Chapter 4
Mitigating Risks

Abstract To mitigate supply chain risks identified by the managers, this chapter describes three general risk mitigation strategies: (1) alignment of supply chain partners incentives to reduce the behavioral risks within the supply chain, (2) flexibility to reduce not only demand risks but also supply and process risks, and (3) building "buffers" or redundancies. We also discuss ways for managers to adapt these general risk-mitigation strategies to the circumstances of their particular company.

4.1 Introduction

In this chapter, we describe strategies to mitigate the supply chain risks we identified in Chapter 2. We also discuss how to tailor these strategies for a given company's context.

A notable example of supply chain risk is a fire that erupted at a Philips' chip manufacturing plant that impacted mobile-phone manufacturers Ericsson and Nokia. The two companies responded differently with dramatically different results. On March 17, 2000, a lightning bolt hit a power line in Albuquerque, New Mexico. The bolt caused a massive surge in the surrounding electrical grid, which in turn started a fire at a local Philips plant, damaging millions of radio frequency microchips. Nokia, a Scandinavian mobile-phone manufacturer and a major customer of this Philips plant, was ready to deal with such an unpredictable event, however. Almost immediately, the company began switching its chip orders to other Philips plants, as well as to other Japanese and American suppliers. Thanks to its multiple-supplier strategy and responsiveness, Nokia's production suffered little during the crisis.

In contrast, Ericsson, another mobile-phone customer of the Philips plant, employed a single-sourcing policy. As a result, when the Philips plant shut down after the fire, Ericsson had no other source of microchips and its production of mobile phones was disrupted for many months. Ultimately, the disaster and company de-

M.S. Sodhi, C.S. Tang, *Managing Supply Chain Risk*,
International Series in Operations Research & Management Science 172,
DOI 10.1007/978-1-4614-3238-8_4,

pendence on a sole supplier cost Ericsson $400 million in lost sales after the first quarter alone.[1]

These two dramatically different outcomes from this risk incident demonstrate the importance of proactively managing supply-chain risk. Ericsson has since implemented new processes and tools for managing supply-chain risk proactively (Norrman and Jansson, 2004).

This risk incident raises a key question: how can companies avoid risk incidents or reduce the impact of risk incents? Essentially, once a particular supply chain risk is identified, assessed, and selected for mitigation, it can be mitigated by decreasing its likelihood, reducing its potential consequences or both. Paulsson and Nilsson (2008) present 23 methods for mitigating risks; however, there are three basic approaches: *accept, avoid*, and *mitigate*; and it is the last of these that we focus on in this chapter. *Responding* to a risk incident that has already occurred, usually regarded as within the domain of business continuity, is the subject of Chapter 5.

Accepting the risk does not require doing anything other than the company bearing the entire consequence in case there is a risk incident or the company transferring part of the consequences to its insurance company or its supply chain partner. However, transferring risk through insurance or through financial instruments like swaps does not actually reduce the likelihood of the risk. Even if it reduces the impact of the risk to a certain extent, it may result in *moral hazard* whereby the company can become more risk-prone knowing that is can transfer some or all of the financial consequences. Likewise, liability insurance may offer financial compensations to customers who suffer from using unsafe products, but it does not reduce the damage to the reputation of the company nor the suffering of the people who used these products.

Avoiding risks entails efforts to prevent the occurrence of undesirable incidents. Such efforts entail the development of fail-safe systems, i.e., systems that cannot fail or that can trigger corrective actions to prevent failures, and the application of quality-based principles to ensure there is no failure in the detection of a risk incident with highly negative consequences. These approaches can be quite useful in security-related risks where preventing an incident from ever happening is the best approach. Lee and Wolfe (2003) illustrate how certain technologies, say, biometric systems for positive identification of personnel and smart container systems for monitoring internal temperature and pressure of each container, can be used to prevent containers being tampered with throughout the shipping process. The U.S. Homeland Security has developed the Container Security Initiative (CSI) that requires all containers to be pre-screened at the port of departure before they arrive at U.S. ports to reduce the likelihood of seaport terrorist attacks in the U.S.

