates on collaboration between network partners. They suggest dividing risks in supplier networks into dimensions of severity (insignificant, minor, serious, or catastrophic) and probability (very unlikely, improbable, probable, or very probable).

Manuj and Mentzer [52] created an integrated framework for global Supply Chain Risk Management with the aid of linked tables. Their five-step approach includes a mix of multiple risk assessment tools and contains risk identification, risk assessment and evaluation, selection of appropriate risk management, implementation of Supply Chain Risk Management strategies, and mitigation of supply chain risks. They refer to supply risks, operational risks, demand risks, and security risks but also to macro risks, policy risks, competitive risks, and resource risks. Their approach distinguishes itself by its high particularization level. In dependence on supply uncertainty (low/high) and demand uncertainty (low/high), they differentiate between four supply chain types, which they assign the respective seven risk management strategies: avoidance, postponement, speculation, hedging, control, transferring/sharing risk, and security.

Hauser [53] suggests a business case framework to assess and manage risk in an organization. The framework consists of process/risk identification, vulnerability identification, redefinition of the model, creating a complexity/risk portfolio, finalized model, developed initiatives, and performance measurement.

According to a case study, Norrman and Jansson [19] describe how Ericsson has implemented a new organization, new processes, and tools for Supply Chain Risk Management after a serious sub-supplier accident.

A comprehensive framework to categorize various managerial actions that take risk into account was

suggested by Norrman and Lindroth [54]. They arrange their Supply Chain Risk Management framework by three dimensions: Risk handling focus (risk analysis, risk assessment, risk management), type of risk (operational accidents, operational catastrophes, strategic uncertainties), unit of analysis (single logistics activities, company logistics, dyads logistics, supply chain logistics).

An extensive Supply Chain Risk Management framework from requirements to implementation is presented by Franck [55]. Principles of the Supply Chain Risk Management process (supply chain design and structure, visibility, cooperation, communication) are based on this philosophy. The process orients itself by the framework developed by Norrman and Lindroth [54]. We've come full circle with realized risk and retroactive processes (business continuity management, learning). Process continuity (performance measures, continuous updating, monitoring) is seen as fundamental for Supply Chain Risk Management.

Kleindorfer and Saad [21] developed a conceptual framework that contains specification of sources and vulnerabilities, assessment, and mitigation. They categorized their proposed strategies in two dimensions: actions and necessary conditions for effective implementation. With a set of ten principles, they guide practise. Addressed risks may arise from natural disasters, from strikes and economic disruptions, and from acts of purposeful agents, including terrorists.

Faisal, Banwet and Shanker [56] defined a model of supply chain risk susceptibility by using the supply chain operations reference (SCOR) approach. They combined an analytic network process approach with the SCOR model. Their framework refers especially to physical, informational, relational, and financial risks.

Based on case study research, Thom developed a SCOR-oriented model to manage risks in production networks [57]. Several risk management methods are applied to the supply chain context and are integrated in a comprehensive model.

Pfohl, Gallus and Köhler [15] divide Supply Chain Risk Management activities into internal modules and cross-company modules. First, internal requirements for Supply Chain Risk Management have to be fulfilled: risk policy, internal risk management process, and responsibilities for supply chain risks. Only then, cross-company modules are able to work properly: principles of collaboration, a cross-company risk management process, a cross-company risk management catalogue, coherent risk sheets, a supply chain risk map, and central coordination for Supply Chain Risk Management.

The analysis of the approaches presented here reveals that in many cases only single risks or risk categories such as procurement risks are taken into account within the

Supply Chain Risk Management process [22, 58–60]. Sometimes the demand side is also considered [29, 60]. Number and details of the process steps vary, as well as availability of standardized templates and checklists, which support an implementation on supply chain level. In many cases, there is a lack of definition how to integrate partners into cross-company Supply Chain Risk Management and how to implement Supply Chain Risk Management.

Supply Chain Risk Management does not work simply by applying a number of methods. It rather is a philosophy that is supposed to be deeply rooted within the company and the supply chain. In order to do so, companies and supply chains have to pass certain evolutionary steps which will be presented in the following.

