Chapter 5
Response as a Mitigation Approach

Abstract As supply chains become more complex, companies find their supply chains more vulnerable to unforeseen disruptions in their supply chains. Without responsive systems in place, such disruptions can have huge impact in terms of cost and recovery time to the company (and its customers as well as suppliers). This chapter presents a *time-based risk management* framework to motivate improved practice and research into systematic and pre-planned response to risk incidents. Our time-based risk management framework focuses on *time* and *processes* as regards the companys response to disruptions when they occur rather than on their cost, likelihood or impact.

5.1 Introduction

Many companies are expanding their supply chains to more external partners in different countries as a way to reduce cost and product development cycle and to explore new markets. For example, Boeing increased the outsourced content from 50% to 70% when it was developing the 787 model, spreading its supplier base across 20 countries. Also, according to an industry study conducted by AMR in 2006, over 42% of the companies manage more than 5 different global supply chains for different products in different markets. As supply chains become more complex, companies find their supply chains more vulnerable to unforeseen disruptions—rare but severe events that disrupt the flow of goods and information in a supply chain. Without a disruption management system put in place, these disruptions can have huge impact (in terms of cost and recovery time) to the company (and its customers).

5.1.1 Examples of Disruptions and Their Impacts

Notable examples of disruptions and their impacts include:

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1. Ericsson lost 400 million euros in the quarter following a minor fire at their supplier's semiconductor plant in 2000 (Chapter 4). In addition, due to a design flaw of the Pentium microprocessors, the recall of 5.3 million chips has cost Intel $500 million in 1994.
2. New Orleans did not fully recover even six years after the landfall of Hurricane Katrina in 2005.
3. Based on an analysis of 827 disruption announcements made over a 10-year period, Hendricks and Singhal (2005a) found that companies suffering from supply chain disruptions experienced 33-40% lower stock returns relative to their industry benchmarks over a 3-year time period that starts one year before and ends two years after the disruption announcement date.
4. Over 100 patients have died in 2008 as a result of blood thinning drug Heparin contaminated with unsafe substance (Pyke and Tang (2008)).

Other examples of significant supply chain disruptions include: Mattel's recall of over 18 millions of toys in 2007 (Casey and Pasztor, 2007), Dell's recall of 4 million laptop computer batteries made by Sony in 2006. Land Rover had to lay off 1400 workers after their supplier became insolvent in 2001 as production could not continue without parts. Dole suffered a large revenue decline after their banana plantations were destroyed after Hurricane Mitch hit South America in 1998. And, after 9/11 attacks in 2001, Ford had to close five plants for several days owing to the suspension of all air traffic.[1]

5.1.2 Dealing with Disruptions

Supply-chain disruptions are getting CEOs' attention these days because of their short term effects (negative publicity, low consumer confidence, market share loss, etc.) and long-term effects (stock prices and equity risk). Despite these potentially detrimental effects, not many firms may be willing to invest in initiatives to decrease disruption risk. According to a study conducted by Computer Sciences Corporation in 2004, 60% of the firms reported that their supply chains are vulnerable to disruption (Poirier and Quinn, 2003). Another survey conducted by CFO Research Services concluded that 38% of 247 companies acknowledged that they have too much unmanaged supply chain risk (c.f., Eskew (2004)). While the exact reasons are not known, Rice and Caniato (2003) and Zsidisin et al. (2000) conjecture two key reasons: (1) firms are not familiar with how to manage supply chain risk; and that (2) firms find it difficult to justify investment in risk reduction programs or contingency plans.

To garner support for implementing certain risk reduction programs *without* exact cost/benefit analyses of certain risk reduction programs, effective risk reduction programs must provide strategic value *and* reduce supply chain risks at the same

[1] See, for example, Christopher (2004), Martha and Subbakrishna (2002), and Chopra and Sodhi (2004) for more details.

time. Therefore, the biggest challenge is to determine ways to mitigate supply chain risks and increase profits simultaneously so that companies can achieve a higher level of efficiency while reducing risk—this is also our aim with time-based risk management.