While acceptance or avoidance are appropriate in some circumstances, companies tend to focus on developing approaches for mitigating supply chain risks, whether normal (delays) or abnormal (disruptions).

[1] "Can suppliers bring down your firm?" *Sunday Times* (London), November 23, 2003

4.2 Risk Mitigation Strategies

Risk mitigation entails efforts to reduce the impact of risk incidents in case such incidents do occur. Broad risk mitigation strategies in this category are (1) alignment of supply chain partners' incentives to reduce the behavioural risks within the supply chain, (2) flexibility to reduce not only demand risks but also supply and process risks, and (3) building "buffers" or redundancies. All three are useful to mitigate normal and abnormal risks in the supply chain. We describe the first two briefly below and the third approach in the next section.

Alignment. Besides long-term partnerships, there are other mechanisms to coordinate the interests of the different supply chain partners. Tang (2006b) reviewed different types of supply contracts to coordinate a supply chain so that all parties will act in the interest of the entire supply chain when dealing with demand risks including *wholesale price contracts, buyback contracts, and revenue sharing contracts*. A two-part tariff, i.e., a fixed cost and a per unit wholesale price, can be used to entice the downstream partner to order according to the optimal order quantity (as per the newsvendor solution) for the entire supply chain. A buy-back contract is a returns policy under which the manufacturer is required to buy back the retailer's excess inventory at a reduced price. Under certain conditions, doing so can achieve supply chain coordination. Under a revenue sharing contract, the retailer shares the revenue with the manufacturer and obtains a reduction in the wholesale price in return, achieving supply chain coordination. Narayanan and Raman (2004) have studied *risk sharing* and revenue sharing to align incentives across supply chain partners.

Flexibility. There are at least five different types of flexibility strategies corresponding to *multiple suppliers, flexible supply contracts, flexible manufacturing process, postponement* and *responsive pricing*. The ability to shift order quantities across suppliers can be a powerful mechanism for the manufacturer to hedge against supply risks. Under flexible supply contracts, the manufacturer is allowed to adjust the order quantity within a pre-specified range, say, a few percent of the order quantity. This helps to mitigate the impact associated with demand risks (c.f., Tsay and Lovejoy, 1999). The manufacturing process is flexible if different types of products can be manufactured in the same plant, enabling the manufacturer to reduce supply, process, or demand risks (c.f., Jordan and Graves, 1995). Postponement calls for delayed product differentiation by producing a generic product initially and then customizing it for different markets and customers later, thus allowing a company to respond to demand changes across multiple markets quickly (c.f., Lee and Tang (1997)). Responsive pricing is an effective tool to mitigate supply or demand risks by manipulating demand when the supply is inflexible. For example, as the supply of certain components from Taiwan was affected by an earthquake, Dell's response was to lower the price of certain products so as entice their online customers to "shift" their demands to other Dell computers that utilized components from other countries.

Similar to the above strategies are the "AAA" principles of *alignment*, *agility*, and *adaptability* that are intended to reduce the impact associated different types of supply chain risks (Lee 2004). *Alignment* calls for an aligned interests among supply chain partners so as to facilitate close communication, cooperation, and collaboration; *agility* entails flexibility and responsiveness; and *adaptability* requires close monitoring of the environment so that one can deploy a recovery plan in a timely manner, something we will discuss as part of responding to risk incidents in the next chapter.

4.3 Building Reserves for Redundancy

Firms can always build in some redundancies throughout the supply chain so as to reduce the cost implications of certain undesirable events associated with supply, process, and demand risks; Chopra and Sodhi (2004) refer to these as "reserves" against supply chain risk. For example, extra inventory, extra back-up production capacity, and extra back-up suppliers are "buffers" to absorb the impact against delays and disruptions in the supply chain. However, redundancies can be expensive when used against (rare) unanticipated events (Sheffi, 2005). Also, redundancies disguise inefficiencies in the supply chain, inhibiting the development of a lean supply chain. Flexibility overcomes these disadvantages: it can reduce the impact of the occurrence of certain unanticipated events and it can also be put to use with planned changes, for instance, to produce a greater variety of products.