#### 4 A roadmap for the implementation of supply chain risk management

##### 4.1 Deriving 17 principles of supply chain risk management

Building on the review and analysis of the empirical and conceptual studies of Supply Chain Risk Management that have been presented in the previous sections of this paper, a set of 17 Supply Chain Risk Management principles is derived as a next step in the evolution of the field. We state these first and then discuss the rationale for each of them.

1. The focus of risk management is across company boundaries and on the supply chain.
2. The company has a thorough knowledge of all interfaces within the supply chain.
3. Supply Chain Management and Supply Chain Risk Management are seen integrated and not independent on each other.
4. Internal risk management and Supply Chain Risk Management are coordinated and integrated.
5. Supply Chain Risk Management is part of the corporate strategy.
6. Top management supports Supply Chain Risk Management and is responsible for it.
7. All actors within the supply chain have a mutual comprehension of potential risks.
8. Risk information in the supply chain is available for a company.
9. Supply chain companies have a close, cooperative, and fair relationship.
10. Supply chain companies mutually trust strongly.
11. Information asymmetries between companies do not exist.
12. Companies have mutual goals and planning processes for the supply chain.
13. Risk information is exchanged in the supply chain.
14. Direct supply chain partners cooperate with regard to risk management.
15. Risks as well as rewards of risk management are achieved and shared together.
16. All actors of the supply chain (from suppliers to customers, from employees to top management) are involved in risk management activities.
17. All actors of the supply chain aim at the same goals with regard to Supply Chain Risk Management.

Supply Chain Risk Management refers to risk management with a focus on the supply chain and its risks, which have an impact on the company [54]. It is the very first principle of Supply Chain Risk Management. Internal risks must not remain unobserved. Any further area outside of the company rather has to be taken into account. Above all, it is essential to think in a cross-company manner, to consider possible ripple effects, and to take mutual dependencies of risks into account [54, 61].

The outcome of this is a further principle of Supply Chain Risk Management: Companies conducting Supply Chain Risk Management need to have accurate knowledge of the links within the supply chain. They need to have a precise idea of sources and drains of the supply chain and what kind of links exists between them [10]. Only then, a company and its risk management are able to apprehend internal risks and their dependencies.

Furthermore, Supply Chain Management and Supply Chain Risk Management need to be coordinated, at best even integrated [17]. Risk management is only able to contribute to the improvement of a risk situation by implementing control procedures, and not by preventing the Supply Chain Management's initiatives of optimization, efficiency enhancement, and downsizing [16]. The same applies for general risk management and Supply Chain Risk Management of a company. Those have to be coordinated and integrated as well [62].

Internal risk management as well as Supply Chain Risk Management have to become integrated into corporate strategy. Risk targets are thus considered already when making fundamental decisions on how to develop a supply chain [63]. Equally important is support of top management since supply chain risks might become threatening to a company's existence [51].

In order to be able to make cross-company comparisons of risks, and operate them with regard to their importance, it is essential to apply a coherent risk measurement beyond the entire supply chain. Participating companies of a supply chain therefore have to develop a common understanding of risks and agree on a coherent standard of risk evaluation, which allows to evaluate the identified risks irrespective of the firm-specific willingness to take risks [17, 30]. Based

on this, risk information on all nodes and connections within the supply chain has to be available [10].

For this purpose, a close and cooperative relationship is necessary between supply chain partners [21]. Companies which enter into a partnership for a short time for cost reduction purposes normally do not want to introduce relationship-specific standards or coordinate processes. However, those standards and coordinated processes are necessary for a cross-company risk management. Those companies might rather tend to act opportunely with regard to costs, instead of giving up their own short-dated profit in favour of progression of total profit of the supply chain, and develop control risk measures collectively [21, 44].

This mutual trust is at the same time an important requirement for a good distribution of information of all participating companies along the supply chain [26, 64]. This plays a central role as early as in Supply Chain Management. Not least, because the bullwhip-effect emerges due to a lack of information on sales figures by producing companies for consumers. Status information on the entire supply chain is also important in Supply Chain Risk Management in order to identify and consider precarious developments and their effects on other areas within the supply chain at an early stage.