One stream of the risk-mitigation literature focuses on preventing rare risk events. For instance, different initiatives developed by Homeland Security (e.g., smart containers, Customs -Trade Partnership against Terrorism) would prevent terrorist attacks at various ports in the United States. However, these prevention initiatives may not be economical for preventing rare disruptions that could occur anywhere in a complex supply chain (Lee and Wolfe, 2003). When a company cannot prevent a risk incident from occurring, it has to figure out ways to respond quickly so as to contain the damage. The focus is really on time and therefore we call it time-based risk management.

5.2 Time-Based Risk Management

Rare events that can cause huge disruption to the supply chain are costly to prevent and companies may be reluctant to invest in prevention as the returns are unclear. However, companies may be more willing to develop ways to respond to risk incidents more effectively *after* their occurrence by containing their impact through "quick response." Our aim in this chapter is to motivate improved practice and research into systematic and pre-planned response to risk incidents. We provide a simple framework to think about response and motivate further research and improved practice through a variety of examples both within and outside supply chain management.

Our proposed framework extends *business continuity* efforts in practice from a local context to a supply chain wide one. Akin to various time-based initiatives such as *time-based competition* (c.f., Blackburn (1990) and Stalk and Hout (1990)), our "time-based risk management" concept focuses on ***time*** and response processes instead of ***cost***, ***probabilities*** or ***impact***. Specifically, we break up a "response" into three time elements—time to *detect* the event across the supply chain ($D1$), time to *design* a response ($D2$), and time to *deploy* the response ($D3$)—that we refer to as the **3-D framework**. By focusing its efforts on ensuring that systems and processes are in place to reduce these three time elements, a company reduces the overall *response* time (R1) and thus *recovery* time (R2) and total impact. We illustrate this concept through examples from a variety of contexts. Specifically, we shall argue that companies can reduce the impact of supply chain risk incidents by shortening these three elements of time and hence the response time. Increasing responsiveness can help in general and may help increase market competitiveness for the company.

Our time-based risk management framework is intended to help with planning and setting up procedures and protocols *before* a risk event occurs: detection systems and procedures to reduce $D1$, pre-packaged designs to reduce $D2$, and identified communication channels for deployment to reduce $D3$. Just as 80% of the total cost of a product is determined during the product design phase, the activities that take place for designing response can have a significant effect on the overall impact of a disruption.

Our contribution is to highlight a potentially rich area of empirical and modelling research. This should add to the literature that has focused on prevention of delays and disruptions through various means rather than on planning for post-incident recovery. Managerial implications are that time-based risk management dovetails into the company's business continuity efforts and provides a basis for risk reporting for its lenders and investors. With time-based risk management, investment in risk management is low while still increasing competitiveness due to improved responsiveness through more awareness of supply chain processes as well as more communication across the supply chain. This chapter is limited to presenting the concept, although we provide avenues for research and the basis for improved practice.

5.2.1 The 3-D Framework: Detect, Design, and Deploy

Once the supply chain partners have identified and assessed certain types of supply chain risks and developed certain risk mitigation plans based on either the alignment or the agility strategies, it remains to develop adaptive capabilities for quick response to risk incidents; i.e., reduce response lead time comprising of the time to *detect* a risk incident ($D1$), the time to *design* one or more solutions as well as *selecting* one solution in response to the incident ($D2$), and the time to *deploy* the solution ($D3$). Companies can reduce the impact of supply chain risk incidents by shortening these three elements of time and hence the response time ($R1 = D1 + D2 + D3$). After deployment, the time it takes to restore the supply chain operations is the recovery time.

