# Supply Chain Disruptions: Managing Risks vs. Managing Crises

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MASTER OF ENGINEERING IN LOGISTICS

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JUNE 2007

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## Abstract

This thesis looks at two back-to-back disruptive supply chain events, one due to a sole-supplier's bankruptcy and the other caused by Hurricane Rita, that occurred at a specialty chemical company, and uses these examples to demonstrate how managing crises is more costly than managing risks. In examining the events surrounding the sole-supplier bankruptcy, managing a crisis cost this specialty chemical company 45% more money than managing a risk.

Through the findings of these two disruptive events, a framework, the *Eye of Providence*, is created to manage supply chain risks. First, an organization must determine how developed its risk-management protocol is. Next, by studying past disruptive events and determining the key impact factors, an organization could calculate and learn about the opportunity cost of managing crisis. Then, by continuously evaluating its suppliers and rigorously applying those key impact factors to the analysis of its supply chain practice, an organization could evaluate and identify its current vulnerabilities. Finally, by proactively monitoring event-based warning signals, or disruption indicators, an organization could assess its potential supply chain risks, and plan accordingly.

Whether a company is low on the risk-maturity level or has already integrated risk management into its corporate culture, the process developed in this thesis serves as a versatile tool that can help businesses structure a more dynamic, resilient supply chain.

**Thesis Advisor:** **Yossi Sheffi**
**Title:** **Director, MIT Center for Transportation and Logistics**

## Acknowledgements

We would like to thank our advisor Dr. Yossi Sheffi for his guidance, teaching, and support, leading us in the right direction. We would also like to thank Dr. Chris Caplice, Dr. Edgar Blanco, and rest of the MIT Risk Metrics Team for their valuable input.

Special thanks to William Haas for giving us feedback on content.

We thank our sponsor for providing us with the resources as well as the opportunity to study the company and its operations. Special thanks to Eric Simeonidis for doing his best in helping us with our research, and David Baur, Kati Hazrati, Jose Hernandez, Gary Hutchinson, Craig Merrill, Mark Patterson, David Simkins, and Gregory VanFleet for taking their time to furnish us with insightful information.

Garrett and Zen also thank each other for getting this done, but that goes without saying.

**Garrett**

I would like to thank my family for providing me with the foundation from which to learn and grow.

I would also like to thank my friends and peers in MLOG, past coworkers and current friends who constantly raise the bar and push and challenge me to new levels each and every day.

And Jenny Liu, who supported and encouraged my decision to move east even though it meant being 3,000 miles apart.

**Zen**

I thank God for this great opportunity, as well as for everything else.

I thank my parents Dr. John Chang and Ellen, my brother Roger, and the rest of my family for their endless support. Without them, my existence would also not have been possible.

I also thank my dear friends Amy Alejandro, Tam Cao, Kashif Haq, Beverly Ibarrola, Lyndsey Nations, Mingjie Nahidi, Sang-Real Shin, Michael Tsai and family, and Sukie Young for their wonderful moral support, keeping my sanity in check over the years.

Finally, good luck to my friends and comrades in the MLOG Class of 2007! Also, I thank Saskia Michl for putting up with me.

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# 1 Introduction

SpecChem, a specialty chemical company, fought its way through two back-to-back supply chain disruptions, one due to a sole-supplier bankruptcy and the other caused by Hurricane Rita. Since SpecChem did not have an official risk-management protocol, costly crisis-management responses were used to avoid complete operations meltdown. In excess of $600,000 was spent managing these risks, with $120 million in revenues at stake. Mitigating these risks in advance would have been 45% cheaper and the danger to revenues would have been negligible.

## 1.1 Disruption of Supply: Sole-Supplier Bankruptcy

At five o'clock EST in the afternoon on February 16th, 2006, the Purchasing Manager of SpecChem received a shocking phone call just as he was wrapping up for the day. The call, surprisingly, had come from one of SpecChem's competitors, informing the Purchasing Manager that SP, a common raw material supplier for both firms, had just declared bankruptcy, which had been confirmed by SP's Chief Operating Officer.