Apart from coherent distribution of information, a collective planning processes and targets for Supply Chain Risk Management is also important at this stage [17]. The latter allow for a supportive and non-competitive behaviour between participating companies in case a risk occurs.

Furthermore, exchanging risk information between all levels and all companies is essential, without running the risk of opportune behaviour [12, 17]. Interlocking relationships without trust also lack willingness to communicate information, e.g., on the common condition of the company, especially if the latter represents a risk. There would be the constant danger of opportune utilization to the disadvantage of the own company [58]. Passing on risk information between the companies is however necessary in order to effectively implement Supply Chain Risk Management. All companies have to coordinate process organization and identify possible weak points within the supply chain, e.g., when developing supply chain continuity plans. This therefore means cooperation between participating companies, also with regard to control procedures, to allow for continuity plans to complement each other, and not affect each other negatively [18, 30].

Finally, it is important that companies participating in Supply Chain Risk Management perceive risks within the supply chain as mutual risks. Achievements of Supply Chain Risk Management are therefore mutual achievements [17]. This kind of comprehension might support and simplify control risk. This applies whenever a partner takes control risk measures substitutionally for the supply chain,

because he is more than others able to influence a risk. This applies e.g., if a wholesaler introduces an additional emergency stock which benefits all companies in the case of own fluctuation in demand. As a reward, it is then possible for the company to compensate the wholesaler for his additional costs since they do not have to bear the costs on their own. In general, all participants are better off due to this kind of measure since there is no need for every single company to have their own buffer for fluctuations.

Participation of all relevant actors within a supply chain, from raw material supplier to end customer, has to be a main target for Supply Chain Risk Management [16]. Only including all those relevant actors and aiming at the same targets in Supply Chain Risk Management allows for fully exhaust the possibilities of Supply Chain Risk Management.

In order to implement a far reaching Supply Chain Risk Management, all relevant companies have to fulfil the 17 requirements mentioned above. However, further intermediate levels and evolutionary steps exist when implementing Supply Chain Risk Management. They will be elaborated on in the following.

#### 4.2 Evolutionary approach to broadening the scope of supply chain risk management

A first starting point in order to define evolutionary steps in Supply Chain Risk Management might be the stages of development of *general risk management*. Martin and Bär e.g., define three stages of development which align themselves with extent and phases of the general risk management process. The first stage is a risk management which is limited to shifting single risks to insurances. It can be expanded to a more extensive management of single risks by several control procedures. The third stage constitutes an extensive, proactive risk management, which deals with all risks of entrepreneurial actions [65].

Another starting point for developing evolutionary steps of Supply Chain Risk Management is *Supply Chain Management*. Pfohl [66] and Werner [67] distinguish between four stages of development based on the extent and degree of integration in Supply Chain Management. The first stage assumes a limitation with regard to subsystems within the company. Procurement, production, and sales are organized separately. The following stage integrates those organizations, which ensures direct and internal exchange of information between the divisions, and allows for coordination of processes. The next evolutionary step additionally includes cross-company cooperation with suppliers and customers. Coordination of processes in procurement and sales is only possible by involving participating companies. The fourth evolutionary step expands this cross-company aspect by the component of a

collaborative management. Internal and external processes get integrated and synchronized.

Those two patterns of evolutionary steps in risk management and Supply Chain Management offer starting points which help defining evolutionary steps for Supply Chain Risk Management. They might be distinguished with regard to the extent of risk management or with regard to degree of integration of participating companies, respectively [63]. This results in five evolutionary steps (see Table 1).

*Stage 1:* A company is located on stage 1 if a general risk management is established within the company, but supply chain risks are only considered unsystematically [16, 68]. This kind of risk management is already suitable to identify supply chain risks. However, it only applies with regard to obvious risks since the identification process is not based on a certain system concerning supply chain risks. Moreover, those results in control risk rather lead to passive control than to active control, such as design principles for the supply chain.

*Stage 2:* On stage 2, supply risks are systematically considered as part of internal risk management [30, 68].