The three "D" components of time can be illustrated by using the failed relief efforts associated with Hurricane Katrina. Despite live TV coverage of Katrina's aftermath in late August of 2005, it took 3 days for FEMA director Michael Brown to learn of the 3000 stranded evacuees at New Orleans' Convention Center. In our terminology, the detection lead time $D1 = 3$ days. According to the Reynolds (2005), coordination between FEMA and local authorities was poor: it took days to sort out who should do what, when and how. For example, it took two days for Louisiana Governor Blanco to decide on the use of school buses to remove the stranded evacuees. In our context, the design time $D2$ is therefore two days. However, as seen on live TV, most school buses were stranded in the flooded parking lots. FEMA requested over 1000 buses to help out but only a dozen or so arrived the day after; hence, the deploy lead time $D3$ was quite long. As a result, New Orleans had not fully recovered even after six years and displaced people continue to live in temporary accommodation so the recovery time $R2$ exceeds six years. The Katrina fiasco suggests that one can reduce the impact—number of deaths, costs, and recovery time $R2$—associated with a disruption by reducing the response lead time $R1 = D1 + D2 + D3$.

There are various ways to shorten the following time elements:

1. *Detection time* (*D*1) can be reduced by developing mechanisms to discover a risk incident quickly when it occurs or even to predict it before it occurs. Companies must also identify ways to share the information with their supply-chain partners. Monitoring and advance warning systems can enable firms to reduce the detection lead time. For instance, many firms have various IT systems for monitoring the material flows (delivery and sales), information flows (demand forecasts, production schedule, inventory level, quality) along the supply chain on a regular basis. For example, Nike has a "virtual radar screen" for monitoring its supply chain operations[2]; Nokia monitors the delivery schedule of suppliers; and Seven-Eleven Japan monitors the production/delivery schedule from their vendors (suppliers) as well as the point of sales data from different stores throughout the day (Lee and Whang 2006). Such monitoring systems typically use various types of control charts to monitor the operations and to issue an alert should any anomaly occur. Advance warning systems, by contrast, are intended to detect an undesirable event before it actually occurs thus reducing detection time to a minimum. For example, smart alert systems enable GE to conduct remote-sensing and diagnostics so it can deploy engineers to service turbines before catastrophic failures occur.
2. *Design time* (*D*2) can be reduced if the company and its partners can develop contingent recovery plans for different types of disruptions *in advance*. Many organizations seek to do so through *business continuity* efforts. For example, Li and Fung has a variety of different contingent supply plans to enable them to switch from one supplier in one country to another supplier in a different country (St. George 1998). Seven-Eleven Japan has developed contingency delivery plans to enable them to switch from one transportation mode (trucks) to another (motorcycles), depending on traffic conditions (Lee and Whang 2006). A company may find it useful to use decision analysis tools such as decision-tree analysis to refine and select a recovery plan. Sarin (2001) presents a decision-analysis framework for evaluating different earthquake-safety plans.
3. *Deployment lead time* (*D*3) can be shortened by improving communication and coordination among supply chain entities within the company or within supply chain partner firms, once a recovery plan has been selected. Van Wassenhove (2006) suggested three forms of coordination: (1) by command (central coordination), (2) by consensus (information sharing), and (3) by default (routine communication). In the event of a major disruption, coordination by command seems to be more appropriate during the design phase of a recovery plan and its deployment. Once the recovery plan is deployed, coordination by consensus would seem appropriate especially when each party has a clear role and responsibility established in advance.

Communication, an important aspect of crisis management, is also a time-based response approach motivated by public perception. Companies need to develop crisis management plans to manage the public perception so as to reduce the long term

[2] Hartwigsen, 2005.

impact on the company's reputation. Immediately after a risk incident, the involved supply chain parties need to develop plans to restore customer relationship and communicate their approach for rebuilding public confidence. For example, soon after issuing multiple recalls in 2007, Mattel created simple ways for consumers to return the recalled products using downloadable forms, and free shipping mailers. To restore trust, the company acknowledged problems to stakeholders and apologized to customers publicly in the press. In exchange for returned toys, it offered coupons for customers to buy other Mattel products of the same value. It also announced the three-stage safety check system in September 2007: test every batch of inputs (paint); test every batch of production; and test samples of finished goods from each production run. In addition to external communication, internal communication is important to better manage supply chain risk in the future (c.f., Zsidisin et al., 2005). At Mattel, a new position was created reporting directly to the Mattel's CEO to ensure that potential recall risks were quickly addressed, and, if necessary, elevated within the company for improved internal communication (c.f., Pyke and Tang 2008).

