

PART ONE

Foundations and Overview

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Integrated Risk Management: A Conceptual Framework with Research Overview and Applications in Practice

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1.1 Introduction

The past three decades have witnessed unprecedented growth in global trade. Firms in one part of the world can enjoy the great opportunity to access the input and output markets, technologies, and capitals in other parts of the world. The economically well-connected world exposes firms to multiple and high magnitude risks. The set of the normal business risks is expanded as firms are now often facing unfamiliar and uncertain demand and supply markets, and unanticipated commodity price shocks and currency exchange rate fluctuations. The previously perceived unusual business risks, such as unexpected supplier bankruptcies in a turbulent global economy, and supply disruptions as a result of physical disasters

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and terrorist attacks, have been intensified and cannot be neglected any longer as the frequency of these events has been increasing, posing a significant threat to business continuity. Although the existence of risk is not news to the business world (i. e., companies have long been buying insurances to protect them against certain risks) the development of advanced risk management tools did not start until the advancement of economic theory and information technology less than three decades ago, and its progress varies by industry.

Challenges in practice have motivated growing interests among academicians, especially researchers in supply chain management, in developing economically sound and practically feasible risk measures, understanding the influence of firms' risk preferences on supply chain decisions, and building multifunctional tools for risk management and control.

In this chapter we present an action-based supply chain risk management framework that has emerged from industry practice and academic research. For practitioners, this conceptual framework can serve as a guideline to devise risk management strategies that suit their specific supply chain environments. For academicians, we map the research in the growing field of integrated risk management research within the context of this framework, and identify potentially fruitful directions for future research.

1.2 An Action-Based Framework for Supply Chain Risk Management

The framework of supply chain risk management proposes a two-stage action plan: a *planning* stage and an *execution* stage. In the planning stage, carefully thought-out plans and proactive actions should be put in place to ensure business continuity and to sustain profitability in the event of an undesirable scenario. The main actions include identifying the prospective supply chain risks, assessing the likelihood of risk occurrence and the severity of consequences, and devising risk mitigation plans and putting counter measures in place to avoid or reduce (if possible) the probability of risk events and to reduce the damages/disruptions to the supply chain. In the execution stage, firms should establish a risk scanning mechanism to detect signs of risk events, put in place a real-time risk response process that is ready to deploy recovery plans immediately, and have a measuring system to assess all relevant data and analyze the effectiveness of the scanning and response processes.

We will discuss in more detail the activities involved in the two stages in the sections that follow.

1.2.1 PLANNING STAGE

Three steps of actions should take place in the planning stage: risk identification, risk assessment, and risk mitigation planning.

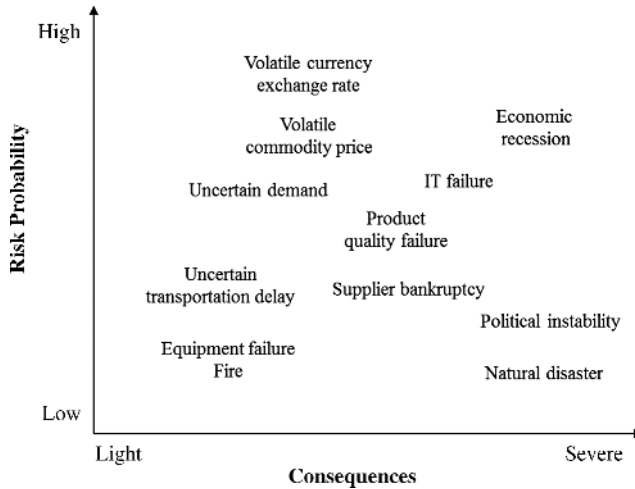


FIGURE 1.1 Supply chain vulnerability map.