The reason for the rise of an active management of supply risks might be a higher awareness of supply risks than of demand risks for the own company, as long as there is a higher sensitivity for failure of delivery. This attitude is profoundly different on stage 3.

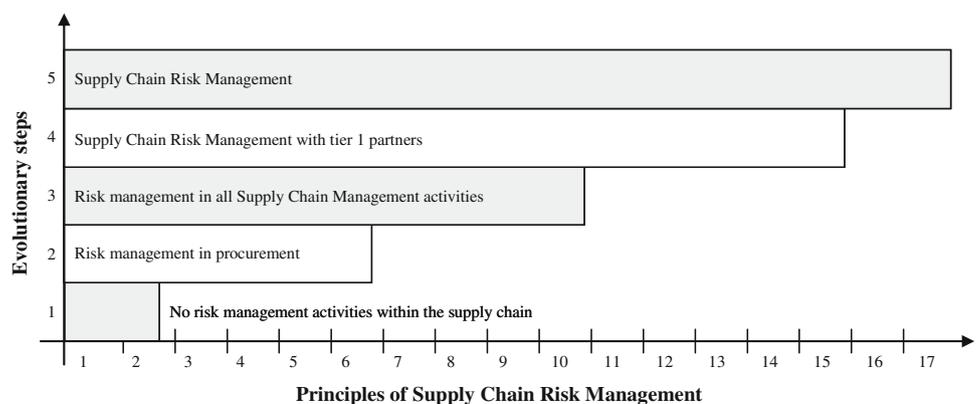
*Stage 3:* Based on better knowledge of all coherences within the supply chain, internal risk management considers all risk areas of the supply chain: supply risks, process and control risks, demand risks, and environmental risks [16, 33, 68]. Those risks are infected systematically. They may be complemented by indications by suppliers and customers. However, evaluation, control, and supervision are performed dependently. Responsibility for risk management is solely carried by the focal company.

*Stage 4:* On stage 4, risk management across company boundaries is implemented. It is limited to collaboration between the focal company and customers, tier 1, and probably tier 2 suppliers [16, 68]. This collaboration already ranges to all phases of the risk management process. Control procedures are carried out cooperatively. This stage is one of the last intermediate levels towards a “real” Supply Chain Risk Management on stage 5. For this

**Table 1** Evolutionary steps in supply chain risk management [16, 30, 33, 68]

Evolutionary step	Description	
1	No significant risk management of activities within the supply chain	There does exist a risk management within the company, which however does not focus on the supply chain. Moreover, there are no links to the supply chain
2	Risk management in procurement	Procurement risks are considered part of the internal risk management
3	Risk management includes all activities of supply chain management	There does exist some sort of internal Supply Chain Risk Management that is to say a risk management focussing on the supply chain. In the course of this, there might be collaborative analyses with direct suppliers and customers
4	Supply Chain Risk Management with direct partners (tier 1 and perhaps tier 2 suppliers and customers)	There is a risk management process with direct customers and suppliers which includes collaborative analysis, evaluation, control, and supervision
5	Integrated and general Supply Chain Risk Management	All actors within the supply chain run a collaborative Supply Chain Risk Management system. There exist general standards, definitions, structures, and processes for the latter

**Fig. 2** Supply chain risk management principles and evolutionary steps



purpose, already fulfilled requirements have to be transferred to further partners.

*Stage 5:* On stage 5, a “real” Supply Chain Risk Management is eventually on hand. In the course of a process across company boundaries, risks are identified, evaluated, controlled, and supervised mutually. Bound information is communicated along the entire supply chain [16, 30, 33].

Figure 2 shows the evolution of a Supply Chain Risk Management in steps, and links the evolutionary steps to the principles discussed above.

It is possible for a company to be situated on different evolutionary stages with different supply chain partners [33]. There might be a collectively operated Supply Chain Risk Management with a long-standing supplier due to a strong mutual trust for instance. However, suppliers and customers who are merely short-term business related are only considered with regard to risk management (stage 3). They are not included in the cross-company process.