5.3 Response Time and Impact

To understand the importance of shortening the response time $R1$, consider the following examples:

Eradicating med flies in California in 1980: Despite the initial med fly eradication efforts in the mid-70s, med flies were detected in California again in the early part of 1980. Instead of calling for aerial spray of Malathion in a small area (30 square miles) that is proven to be effective but costly, Governor Brown approved the release of sterile male flies and traps. Unfortunately, these methods were not effective and the area of infestation had expanded more than 20-fold within 1 year—from 30 square miles in June of 1980 to 620 square miles in July of 1981. As Japan and other countries imposed import restrictions, Governor Brown was under political pressure to approve the aerial spray over an area of 1500 square miles starting July 14, 1981. This delayed action came at a significant cost: an expenditure of over $100 million and Governor Brown's political career (Dawson et al., 1998; Denardo, 2002).

Ground shipping after September 11: Immediately after September 11, Chrysler was the first to request their logistics providers to switch the mode of transportation from air to ground. Speedy deployment of this strategy has enabled Chrysler to get the parts from their supplier such as TRW via ground transportation. Ford was unable to deploy the same strategy because, by the time Ford decided to switch to ground shipping, all ground transportation capacity has been taken up. Facing part delivery problems, Ford had to shut down 5 of the U.S. plants for weeks and reduce its production volume by 13% in the fourth quarter of 2001 (c.f., Hicks, 2002).

Recovering after supply disruption: Both Ericsson and Nokia were facing supply shortage of a critical cellular phone component (radio frequency chips) after their key supplier, Philip's Electronics semiconductor plant in New Mexico, caught on fire in March of 2000. Nokia recovered quickly by doing the following. First, Nokia immediately sent an executive team to visit Philip's in New Mexico so as to assess the situation. Second, Nokia reconfigured the design of their basic phones so that the modified phones can accept slightly different chips from other Philip's plants; and third, Nokia requested Philip's to produce these alternative chips immediately at other locations. Consequently, Nokia satisfied customer demand smoothly and obtained a stronger market position mainly due to their speedy deployment of their recovery plan. On the contrary, Ericsson was unable to deploy a similar strategy later because all Philip's production capacity at other plants has been taken up by Nokia and other existing customers. Facing with supply delay, Ericsson lost $400 million in sales (Hopkins, 2005).

The above examples suggest that the recovery lead time $R2$ is by and large increasing in the response lead time $R1$. This is mainly because the impact of the event can escalate exponentially before an effective response is made.

5.3.1 Modeling Disruption Impact over Time

To study the impact of a risk incident over time, we could look into the epidemiology and the forest fire literature. Specifically, the total impact of a natural disruption (an epidemic or a forest fire) tends to increase super-linearly or even exponentially with time initially and then to taper off. Thus, as shown in Fig. 5.1, shortening the response time $R1$ $(= D1 + D2 + D3)$ can reduce the total recovery time $R2$ and hence the total eventual impact of the disruption.

Epidemic models: The simplest form of epidemic model is the *exponential model* that can be explained as follows. Let $I(t)$ be the number of people infected at time t. In this case, the rate of infection can be defined by the differential equation: $\mathrm{d}I(t)/\mathrm{d}t = kI(t)$, where the parameter $k > 0$. This differential equation yields $I(t) = I_0 \mathrm{e}^{kt}$, where I_0 is the number of people infected at time 0. Therefore, the number of people infected grows exponentially overtime. By contrast, the *logistic model* is another simple model that stipulates that the infection rate depends on the number of people infected and the number of people who is susceptible to the infection. The number of people infected $I(t)$ grows exponentially initially and plateaus later on (Mollison, 2003).