- 1. Risk identification.** This step identifies each possible adverse event, large or small, and produces a supply chain vulnerability map where the likelihood of those events and the severity of their consequences are estimated roughly. Risk identification is an important step of supply chain risk management and should involve multiple business functions and/or supply chain members, because this exercise not only raises the awareness of the various risks that the supply chain is exposed to, it also leads management to prioritize efforts in the following tasks of risk assessment and mitigation planning. Figure 1.1 provides an example of supply chain vulnerability map, where the vertical axis represents the probability that a risk event occurs and the horizontal axis represents the severity of the consequence.

There are a number of ways to further analyze supply chain risks. One approach is to distinguish between the *internal risks* and the *external risks*. *Internal risks* are driven by the weakness of planning/control/coordination within the supply chain, for example, inaccurate demand forecasts, machine failures, uncertain yields, and supplier bankruptcy; *external risks* are driven by the events that are outside control of the supply chain members, for example, fluctuations in commodity prices, currency exchange and interest rates, natural hazards, war, and terrorism. Distinguishing between the internal and external risks directs firms to apply suitable risk avoidance and risk mitigation strategies to different types of risks.

Another approach is to categorize the risks as *normal business risks* versus *disruption risks*. The *normal business risks* are driven by uncertainties inherent in the business with moderate-to-high frequency of occurrences, including uncertainties in supply and demand, and in costs and prices. The *disruption risks* are driven by relatively low-probability adverse events that can disrupt the normal function of the supply chain and lead to business discontinuity;

examples include natural or man-made disasters (earthquake, fire, flood, pandemic diseases, etc.) and other unforeseeable events. Accordingly, the goal of devising risk mitigation strategies will be different. Because of the reoccurring nature of the normal business risks, they are to be dealt with on the daily basis; a supply chain should be *robust* enough to perform effectively in a wide range of operating conditions. Disruptions, however, occur once in a while and organizations should develop the ability to quickly adapt to and overcome the disruptions; in other words, a supply chain should build in *resilience* to respond to the changing environments.

2. Risk assessment. Building upon the work of the risk identification step, this step quantitatively assesses the probability of the risk events and their implications for the supply chain. Several challenges can arise in performing this task:

- Insufficient data for performing statistical analysis in order to derive the probability distribution of certain risk events. Expert opinions are often sought to assign such probabilities.
- Risk events may be driven by some common factors, and therefore, their occurrences can be correlated. The process of identifying the underlying drivers and the likelihood they would lead to various risk events, and deriving the correlation among those risk events also often rely on experts' subjective inputs.
- Risk events often have multifaceted impact on supply chain performance. Assessing the scope and the magnitude of their consequences requires, again, cross-functional, cross-organizational communication.

The outcome of the assessment should help firms to prioritize risks—what risks are essential to control and mitigate, and what can be neglected.

3. Risk mitigation planning: Risk prevention plans and countermeasures are devised in this step to decrease the probability of adverse events and decrease the severity of the consequence.

The discussion of the risk identification step suggests that using different categorization of supply chain risks allows firms to see the differences in the nature of the risk mitigation strategies. Understanding whether a risk is internal or external to the supply chain helps firms to set realistic expectations of what risk mitigation can achieve. For external risks, which are out of the firms' control, risk mitigation strategies should strive to reduce the magnitude of the negative impact, although in some circumstances, some external risks such as earthquake and flood can be avoided by careful design of the global facility network of the supply chain (e.g., by choosing facility locations far away from risk regions). For internal risks, whose likelihood is largely determined by the management of the supply chain, risk mitigation strategies should be more focused on identifying the root causes of those risks and deriving control or coordination mechanisms to prevent the risk events from happening.

Viewing risks as normal business risks versus disruption risks, firms should be aware that risk mitigations plans are different in their relationship

to the firms' overall supply chain management strategies. Risk mitigation strategies managing normal business risks are themselves an integral part of the supply chain strategy, and should be applied seamlessly in daily operations to respond to the anticipated, frequent, normal risk events. For disruption risks, because of the high uncertainty in when, where, what will happen, and the scope of the impact, the risk mitigation strategies cannot be designed precisely at the tactical level, because many pieces of the plan will be designed and executed 'on the fly' in real-time as updated information of the specific disruption or crisis becomes available. The three processes of the execution stage (to be discussed below) are critical for such disruption management, although they are also relevant to managing normal business risks.