## 5 A vision for future research

The implementation of a supply chain wide risk management is a complex task. It is essential for a suitable Supply Chain Risk Management in practice to link decentralized operated risk management activities by all participating companies within a supply chain. The analysis of the state of the art in Supply Chain Risk Management in this paper showed that existing concepts introduced in the literature are a good foundation for the characterization of a well-structured risk management process across company boundaries.

A Supply Chain Risk Management doesn't have to be implemented with all actors of the supply chain right away. In the last part of this paper, steps are suggested to broaden the scope of the field and to successfully implement Supply Chain Risk Management in business practice. A “real” extensive and effective supply chain wide with *all* supply chain partners risk management is ideal. An entire implementation of the concept in supply chain practise seems to be impossible due to intersections and the length of today's supply chains. However, an implementation e.g., based on collaboration between the focal company and its tier-1 and tier-2 suppliers and customers is possible and worthwhile. For this purpose, companies have to fulfil the requirement of having precise knowledge of their supply chain and the nature of relation to their partners.

## References

- Harland C, Brenchley R, Walker H (2003) Risk in supply networks. *J Purch Supply Manage* 9(2):51–62
- Crone M (2006) Are global supply chains too risky? *Supply Chain Manage Rev* 10(4):28–35
- Peck H (2006) Reconciling supply chain vulnerability, risk and supply chain management. *Int J Logistics Res Appl* 9(2):127–142
- Sheffi Y (2001) Supply chain management under the threat of international terrorism. *Int J Logistics Manage* 12(2):1–11
- Miller K (1992) A framework for integrated risk management in international business. *J Int Bus Stud* 23(2):311–331
- Imboden C (1983) *Risikohandhabung. Entscheidungsbezogenes Verfahren*, Haupt
- March JG, Shapira Z (1987) Managerial perspectives on risk and risk taking. *Manage Sci* 33(11):1404–1418
- Pfohl H (2002) Risiken und Chancen: Strategische Analyse in der Supply Chain. In: Pfohl H (ed) *Risiko- und Chancenmanagement in der Supply Chain: proaktiv-ganzheitlich-nachhaltig*. Erich Schmidt Verlag, Berlin, pp 1–56
- Wehmeier S, McIntosh C, Turnbull J (2005) *Oxford advanced leaner's dictionary*. Oxford University Press, Oxford
- Christopher M, Peck H (2004) Building the resilient supply chain. *Int J Logistics Manage* 15(2):1–14
- Coutu DL (2002) How resilience works. *Harv Bus Rev* 80(5):46–55
- Sheffi Y (2005) Building a resilient supply chain. *Harv Bus Rev* 1(8):1–4
- Jüttner U, Peck H, Christopher M (2003) Supply chain risk management: outlining an agenda for future research. *Int J Logistics Res Appl* 6(4):197–210
- Goankar RS, Viswanadham N (2007) Analytic framework for the management of risk in supply chains. *IEEE Trans Automat Sci Eng* 4(2):265–273
- Pfohl H, Gallus P, Köhler H (2008) Konzeption des Supply Chain Risikomanagements. In: Pfohl H (ed) *Sicherheit und Risikomanagement in der Supply Chain. Gestaltungsansätze und praktische Umsetzung*. Deutscher Verkehrs-Verlag, Bremen, pp 7–94
- Waters D (2007) *Supply chain risk management. Vulnerability and resilience in logistics*. Kogan Page, London
- Jüttner U (2005) Supply chain risk management. Understanding the business requirements from a practitioner perspective. *Int J Logistics Manage* 16(1):120–141
- Christopher M et al (2002) *Supply chain vulnerability*, Report for Department for Transport Local Government and Region, Cranfield University, January
- Norrman A, Jansson U (2004) Ericsson's proactive supply chain risk management approach after a serious sub-supplier accident. *Int J Phys Distrib Logistics Manage* 34(5):434–456
- Christopher M (2005) *Logistics and supply chain management. Creating value-adding networks*. Financial Times, Harlow
- Kleindorfer PR, Saad GH (2005) Managing disruption risks in supply chains. *Product Operat Manage* 14(1):53–68
- Zsidisin GA, Ellram LM (2003) An agency theory investigation of supply risk management. *J Supply Chain Manage* 39(3):15–29
- Wagner SM, Bode C (2006) An empirical investigation into supply chain vulnerability. *J Purch Supply Manage* 12(6):301–312
- Zsidisin G, Ragatz G, Melnyk S (2005) The dark side of supply chain management. *Supply Chain Manage Rev* 9(3):46–52
- European Logistics Association, Kearney AT (2004) *Differentiation for performance excellence in logistics 2004*. Deutscher Verkehrs-Verlag, Hamburg
- Spekman RE, Davis EW (2004) Risky business. Expanding the discussion on risk and the extended enterprise. *J Phys Distrib Logistics Manage* 34(5):414–433
- Christopher M, Lee H (2004) Mitigating supply chain risk through improved confidence. *Int J Phys Distrib Logistics Manage* 34(5):388–396
- Svensson G (2000) A conceptual framework for the analysis of vulnerability in supply chains. *Int J Phys Distrib Logistics Manage* 30(9):731–749