Fire impact models: There are many different types of fire models based on a system of differential equations for estimating the burned areas over time—see, for example, Richards (1995) and Janssens (2000) for various fire spread models. The simplest model is the elliptical fire spread model presented in Arora and Boer (2005). Essentially, they assume that the burned area takes on the form of an ellipse with the point of ignition at one of the foci. By assuming that the fire

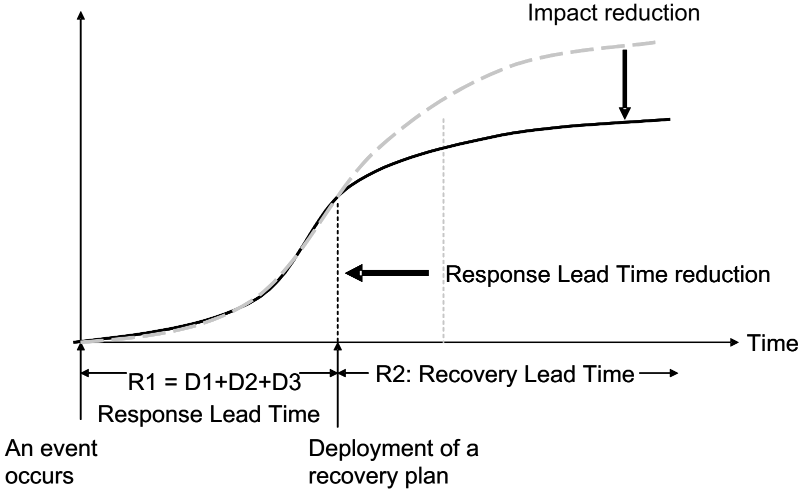

Fig. 5.1 The effect of reducing the response lead time $R1$

spreads linearly over time along a 2-dimensional space, they show that the total area burned (size of the ellipse) grows as a squared function of time elapsed since the start of the fire. Thus, the total area burned grows exponentially over time (but slows down as the area of the remaining forest decreases).

In addition to these two models, there are hazards analysis reports highlighting that the magnitude of the problems associated with many hazards (fire, terrorism, earthquake, etc.) tend to grow super-linearly or exponentially over time (Anderson, 2002).

While we are not aware of any scientific study of modeling impact over time in the context of supply chain risk, it is plausible that a pattern similar to the logistic model will emerge (Fig. 5.1). For instance, a week's supply delay would have caused little damage to Ericsson but several weeks of supply delay resulted in $400 million loss in sales in the first quarter and $2 billion eventually in the first year after the dust had settled.

5.4 Time-Based Risk Management in Practice

We now present five time-based disruption management activities that would enable a company to reduce the response time $R1 = D1 + D2 + D3$ (and consequently the recovery time $R2$ and the total impact):

1. **Work with suppliers and customers to map risks.** Many companies already identify potential disruptions according to its impact and likelihood as part of business continuity efforts. They can further that effort in two ways by tracing

the impact of each disruption along the supply chain from upstream partners and to downstream customers. Doing so requires discussion among supply-chain partners to creates shared awareness of different types of disruptions and their impacts on different parties. This generates support for collaborative efforts for mitigating risks for all parties.