To prevent the kind of heavy sales losses suffered by Ericsson after the Philips plant fire, managers must perform a delicate balancing act: keeping inventory, capacity and other elements at appropriate levels across the entire supply-chain in a dynamic, fast-changing environment. Dell, Toyota, Motorola and other leading manufacturers excel at identifying risks in their supply chains, and at creating powerful mitigation strategies that neutralize potentially negative effects. With a clear understanding of the types of supply chain risks, managers in many types industries can tailor effective risk-reduction approaches for their own companies.

As we discussed in Chapter 2, supply chain problems resulting from natural disasters, labor disputes, supplier bankruptcy, acts of war and terrorism and other causes can seriously disrupt or delay material, information and cash flows, any of which can damage sales, increase costs—or both. In that chapter, the categories we considered, at different levels, include delays, disruptions, forecast risks, systems risks, intellectual property risks, procurement risks, inventory risks, and capacity risks. Because each risk category has its own risk drivers, it is natural to develop ways to address these drivers (Table 4.1).

However, addressing these risk drivers and thus mitigating the corresponding risks is not the whole story. Managing supply chain risk is difficult. One big reason is that individual risks often connect with other risks. As a result, actions that mitigate one risk can end up exacerbating another. Consider a lean supply chain. While its bare-bones inventory *decreases* the impact of over-estimating customer

Table 4.1 Drivers of different types of risk

Risk Categories	Risk Drivers
Disruptions	• Natural disaster • Labor disputes • Supplier bankruptcy • War and terrorism • Dependency on a single source of supply as well as capacity and responsiveness of alternative suppliers
Delays	• High capacity utilization at supply source • Inflexibility of supply source • Poor quality or yield at supply source • Excessive handling due to border crossings or to change in transportation modes
Systems risk	• Information infrastructure breakdown • System integration or extensive systems networking • E-commerce
Forecast risk	• Inaccurate forecasts due to long lead times, seasonality, product variety, short lifecycles, small customer base • "Bullwhip effect" or information distortion due to sales promotions, incentives, lack of supply-chain visibility, and exaggeration of demand in times of product shortage
Intellectual property risk	• Vertical integration of supply chain • Global outsourcing and markets
Procurement risk	• Exchange rate risk • Fraction of procurement of a key component or raw material from a single source • Industry-wide capacity utilization • Long-term versus short-term contracts
Receivables risk	• Number of customers • Financial strength of customers
Inventory risk	• Rate of product obsolescence • Inventory holding cost • Product value • Demand and supply uncertainty
Capacity risk	• Cost of capacity • Capacity flexibility

demand, it simultaneously *increases* the impact of a supply chain disruption. Similarly, actions taken by any company in the supply-chain can increase risk for any other participating company (Table 4.2).

Table 4.2 Mitigation strategies can reduce some risks but may also exacerbate other risks

Mitigation strategy	Disruption	Delays	Forecast risk	Procurement risk	Receivables risk	Capacity risk	Inventory risk
Add capacity		↓↓		↓		↑↑	↓
Add inventory	↓	↓↓		↓		↓	↑↑
Have redundant suppliers	↓↓			↓		↑	↓
Increase responsiveness		↓↓	↓↓				↓↓
Increase flexibility		↓		↓		↓↓	↓
Aggregate or pool demand			↓↓			↓↓	↓↓
Increase capability		↓					↓
Have more customer accounts					↓		

Note: An up arrow ↑ or ↑↑ indicates how much the strategy increases risk when applied to a particular problem, with two arrows signifying greater risk. A down arrow ↓ indicates a decreased risk. Systems risk and intellectual property risks are not included. Adapted from Chopra and Sodhi (2004).