29. Svensson G (2002) A conceptual framework of vulnerability in firms' inbound and outbound logistics flows. *Int J Phys Distrib Logistics Manage* 32(2):110–134
30. Kajüter P (2003) Risk management in supply chains. In: Seuring S et al (eds) *Strategy and organization in supply chains*. Physica-Verlag, Heidelberg, pp 321–336
31. Williams Z, Lueg JE, LeMay SA (2008) Supply chain security. An overview and research agenda. *Int J Logistics Manage* 19(2):254–281
32. Closs DJ, McFarrell EF (2004) Enhancing security through the supply chain. Special Report Series, IBM Center for The Business of Government, available at: [www.businessofgovernment.org](http://www.businessofgovernment.org)
33. Kajüter P (2007) Risikomanagement in der Supply Chain: Ökonomische, regulatorische und konzeptionelle Grundlagen. In: Vahrenkamp R, Siepermann C (eds) *Risikomanagement in Supply Chains—Gefahren abwehren, Chancen nutzen, Erfolg generieren*. Erich Schmidt Verlag, Berlin, pp 13–28
34. Weber J, Weißenberger BE, Armim L (2001) Risk tracking & reporting: Ein umfassender Ansatz unternehmerischen Chancen- und Risikomanagements. In: Götze U, Henselmann K, Mikus B (eds) *Risikomanagement*. Physica Verlag, Heidelberg, pp 47–65
35. Huther A (2003) *Integriertes Chancen- und Risikomanagement*, Gabler, Wiesbaden
36. Junginger M (2005) *Wertorientierte Steuerung von Risiken im Informationsmanagement*, Gabler, Wiesbaden
37. Hoitsch H, Winter P (2004) Ansätze zur ökonomischen Begründung der Vorteilhaftigkeit eines unternehmensgetragenen Risikomanagements in Industrieunternehmen. *Zeitschrift für Planung* 15(2):115–139
38. Lee HL, Padmanabhan V, Whang S (1997) The bullwhip effect in supply chains. *Sloan Manage Rev* 38(3):93–102
39. Sodhi M (2005) Managing demand risk in tactical supply chain planning for a global consumer electronic company. *Product Operat Manage* 14(1):69–79
40. Autry C, Bobbitt M (2008) Supply chain security orientation: conceptual development and a proposed framework. *Int J Logistics Manage* 19(1):42–64
41. Zsidisin G et al (2004) An analysis of supply risk assessment techniques. *Int J Phys Distrib Logistics Manage* 34(5):397–413
42. Svensson G (2004) Key areas, causes and contingency planning of corporate vulnerability in supply chains. A qualitative approach. *Int J Phys Distrib Logistics Manage* 34(9):728–748
43. Kersten W et al (2006) Supply chain risk management. Development of a theoretical and empirical framework. In: Kersten W, Blecker T (eds) *Managing risks in supply chains. How to build reliable collaboration in logistics*. Erich Schmidt Verlag, Berlin, pp 3–17
44. Hallikas J, Virolainen VM, Tuominen M (2002) Risk analysis and assessment in network environments: a dyadic case study. *Int J Product Econ* 78(1):45–55
45. Pfohl H, Gallus P, Köhler H (2008) Risikomanagement in der Supply Chain. Status Quo und Herausforderungen aus Industrie-, Handels- und Dienstleisterperspektive. In: Pfohl H (ed) *Sicherheit und Risikomanagement in der Supply Chain. Gestaltungsansätze und praktische Umsetzung*. Deutscher Verkehrs-Verlag, Bremen, pp 95–147