2. **Define roles and responsibilities.** Companies should work with all key supply chain partners to define the roles and responsibilities to improve communication and coordination when responding to a disruption. To coordinate response efforts effectively, Van Wassenhove (2006) suggested three forms of coordination: coordination by command (central coordination), coordination by consensus (information sharing), and coordination by default (routine communication). The coordination mechanism, agreed among the parties *before* a risk event has taken place, can then be used without further discussion for design and for deployment of solutions *after* the risk event has occurred. Coordination by command seems to be appropriate during the design and deployment phases (i.e., during D2 and D3). This is because, during these two phases, an identified group within the firm or comprising partners' representatives as well, needs to take central command for collecting and analyzing information to design a recovery plan, and then for disseminating information regarding the deployment of the selected recovery plan. However, to get to this point of agreed upon procedures, coordination by consensus is more effective in agreeing on detection mechanisms and in designing pre-packed solutions that anticipate disruptions.
3. **Develop monitoring/advance warning systems for detection.** Companies need to develop mechanisms to discover a disruption quickly when it occurs and/or to predict a disruption before it occurs. They must also identify ways to share the information with their supply-chain partners and to get similar information from them. Monitoring and advance warning systems can enable firms to reduce detection time. For instance, many firms have IT systems for monitoring the material flows (delivery and sales), information flows (demand forecasts, production schedule, inventory level, quality) along the supply chain on a regular basis. For example, the monitoring systems at Nike, Nokia and Seven Eleven Japan mentioned earlier use various types of control charts to monitor the operations and to issue an alert should any anomaly occur. Hence, these monitoring systems would reduce the detection time $D1$. Besides monitoring systems, advance warning systems are intended to detect an undesirable event before it actually occurs. For example, Allmendinger and Lombreglia (2005) described how different smart alert systems enabled GE to conduct remote sensing and diagnostics so that it can deploy engineers to service their turbines before failures occur.
4. **Design recovery plans.** Develop contingent recovery plans for different types of disruptions. Establishing contingent recovery plans for different types of disruptions *in advance* would certainly reduce the design time $D2$. Many firms have developed various recovery plans (or contingency plans) in advance. For example, Li and Fung has different contingent supply plans that will enable them to switch from one supplier in one country to another supplier in a different country (St. George (1998)). Also, Seven-Eleven Japan has developed different contin-

gent delivery plans that will allow them to switch from one transportation mode (trucks) to a different transportation mode (motorcycles), depending on the traffic condition (Lee and Whang (2006)).

5. **Develop scenario plans and conduct stress tests.** Companies need to create different scenarios and rehearse different simulation runs/drills based on different scenarios with all key supply chain partners (Chapter 4). Because the deployment time $D3$ accounts for the preparation time to launch the selected recovery plan, scenario planning and stress tests are effective mechanisms for reducing $D3$. For example, having rehearsed response and recovery plans at each P&G site under different scenarios previously, P&G restored the operations of its coffee plant in New Orleans by only mid-October 2005 after the Katrina's landfall in late August 2005. P&G attributed their quick recovery ($R1 + R2 = 2$ months) to its readiness (Cottrill, 2006).

5.5 Risk and Reward Considerations

Besides reducing disruption risks, time-based disruption management can increase a firm's competitiveness as well. As we mentioned earlier, effective risk reduction programs must provide strategic value and reduce supply chain risks at the same time (Tang, 2006a). In other words, we should look for ways to mitigate supply chain risks and increase profits simultaneously so that companies can achieve a higher level of efficiency by reducing risk while increasing reward (Chopra and Sodhi, 2004). Time-based risk management may help achieve this (Fig. 5.2).

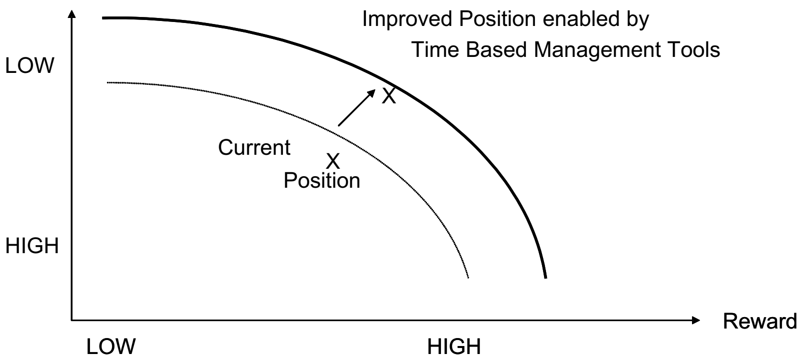

Fig. 5.2 Time-based risk management enables a firm to shift its position to a higher efficiency risk-reward curve (refer to Chapter 4)