Building reserves for redundancy is useful for reducing the impact caused by disruptions and delays that can cause the affected organization(s) problems ranging from a minor to serious. A simple delay along the chain may create a temporary impact, whereas a sole supplier holding up a manufacturer to force a price increase represents a long-term risk. A machine breakdown may have a relatively minor impact for a manufacturing company with redundant capacity, whereas a war that disrupts shipping lanes can have a dramatic impact on a shipping company. Most companies develop plans to protect against the normal risks that are recurrent and low-impact in the supply chain; however, few companies develop plans to handle disruptions. For instance, a supplier with quality problems represents a common, recurrent disruption. Without much effort, the customer can demand improvement or find a substitute. In contrast, in regions where earthquakes are rare, preparedness may be weak or uneven to prevent major disruption.

One way to build a shared vision against both types of risks is to do a stress-testing of the supply chain. *Stress testing* is a group exercise that helps managers and their companies understand and prioritize supply chain risks. "What if" scenarios can help key players focus on the supply-chain one link at a time. This exercise offers an especially effective way to gain buy-in and shared ownership in project teams tackling supply-chain risk.

The first step in stress testing is to identify key suppliers, customers, plant capacity, distribution centers and shipping lanes. Next, the team surveys locations and amounts of inventory represented by components, work-in-process, and finished goods. Then managers probe each potential source of risk. This helps assess possible impacts as well as the level of preparedness within the supply-chain. Facilitators ask questions such as, "What might happen if a particular supplier could not deliver for a month?" or "What if a supplier raised prices by 20% at the termination of contract?" Questions pertaining to key customers might include, "What if demand went up or down by 20%?" or "What if a customer delayed cash payment by a month?" These and other questions related to various sources of risk are summarized in Table 4.3. When considering questions during stress testing, managers should realize that "20%" or "one month" are not sacred figures, but simply represent numbers large enough to be significant and small enough to be realistic. Also, it is wise to position stress testing as "thought experiment" to help the company prepare for unforeseen events rather than ignite a debate on the likelihood of such events. As such, it is useful to frequently remind people of the goal: preparing the supply-chain for unforeseen events and greatly lowering risk, at the lowest cost.

Through stress testing, managers should be able to identify risk-mitigation priorities for the near, the medium, and the long term. They will have identified product families at risk, as well as individual plants, shipping lanes, suppliers, or customers that could pose risks. Managers will also have a clear idea of what is at risk in terms of impact: sales, procurement costs, revenues, prices, or even reputation.

4.4 Tailoring Risk Management for any Given Company

With so many related risks and risk-mitigation approaches to consider, managers must do two things when they begin to construct a supply chain risk management strategy. First, they must create a shared, organization-wide understanding of supply chain risk. Then they must determine how to adapt general risk-mitigation approaches to the circumstances of their particular company. Managers can achieve the first through *stress testing* and the second through *tailoring their reserves to develop robust strategies*.

Leading companies mitigate risk by building various forms of "reserves" including inventory, capacity, redundant suppliers, and responsiveness. Managers must understand and evaluate the tradeoff between the risk and the cost of building a reserve to mitigate it—the research literature refers to this as *the newsvendor problem* (cf. Chopra and Miendl, 2004: 346-352).

Table 4.3 Stress-testing the supply chain by exploring what-if scenarios

	Supplier-related	**Internal**	**Customer-related**
Disruptions	• Supplier of a key part shuts down plant for a month Supplier capacity drops by 20% overnight	• Key plant shuts down unexpectedly for one month • Capacity at a key plant drops by 20% overnight	• Demand goes up by 20% for all products / a key product • Same questions with demand going *down* by 20%
Delays	• Delivery of of key parts or raw materials delayed by a month	• Distribution or production schedule delayed by a month	• Customer orders arrive later than expected by a month
Systems risk	• Supplier's order-entry system goes down for a week	• Key customer's procurement system inside your company goes down for a week • Company's inventory/accounts system goes down for a week	• Order entry system goes down for a week • Key customer's procurement system inside your company goes down for a week • Credit card information stolen from hacked e-commerce system
Information and material flows distortion	• Supplier rations supplies by 20 % • Supplier increases minimum order quantity by 20%	• To take advantage of volume discounts, company begins to order in quantities twice as large as usual, but half as frequently, which impacts supplier's ability to forecast	• To take advantage of volume discounts, key customer begins to order in batches that are twice as large as usual but less frequent, which impacts manufacturer's ability to forecast
Intellectual property risk	• Key supplier redesigns parts or develops its own product		
Procurement risks	• Supplier delays in processing returns by a month • Supplier forced to increase price of key components by 20% due to increase in material costs • Transportation costs go up 20% overnight	• Unforeseen cash squeeze, which causes a month-long delay in paying key suppliers	
Receivables risks			• Key customer withholds payments one month longer than usual • 20% of receivable payments delayed by one month