46. Straube F, Pfohl H (2008) *Globale Netzwerke im Wandel. Umwelt, Sicherheit, Internationalisierung, Menschen*. Deutscher Verkehrs-Verlag, Hamburg
47. Wagner SM, Bode C (2008) An empirical examination of supply chain performance along several dimensions of risk. *J Bus Logistics* 29(1):307–325
48. Papadakis I (2006) Financial performance of supply chains after disruptions. An event study. *Suppl Chain Manage Int J* 11(1):25–53
49. Hendricks KB, Singhal VR (2003) The effect of supply chain glitches on shareholder wealth. *J Operat Manage* 21(5):501–522
50. Hendricks KB, Singhal VR (2005) Association between supply chain glitches and operating performance. *Manage Sci* 51(5):695–711
51. Christopher M, Peck H (2003) *Creating resilient supply chains. A Practical Guide*, Cranfield
52. Manuj I, Mentzer JT (2008) Global supply chain risk management. *J Bus Logistics* 29(1):133–155
53. Hauser LM (2003) Risk-adjusted supply chain management. *Suppl Chain Manage Rev* 7(6):64–71
54. Norrman A, Lindroth R (2004) Categorization of supply chain risk and risk management. In: Brindley C (ed) *Supply chain risk*. Ashgate, Hampshire, pp 14–27
55. Franck C (2007) Framework for supply chain risk management. *Supply chain forum Int J* 8(2):2–13
56. Faisal MN, Banwet DK, Shankar R (2007) Management of risk in supply chains. SCOR approach and analytic network process. *Supply chain forum Int J* 8(2):66–79
57. Thom A (2008) *Entwicklung eines Gestaltungsmodells zum Management von Risiken in Produktionsnetzwerken. Ein Beitrag zum Risikomanagement in der Logistik*. Technische Universität Berlin, Berlin
58. Smeltzer L, Siferd S (1998) Proactive supply management: the management of risk. *Int J Purch Mater Manage* 34(1):38–45
59. Zsidisin GA, Panelli A, Upton R (2000) Purchasing organization involvement in risk assessments, contingency plans, and risk management: an exploratory study. *Supply Chain Manage Int J* 5(4):187–197
60. Johnson M (2001) Learning from toys: lessons in managing supply chain risk from the toy industry. *Calif Manage Rev* 43(3):106–124
61. Chopra S, Sodhi M (2004) Managing risk to avoid supply-chain breakdown. *MIT Sloan Manage Rev* 46(1):53–62
62. Gaudenzi B, Borghesi A (2006) Managing risks in the supply chain using the AHP method. *Int J Logistics Manage* 17(1):114–136
63. Pfohl H (2007) *Supply Chain Risikomanagement*. In: Hausladen I (ed) *Management am Puls der Zeit*. TCW, München, pp 1135–1157
64. Tang CS (2006) Robust strategies for mitigating supply chain disruptions. *Int J Logistics* 9(1):33–45
65. Martin TA, Bär T (2002) *Grundzüge des Risikomanagements nach KonTraG: Das Risikomanagementsystem zur Krisenfrüherkennung nach § 91 Abs. 2 AktG*. Oldenburg, München
66. Pfohl H (2004) *Logistikmanagement. Konzeption und Funktionen*. Springer, Berlin
67. Werner H (2007) *Supply chain management. Grundlagen, Strategien, Instrumente und Controlling*. Gabler, Wiesbaden
68. De Waart D (2006) Getting smart about risk management. *Supply Chain Manage Rev* 10(8):27–33