Risk mitigation strategy has been the main focus of the supply chain risk management research. Section 1.3 of this chapter will discuss in more detail the landscape of the current academic research in this area.

1.2.2 EXECUTION STAGE

The execution stage consists of three processes: scanning, response, and measurement.

- 1. Scanning.** This process tracks what is happening in the supply chain in real-time and informs the appropriate executives immediately when risk events occur. Risks identified in the planning stage should be assigned to corresponding business functions and/or supply chain members to monitor; exception conditions should be defined to distinguish between normal business risks and disruptions, and communication infrastructure should be established to allow for instantaneous attention from management.
- 2. Response.** Clear roles and responsibilities and the organization's flexibility to adapt to changing environments are two elements of the successful execution of this process. This process calls upon specific action plans when a normal risk event happens. For disruption risks, disruption management teams are assembled to design and execute recovery plans.
- 3. Measurement.** This process documents and collects data throughout the organization to assess the effectiveness of activities and processes in the planning stage and the execution stage. For supply chain risk management to be effective, it must be treated as a part of the business process, constantly being revisited and improved upon. Thus, the measurement process closes the loop of the supply chain risk management in two important ways. First, the data documented can be used to facilitate the analysis in risk identification and assessment; second, the analysis conducted after each risk mitigation event allows the organization to learn, to find the strength and weakness in its risk management ability, and to shed light on areas for improvement.

1.3 Risk Mitigation Strategies

The growing research of supply chain risk management can be largely divided into three themes: managing risk through operational strategies, integrated operations-finance risk management, and supply chain finance. We briefly discuss the philosophy and approaches in each research theme.

1.3.1 MANAGING RISK THROUGH OPERATIONS STRATEGIES

Many risk events in supply chain cause delays and disruptions in matching supply with demand. This area of research is mainly focused on operations strategies that ensure the availability of resource (inventory and capacities) to cope with variations in supply and demand conditions. A nice framework to view those operational strategies in four categories, based on the timing when the resources are becoming available at firm's disposal, can be found in Hopp (2007). Table 1.1 provides the definition and examples of each category.

As the costs of carrying out those strategies are different, situations in which they are most effective are also different. Figure 1.2 maps the operational strategies with situations identified by the likelihood of risk event and the severity of consequences (Hopp 2007).

When the severity of consequences is light, it is not worthwhile to adopt any risk mitigating strategies. Buffering and pooling strategies require the firm to keep the physical resources ready for use when a risk event occurs. Uncertain supplier lead times require the firm to plan the orders with excessively large order lead times. When the likelihood of risk events is low or moderate, those strategies are not economically justifiable. Hence, ideally, buffering and pooling strategies should be adopted when risk events are highly likely and their consequences are not too light.

For situations where the likelihood of risk events is moderate, contingency planning (securing the access to resource in times of need through advanced planning or contracts) is a more reasonable strategy to adopt, provided that the

TABLE 1.1 Four Categories of Operational Risk Mitigation Strategies

	Definition	Examples
Buffering	Maintaining excess resources	Safety stock, idling capacity, safety leadtimes
Pooling	Sharing of resources	Flexible technology, common components, transshipment, postponement
Contingency planning	“Virtual buffering” established by a preset course of action	Backup supply, multisourcing/supplier portfolio