Leading companies deal with this range of supply chain risks by holding "reserves." Just as insurance company holds cash reserves to meet claims, top manufacturers hold supply chain reserves that include excess inventory, excess capacity and redundant suppliers. The big challenge for managers here: mitigate risk by smart positioning and sizing of supply chain reserves, without decreasing profits. So while stockpiling inventory may shield a company against delivery delays by suppliers, building reserves willy-nilly also drives up costs and hurts the bottom line. The managers' role here is akin to a stock portfolio manager: achieve the highest achievable profits (reward) for varying levels of supply-chain risk and do so efficiently (Fig. 4.1). This means the manager must seek additional profits for any level of risk protection and preparedness, or increase prevention and preparedness without reducing profits. Success at this task requires a good understanding of supply chain risks and remedies, both broad and tailored in the context of the manager's own company.

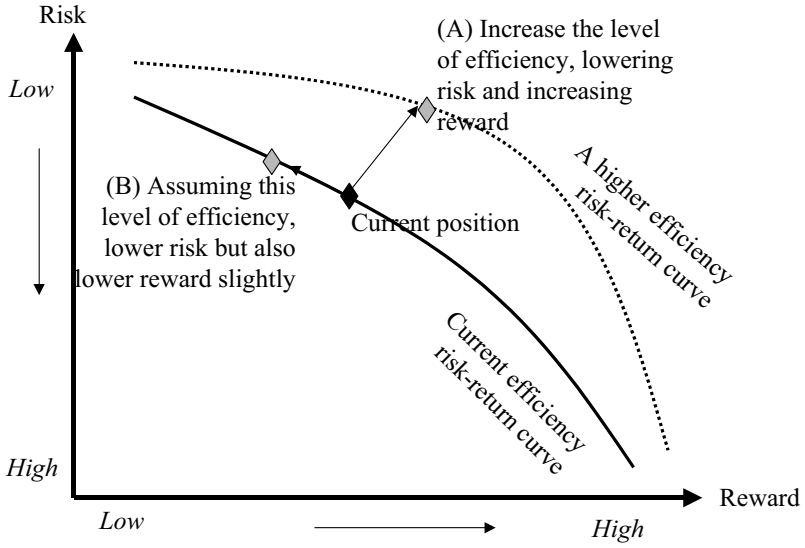

Fig. 4.1 Choosing supply-chain risk/reward tradeoffs—Choice (A) entails moving to a higher level of efficiency, reducing risk while increasing rewards. Choice (B) entails remaining at the current level of efficiency and therefore reducing risk, which also means reducing the reward. Adapted from Chopra and Sodhi (2004).

Just as a generic portfolio strategy needs to be tailored for any given portfolio, we need to tailor the portfolio of reserves for any given company's supply chain risk. There are four aspects to a company's situation that are useful to understand tailoring:

- Cost of a 'reserve' (capacity, inventory, etc.)
- Centralizing versus decentralizing the reserve in question

- Level of risk (high or low), and
- High volume stable demand (low risk) versus low volume uncertain demand (high risk) products.

Given these four aspects, three key relationships influence this optimal balance (see Fig. 4.2) as discussed below:

1. The *first* relationship is the increasing cost of risk reduction. This simply means that using inventory to cover a high level of demand risk costs much more than covering a low level of risk.
2. The *second* relationship shows that pooling forecast risk, receivables risk, or some other risk reduces the amount of reserve required for a given level of risk coverage. For example, the required level of inventory needed to ensure a given level of fill rate decreases when the demand forecasts at different locations are pooled.
3. The *third* relationship shows how the benefit of pooling grows with the level of risk covered: the benefit of pooling inventory is large only if the product has high forecast risk or a high inventory risk.