We can use Spanish apparel maker Zara's success to illustrate how time-based disruption management can enable firms to increase their competitiveness by responding to dynamic changes quickly (as articulated in the time-based competition literature). Despite the fact that fashion retailers are susceptible to many supply chain risks such as uncertain supply, transportation delays, shrinkage and theft, uncertain demand, Zara continues to be the most profitable European fashion retailer with sales and net incoming growing at an annual rate of over 20%. Ferdows et al. (2004) attributed Zara's success to its "rapid fire fulfilment" strategy that enables Zara to increase its competitiveness while reducing risks (Fig. 5.2). Specifically, Zara's claim to fame is time reduction: Zara is capable of design, manufacture and ship a new line of clothing within 2 weeks, while most traditional fashion retailer will take more than 24 weeks. To reduce various measures of time ($D1$, $D2$, $D3$ and $R2$), Zara performs some of those activities we described in Section 5.4.

As reported in Ghemawat and Nueno (2003), Zara operates as a vertically integrated supply chain by co-locating their designers and the factory in Spain, by managing their own warehouses and distribution centers in Spain, and by running their own stores worldwide. Not only does this integrated supply chain provide Zara supply chain visibility, it enables the company to facilitate close communication and coordination with all supply chain partners including their suppliers. By receiving point of sales data from their own stores on a regular basis, Zara has a well established process for analyzing the sales data to detect sudden changes in demand and/or fashion trends. As such, Zara's detect lead time $D1$ is short. Next, by managing centrally and by working closely with all partners, Zara can analyze the situation and prescribe a response should the market change suddenly. Also, by co-locating the designers and the factory, Zara has the capability to deploy different recovery plans by designing and manufacturing new designed clothes very quickly should the sales of existing designs are below expectations. Hence, the design time $D2$ is short.

Next, the close proximity of suppliers, designers, factories, and distribution centres enable Zara to communicate, coordinate, and deploy the selected recovery plan quickly with all supply chain partners (from suppliers to the stores). Hence, the deploy lead time $D3$ is short. In addition, Zara also implements some of the recovery plans to reduce the deploy time $D3$ and recovery time $R2$. For example, Zara engages in "flexible supply contracts" with "multiple suppliers" so that Zara can adjust the order quantity quickly should a demand disruption occur.

Not only do these mechanisms help Zara to reduce $D1$, $D2$, $D3$ and consequently $R2$, they enable Zara to increase its competitiveness and profit by: (a) generating more accurate demand forecasts in a timely manner; (b) designing, producing, and distributing newly designed products in small batches quickly; and (c) reducing the costs associated with price markdowns (due to over-stocking) and lost sales (due to under-stocking). Relative to its competitors, time-based management has enabled Zara to achieve higher profitable growth and lower supply chain disruption risk simultaneously.

5.6 Conclusion

We have used diverse examples and natural disruption models (epidemic model and fire model) and anecdotal evidence to argue that firms can use time-based management to reduce the response lead time and recovery lead time, which will in turn reduce the impact of a disruption. We suggested five activities that would enable a firm to reduce the response lead time $R1$. Finally, we suggested using Zara's example that we may be able to achieve both risk reduction and extra rewards through increased responsiveness enabled by time-based risk management.

However, we have presented a concept that requires validation in practice and further research. For instance, we presented impact models from the epidemiology literature—we need to develop similar models for supply chains. Likewise, we need empirical research to study how and to what extent companies are extending business continuity efforts to respond to risk events. We believe time-based risk management to be a rich area for modeling and for empirical research. For instance, we can propose two hypotheses for further research: (1) the recovery lead time $R2$ and cost can be significantly higher if the deployment of a recovery plan is delayed; and (2) the execution of a recovery plan can become much more difficult if its deployment is delayed.