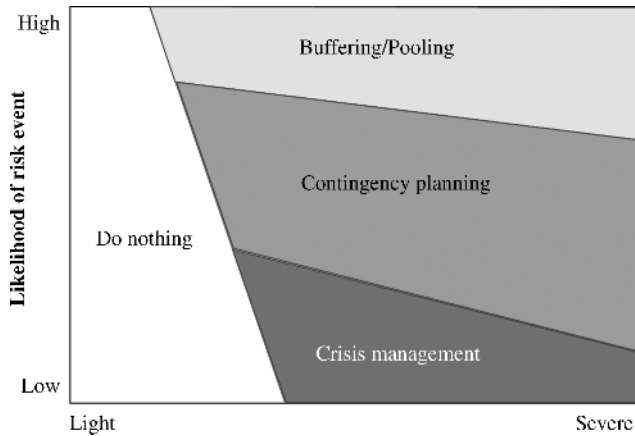


FIGURE 1.2 Matching risk mitigation strategies to types of supply chain risk (Hopp 2007).

cost of doing so is lower than buffering or pooling. Having access to a reliable and responsive backup supplier or buying from a spot market are typical examples of such plans.

For situations where risk events are rare but consequences are severe, crisis management will be needed when resources from buffering/pooling and contingency planning are insufficient to maintain the normal functioning of the business.

Buffering, pooling, and contingency planning have received a great deal of attention in the academic research, with quantitative models deriving the optimal execution of each strategy and comparing effectiveness of various strategies. Research on crisis management remains scarce in supply chain management research, because crisis management, by definition, requires the real-time planning and execution of recovery for unanticipated events. Building organizations capable of such responses has attracted some attention in the organizational behavior and design literature, but often not within a supply chain disruption context.

1.3.2 INTEGRATED OPERATIONS-FINANCE RISK MANAGEMENT

This theme of research recognizes the diverse set of risks that firms face today, and some of those risks, such as fluctuations in commodity prices and currency exchange rates can be mitigated using financial derivative contracts. This research argues that an integrated risk management approach via coordinated operational and financial decisions offers an overall optimal risk control strategy, and provides insights on the important questions of executing these functionally aligned strategies: How to achieve the coordination of these decisions? What are the value drivers of an integrated risk management? Are operational hedging and financial hedging strategic substitutes or complements?

Since risk aversion is one of the main drivers for firms' financial hedging activities, this line of research often incorporates different risk-averse utility functions, such as mean-variance, value-at-risk, and exponential, to explore the trade-offs of the expected payoff and the spread of undesirable outcomes implied by operational and financial hedging strategies.

1.3.3 SUPPLY CHAIN FINANCE

Most of the existing supply chain management research assumes that firms' operational decisions and financial decisions are made independently, and focus on the coordination of the material flow and information flow across supply chain members, leaving the question of how material flows are financed outside the scope of the research. This operations-finance independence assumption is justified by the well-known Modigliani–Miller Theorem, which states that under a set of assumptions a firm's value is unaffected by how the firm is financed. Those assumptions include rational investors, the absence of transaction costs, corporate taxes, and asymmetric information, and thus, a perfect capital market. In practice, those assumptions seldom hold simultaneously, and supply chains decisions more often are affected by how they are financed, and by payment terms, and the pressure of improving cash flow efficiencies. The supply chain finance research explicitly considers the constraints imposed by limited capital, lack of credit for borrowing, taxation, asymmetric information, and so on, and explores the trade-offs involved in making operational and financial decisions, and proposes schemes to coordinate the material, information, and financial flows within the supply chain.

1.4 Research Opportunities

While so far most of the academic research in supply chain risk management is concentrated in understanding and developing risk mitigation strategies, there are still many opportunities for more interdisciplinary research in this area. In integrated risk management, the interface research should develop tailored models to institutional details involved in development of financial hedging strategies, and provide insights on the classification of important uncertainties to hedge, and on the main operational and financial drivers of a profitable integrated risk management program based on industry characteristics.

More research is needed in understanding the value of coordinating financial and operational decisions. One particular domain of interest is the procurement and risk hedging of multitude of commodities. There exist empirical observations about firms centralizing their financial risk management functions over multiple commodities, and at the same time, delegating the physical sourcing of each commodity to separate divisions (i.e., in a decentralized fashion). It would be interesting to analyze conditions where it is better to centralize/decentralize

operational and financial decisions, and the implications on the firm's overall performance.