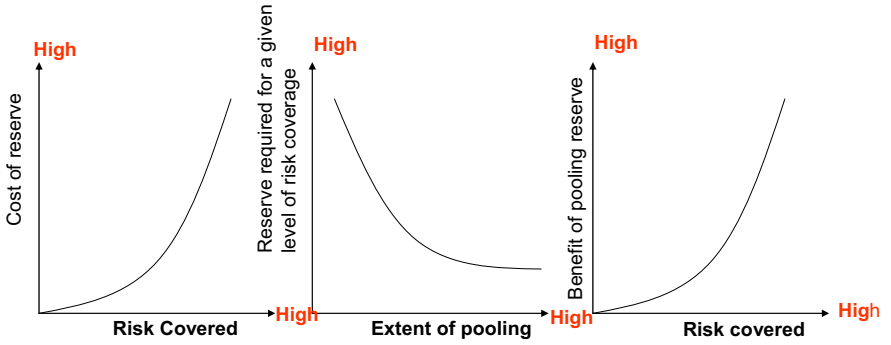

Fig. 4.2 Balancing supply-chain risk/reward relationships: In order to match the cost of building a reserve to the extent of the risk covered, managers must optimally balance three key relationships. (a) The **increasing cost of risk reduction** means covering a high level of demand risk using inventory is proportionally much more expensive than covering a low level of risk using inventory. (b) The **pooling forecast risk, receivables risk**, or other risk reduces the amount of reserve required for a given level of risk coverage so that the required level of inventory needed to mitigate forecast risk decreases as it is pooled. (c) The **benefit of pooling** grows with the level of risk covered so that the benefit of pooling inventory is large only if the product has high forecast or inventory risk. Adapted from Chopra and Sodhi (2004).

Managers can balance these relationships to tailor their response to risk with a surer grasp of extent and cost of reserve. The following rules of thumb can be applied to tailor risk-mitigation strategies: When the cost of building a reserve is low, reserves should be decentralized so that decentralized reserve would enable local entity to respond faster to risk incidents. When the cost for the reserve is high,

reserves should be pooled so as to manage supply chain risk at affordable costs. If the level of risk is low, focus on reducing costs. If the risk is high, focus on risk mitigation (Fig. 4.3). By tailoring reserves for all risk-mitigation strategies, companies can maximize rewards for the same level of risk, or lower risks for the same reward (Fig. 4.3, see also Table 4.4).