The raw material Lignin, a byproduct left behind by an antiquated paper-pulping process, serves as a critical ingredient for SpecChem's main line of cement additives, which are considered commodity products. SP had been SpecChem's sole-provider of this specific ingredient, and without a contingency plan in place, losing the supply stream of this raw material would have halted production at SpecChem.

The available pool of Lignin has been rapidly shrinking over the past decade, as more efficient paper-pulping technology that destroys the byproduct along the process has been introduced and adopted by the paper industry. This advancement effectively reduced the number of potential suppliers. Due to the versatility of Lignin, currently used in dozens of different cement mixtures manufactured with local geological substances across the United States (U.S.), the development of a true synthetic replacement has been slow. Lab-created compounds never quite measured up to the universality of Lignin, as multiple human-made substitutes would have to be fabricated for the different cement types used in the U.S. Thus, the rate of development for suitable chemical substitutions is slower than the rate of diminishing Lignin supply.

Recalling his visit and contract re-negotiation with SP just two weeks before, the Purchasing Manager noted that he had expressed concerns about the supplier's financial health. In the trip report, he indicated that in his opinion, SP may not survive past the end of 2006 if no further actions were taken to improve its profitability. Nevertheless, this crucial information was not taken with the necessary prudence. As a result, crisis-recovery effort ensued at SpecChem in the following months.

After the news traveled through the company, a special taskforce comprised of managers from the Purchasing, Quality, Operations, Product Management, Supply Chain, and Business Development departments was formed to tackle this issue. The team scrambled to secure any inventory available from SP, including the pipeline inventory, and assessed SpecChem's entire supply chain to anticipate the products that would be severely

impacted. In the meantime, a couple of more expensive alternate suppliers, BG and TB, were immediately contacted in an attempt to replace loss in Lignin volume.

Over the next two months, the team at SpecChem coordinated with SP the transportation of any Lignin supply SpecChem could store, and rallied their internal R&D department to qualify raw materials from BG and TB, making sure their Lignins met SpecChem's product specifications. As soon as R&D qualified a sample, new supplies were then shipped from the alternate suppliers to SpecChem's manufacturing facilities, where small test batches of various final products were created and further analyzed, preparing for the eventual depletion of SP's raw materials.

Quality issues initially plagued the cement additives, but were eventually resolved as SpecChem brought down the number of complaints after working together with customers to find solutions. Once R&D stabilized the formula using the new Lignin and the management team gained confidence in the new products, SpecChem proceeded to request a level of commitment for Lignin supply from BG and TB. The Lignin crisis took SpecChem over five months to resolve, while managing this disruption prevented an estimated $60 million loss in company revenues. By August 2006, SP was bought by another firm, and received enough capital to be operational again. SP continues to be a Lignin supplier of SpecChem, but it is no longer the sole vendor.

During the interviews for this project, the management team recounted what its members did well:

*Purchasing Manager*

SpecChem "was able to quickly secure all available stock of the Lignin" at SP.

SP's Product Manager "had good relationship with SpecChem," and since he/she was likely to stay in the same industry, he/she "wanted to treat [SpecChem] well."

SpecChem has had "a long history with the alternate suppliers," and SpecChem "understood [their] material well." More importantly: SpecChem "understood which suppliers were positioned to help most quickly;" SpecChem "had undertaken development with [TB] years ago," even though TB had not been a Lignin supplier in a while; BG, "as market leader, quickly acted to stabilize the market;" "The [alternate] suppliers kept a 'strategic focus.' They saw themselves as affected parties."

SpecChem "organized the response team quickly, and gave [it] power to act. The team stayed on task." Plus, the "goal of making this response 'invisible' to [SpecChem's customers] was established very early."