In supply chain finance, opportunities exist in understanding the relationship between the supply chain inventory policy/ownership and the management of the cash-to-cash cycle, their impact on firms' financial performance, and how the answers are different to firms at different stages of business life cycle, and/or with different risk attitude. As more innovative supply chain financing schemes are being offered by financial institutions, a framework for mapping business environments with the most effective financing schemes would be of greater value.

In both of the above research areas we are only scratching the surface of the large body of finance, economic, and accounting literature. We see great potential in collaborating with colleagues in those areas to develop a more integrated approach to tackle those challenges, as also should be done in practice.

In the operations management field, several papers analyze different operational hedging strategies of firms and delineate their value in specific problem domains (such value of flexible technology in multiproduct firms, value of production switching among different subsidiaries, etc.). The insights generated from these papers tend to depend on the particular setting under consideration. A future challenge is to develop a robust classification of operational hedging strategies with their structural properties relevant for a multitude of operational settings. The general methodology and insights developed in the finance literature for financial hedging is a potential starting point for this purpose. On the other side of the picture, the finance literature can make use of the knowledge base on operational hedging developed in the operations management literature. One immediate future research direction is developing empirical proxies for the measurement of operational hedging capabilities of firms. In the finance literature, the level of operational hedging is generally attributed to the dispersion, that is, the number of different locations of the subsidiaries of the firms. A higher dispersion implies better operationally hedged firms. However, as demonstrated by several scholars in the operations literature, a less dispersed firm can be better operationally hedged than a more dispersed firm if the internal operational flexibility (such as flexible production technologies) of the former is higher.

Academic research in risk assessment and real-time crisis management remain scarce. While academic research has heavily relied on the presence of historical data to assess probability and severity of consequences, the nature of many supply chain risks makes the availability of such relevant data a scarce resource. Climate changes are making even weather events hard to effectively estimate from historical data, and the unpredictability of terrorist plots reduces the importance of previous observations.

Finding ways to estimate probabilities from events that happened in the past, which are not exactly parallel to the ones we are trying to predict using pattern recognition approaches that reveal similarities beyond the immediate obvious; using experts that can bring different domains of knowledge to understand a future event; and exploring the interdependency between our mitigation actions of some future risks and their effects on the probabilities and consequence levels of these events are important directions of future investigation.

Although there has been a great deal of research on risk measures and utility theory in economics, mathematics, and finance literature, there is lack of research on appropriate and consistent risk measures and utility functions to characterize overall supply chain risks, combining operational and financial risks. When different risk-averse utility functions are adopted for a same problem, different results may be obtained. Comparative statistics should be provided for various risk measures and utility functions in the context of supply chain management. Empirical research can be conducted to help understand objectively how firms perceive, measure, and value each supply chain risk. Guidance should be provided to the practitioners on what utility functions are appropriate for what type of supply chain, where the type may be determined by, but not limited to, the magnitude of the risks, nature of risks, and interaction of these risks.

There is a need to place more emphasis on understanding the development of organizational capabilities and leadership in managing risk events and crisis situations. In environments of high uncertainty and unpredictable nature events, risks have to be managed in ways substantially different than our traditional project risk management approaches. There is the need to develop organizational units that are very flexible in their structures, which can identify and solve problems in rapid cycles, when communication and reporting happens very frequently and often informally. While our traditional risk planning and mitigation approaches emphasize redundancy of resources and portfolio approaches in risk mitigation, the organizational responses will rely on tightly linked systems that cherish interdependency and the risk of failure as motivators for outside-of-the-box thinking and fast, innovative responses using all available talents and resources leveraging the intimate understanding of individual player capabilities. Research that identifies organizational designs, training approaches, team building methodologies, incentive systems, and leader development pathways to effective crisis management is a vital missing block in our current integrated risk management theory. Actually, practice and effective corporate responses witnessed in certain recent crises can guide theory development in this area.

REFERENCE

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