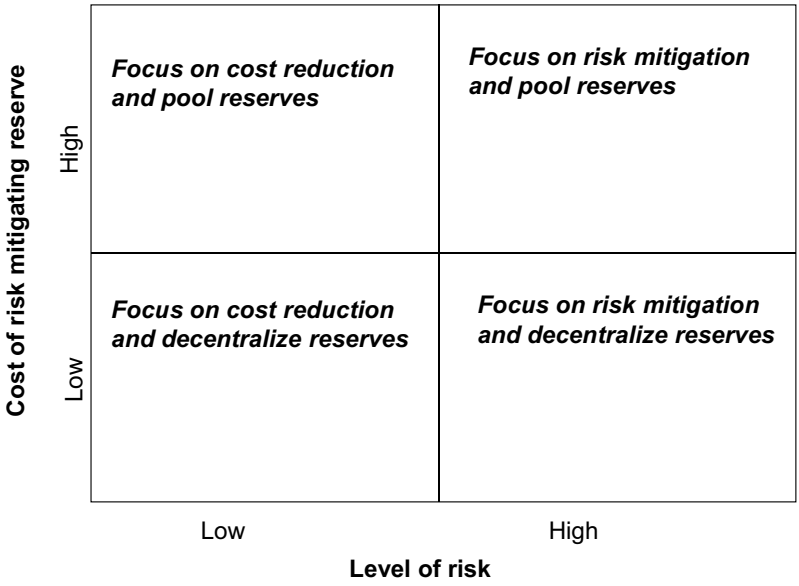

Fig. 4.3 Rules of thumb for tailored risk management

Besides the cost of building the reserve, companies must consider product volumes. Fast-moving standard products, with low margins and low forecast risk, call for different types of reserves than slow-moving special products with high margins and greater forecast risk. When planning capacity, managers should select a low-cost supplier for supplying high-volume stable demand (low-risk and low-margin) items. In contrast, a more responsive supplier is better suited for supplying low-volume uncertain demand (high-risk and high-margin) items. Case in point: Cisco tailors its response by manufacturing high-volume products with stable demand in specialized, inexpensive but not-so-responsive Chinese plants. Low-volume items with uncertain demand (and with high margins) get assembled in responsive, flexible (and more expensive) U.S. plants. Sony also exploits a similar strategy using flexible but high-cost plants in Japan, and low-cost but specialized plants in Malaysia and China.

As much as possible, a specialized and decentralized approach offers the best way to keep capacity for *high-volume* commodity items with *low forecast risk*. Doing so should produce greater responsiveness and lower transportation costs—but only if doing so maintains adequate economies of scale. In contrast, capacity for

Table 4.4 Tailoring reserves for a given company's context

General Risk Mitigation Strategy	Tailored Strategies
Increase capacity	• Focus on low-cost, decentralized capacity for predictable demand. • Build centralized capacity for unpredictable demand. Increase decentralization as cost of capacity drops.
Get redundant suppliers	• More redundant supply for high-volume products with stable demand, less redundancy for low-volume products with uncertain demand • Centralize redundancy for low-volume products with uncertain demand in a few flexible suppliers.
Increase responsiveness	• Favor cost over responsiveness for commodity products. Favor responsiveness over cost for short- lifecycle products.
Increase inventory	• Decentralize inventory for low-value products with stable demand. Centralize inventory for high-value products with uncertain demand.
Increase flexibility	• Favor cost over flexibility for predictable, high- volume products. Favor flexibility for low-volume unpredictable products. Centralize flexibility in a few locations if it is expensive.
Pool or aggregate demand	• Increase aggregation as unpredictability grows.
Increase capability	• Prefer capability over cost for high-value, high-risk products. Favor cost over capability for low-value commodity products. Centralize high capability in flexible source if possible.

low-volume, short life-cycle products with *high* forecast risk should be made more flexible and centralized to pool demand. That helps explain why auto makers, for example, build specialized plants in each major market for fast-moving products. But plants for high-end, slower-selling cars should be centralized and more flexible.

When capacity is expensive, managers can reduce supply-chain costs by centralizing capacity to pool risk. As costs decline, capacity can be decentralized further to be more responsive to local markets. Consider the personal computer industry. PCs can be assembled to order in two different ways: One is the Dell model in which capacity is centralized. The other is the model widely used in India, in which several companies sell component kits to local assemblers for assembly on demand. Given the low cost of assembly capacity in India, it is economical to decentralize capacity, even though this action reduces pooling and increases the overall size of assembly capacity across the supply-chain. In contrast, given the higher cost of capacity in the United States, centralizing buffer capacity is more effective.

In addition to separating products with different risk characteristics, managers must also consider separating capacity for the low-risk and high-risk aspects of each product. Utility companies use this strategy by employing low-cost, coal-fired power

plants to handle predictable base demand, and utilizing responsive but high-cost gas- and oil-fired power plants to handle uncertain peak demand. Similarly, General Electric (GE) ships bulbs by sea on a weekly basis from its plant in China to cover the predictable portion of demand. But the company also maintains an inventory of bulbs in the United States, or flies them in from China, to cover unpredictable demand.

4.5 Conclusion

Successful management of supply chain risks begins with an understanding of the various threats, alone and collectively. By continually stress testing their supply-chains and tailoring reserves, managers can protect and improve the bottom line in the face of many types of supply-chain risks.