- Key Points
  - SpecChem communicated the crisis promptly
  - SpecChem had a decent relationship with SP, who was willing to help
  - Alternate suppliers cooperated with SpecChem during a critical time because SpecChem had established a good rapport with them long ago

*Director of Operations*

The departments got closer "because they went through the process" as a team, and people "started seeing from one another's [viewpoints]." Employees now have "more respect of what other people do after learning more about others' functions" at SpecChem.

"We now have better view of suppliers." "We are not as focused to get the best price." Instead, SpecChem works to achieve "greater flexibility in supply chain." The company also proved that it "could model network well and make quick changes, [satisfying its] customers without running into service disruptions."

- Key Points
  - The departments at SpecChem worked as a team to resolve this crisis
  - The departments now have more respect for one another, further breaking down organizational silos
  - SpecChem realized the importance of a more flexible supply chain

Asked what the team could have done better, its members replied:

*Director of Operations*

There was never "a complete postmortem" for why supplier failure was not detected in advance. It "would have been nice to know" ahead about the situation, and observe the warning signals before it was too late.

- ❖ Key Point
    - o SpecChem would have benefited from a reflection of the lessons learned

*Quality Manager*

"Communication and reporting of findings [could have been] better," and SpecChem could have "proactively read between the lines and the financial indicators."

- ❖ Key Point
    - o SpecChem could have benefited from a much deeper relationship with SP, who in turn may have been more comfortable in confiding its financial difficulties

### 1.2 Disruption of Supply: Hurricane Rita

In mid-September 2005, merely a few weeks after Hurricane Katrina had ravaged the Gulf States, the weather bureau reported that Hurricane Rita, a newly formed Category 5 storm, was quickly approaching Houston, Texas. This hurricane could not have come at a worse time, as the devastation left behind by Hurricane Katrina was still freshly ingrained in people's memories.

In contrast with the Lignin crisis, the supply disruption caused by Hurricane Rita was minimal because SpecChem had two weeks to prepare, and management diligently tracked the storm in order to plot a contingency plan. In the wake of destruction caused

by Hurricane Katrina, the company became more cautious of the new storm. Therefore, SpecChem asked Houston-based suppliers HM and LD to ramp up production to ensure ample supplies of Polycarboxylate, a key ingredient used in SpecChem's high-performance products, during emergency shutdown should such action become necessary. However, with the absence of a risk-management protocol, SpecChem once again managed a crisis, rather than managing a risk.

With a shelf-life of two years, Polycarboxylate is used in high-performance concrete products for airplane runways, skyscrapers, large-scale highways, etc. Since Polycarboxylate is a specialty chemical, it is difficult for SpecChem to switch suppliers because of its unique properties. It is also challenging for SpecChem to find suppliers that can produce the chemical to exact specifications, unless the supplier has worked with SpecChem. Therefore, the supplier switching costs are high. Furthermore, raw material variability is wide, capacity is an issue, and testing before launching the product takes time, as process integration on customers' sites is challenging.

After Rita, upper management at SpecChem strategically employed one new Japanese Polycarboxylate vendor, NA, who is currently constructing a new chemical plant in Tennessee. In fact, management had begun negotiation with NA since the beginning of 2005, with the contract finalized in February 2006. This move could further mitigate SpecChem's supply chain risks, increasing the repertoire of suppliers to four with HM-Houston, LD-Houston, KC-Japan, and NA-Japan, as the company's Polycarboxylate suppliers are now more geographically dispersed. Although there is presently no one

supplier that could meet all of SpecChem's capacity demand for the raw material, the new manufacturing plant in Tennessee will eventually be able to satisfy 60% of SpecChem's requirements. SpecChem has since joined with this Japanese supplier to formulate Polycarboxylates that are up to the company's quality standards.

Since SpecChem had ample time to prepare for Hurricane Rita and increase inventory, the management team did not perceive the storm as a high-level threat. Thus, other than continuously monitoring the weather updates and supplier reports, plus preparing to outsource formulation with backup suppliers in the event of total devastation, no dramatic actions took place. Throughout our interviews, the Rita experience was dismissed as an afterthought, even though the potential threat to the company's revenues was also estimated to be $60 million. The Houston-based suppliers became operational again only one month after Hurricane Rita, but their supply contributions were decreased by early 2006, at the request of SpecChem, to ensure a balanced supply distribution.

### 1.3 Scope of Project

In the absence of formal risk-management measures in SpecChem's supply chain organization, communicating risk within the organization is challenging. Risk is also evaluated on an individual, reactive basis, based on the specific material involved.

In this thesis we demonstrate how an organization can proactively approach risk management using a framework we developed, coined the *Eye of Providence*, starting

with knowing where a company currently stands on the six maturity levels of risk management [Pickett, 2006]:

- Level 1: Crisis Management
  - No signs of risk-management measures, responses purely reactive
- Level 2: Pockets of Risk Management
  - Some risk-management activities scattered across an organization
- Level 3: Running Themes
  - Management realizes the need for risk management
- Level 4: Risk Management Policies
  - Majority of the workforce begins to realize the importance of risk management and accepts new policies
- Level 5: Board-Driven
  - Executive management builds a sensible risk-management process and supports the cause
- Level 6: Immersed in Business
  - Risk management is a part of the corporate culture

With the absence of risk management, SpecChem resides on Level 1. The company has no formal protocol in actively preventing and controlling risks.

Using a Risk Impact Scorecard, which is explained later in Chapters 3 and 4, we identified the prominent aspects that contributed to the extra costs incurred managing a

supply chain crisis. These aspects are than quantified and added together to calculate the cost of disruption recovery, so that an organization can understand how much more expensive it is to manage a crisis than manage a risk.

Next, using inventory and supplier data after the disruptions through March 2007, we studied the inventory levels, the number of suppliers, and the percentage of raw material supplied by each vendor for a specific product before and after a disruptive event to analyze current supply chain vulnerabilities.

With the information extracted from our interviews, we mapped the organization's existing ad hoc supplier evaluation procedures, which are structurally sound, and suggested a standardized protocol to select as well as monitor suppliers to ensure their quality.

Finally, we evaluated potential supply chain risks by actively searching for event-based warning signals, or disruption indicators, in documentations and reports written about a supplier.

### 1.4 Overview of Topics

For this thesis, we conducted multiple interviews with employees at SpecChem to get more information of the logic behind response/strategic decisions and the state of mind when the two disruptive events occurred. The interview questions are shown in Appendix A. When organizing our interviews, we noted discrepancies, different

departmental aspects, and the consensus of each team member, as many had their own issues in mind before seeing the crises as an integrated supply chain problem. We also acquired a detailed master timeline for the Lignin disruption. Many at SpecChem do not view the Rita incident as a critical issue, so we put more focus on the sole-supplier failure.

As for a more quantitative aspect of this project, SpecChem provided us with raw material and finished goods inventory data of Lignin and Polycarboxylate, obtained from its Enterprise Resource Planning (ERP) system. All other figures such as management hours, inventory holding costs, worker hours, and supplier switching costs were approximated by SpecChem's Supply Chain Manager. We then processed the quantitative information to produce our results and present our analyses. Below is an overview of the topic outline.

Chapter 2 presents the literature review, citing current industry risk-management practice from various journals and describing the book and articles that inspired and validated our research approach.

Chapter 3 describes our framework for calculating the cost of managing supply chain crises, evaluating current supply chain vulnerabilities, and assessing potential supply chain risks.

Chapter 4 illustrates our findings using our *Eye of Providence* framework in Chapter 3. In this Chapter, we explain how we used our Risk Impact Scorecard to find key impact factors. Then, we present the cost of recovering from supply chain disruptions, the differences between resolving supplier failure and handling natural disaster issues, the current supply chain vulnerabilities, the supplier evaluation procedures, and the indicators of potential supply disruption.

Chapter 5 wraps up our findings of this project, and summarizes the key points discussed.

Chapter 6 offers some recommendations to provide future researchers with several ideas to expand or refine the research on supply chain risk management.

# 2 Literature Review

This thesis focuses on the calculation of the extra costs incurred by managing supply chain crises, the evaluation of current supply chain vulnerabilities, and the assessment of potential supply chain risks. We referenced articles and literature relevant to our topic to help explore current industry practice as well as to inspire a research approach.

## 2.1 Current Industry Practice

Several articles pertinent to existing industry and academic viewpoints of supply chain risk management are found in *International Journal of Purchasing and Materials Management*, *Journal of Supply Chain Management*, *MIT Sloan Management Review*, and *Harvard Business Review*. Three key areas are emphasized throughout the aforementioned journals: Smeltzer & Siferd [1998] in *International Journal of Purchasing and Materials Management*, and Zsidisin & Smith [2005] in *Journal of Supply Chain Management*, place emphasis on building relationships with suppliers; Sheffi & Rice [2005] in *MIT Sloan Management Review* present results based on research and analysis of low-probability, high-impact disruptive events; Argenti [2002] in *Harvard Business Review* stresses the importance of managerial vision and crisis-communication strategy within an organization. The findings of these publications are summarized below.

With a deeper vendor-customer relationship, SpecChem could have obtained vital information on SP's financial health and worked with the company in advance to find a

win-win solution for both organizations. SP, in the presence of a stronger alliance with SpecChem and its other clients, perhaps would have been more comfortable in disclosing its ailing financial situation and asking for assistance through increased prices, contractual concessions, improved supply chain cooperation, and/or streamlined supply chain activities.

By proactively involving suppliers in purchasing management and product development, Smeltzer & Siferd [1998] and Zsidisin & Smith [2005] argue, businesses can minimize uncertainties and reduce supply chain risks through collaboration. Both papers indicate the value of forging strong customer-vendor relationships early and continuously in order to develop a clear expectation and understanding of inherent business-related risks for both parties. Through strategic alliance, customers view suppliers as business partners and work together to improve product design, decrease development cycle, increase product quality, cut expenses, assure availability and timeliness of material supply and service, achieve highest total profitability and lowest total associated cost, and obtain a competitive edge. Furthermore, understanding the difference between proactive and reactive supply chain management can greatly mitigate overall risks in case of disruption.

To minimize the impact of any potential disruption, SpecChem needs to adopt a risk-management mentality, searching for ways to improve the firm's supply chain readiness, resilience, and flexibility. SpecChem will have to understand its supply chain vulnerabilities, explore the weaknesses within its current response strategies, design a

flexible risk-management system that adapts to various disruptions, and implement the new plan across the company to strengthen its supply chain.

The paper by Sheffi & Rice [2005] draws upon the ongoing research of supply chain disruption at MIT's Center for Transportation and Logistics (CTL), and discusses the eight phases of disruption:

1. Preparation → 2. The Disruptive Event → 3. First Response → 4. Initial Impact →
5. Full Impact → 6. Recovery Preparations → 7. Recovery → 8. Long-Term Impact

To ensure readiness and resiliency in the event of a high-impact disruption, businesses should invest more in flexibility than in redundancy to both mitigate risks and avoid added costs. By tapping into frameworks such as the vulnerability map, which visually charts the probability of disruptions and the severity of consequences of various potential threats that a company might face, as well as the company position and responsiveness graph, which displays the responsiveness and the market position that determines a company's resilience, the management of a given organization can plan its risk strategy to quickly respond to the impending disruption and promptly adapt in the situation.

Communication was not optimized inside SpecChem, with different departments working in silos prior to the disruptions. It is necessary for SpecChem's upper management to breakdown those organizational walls and unite the employees under a common goal. It is also imperative to convey management's risk-management effort clearly and integrate the strategy into its corporate culture.

Argenti [2002] reports that to prepare for unforeseen disasters that could potentially disrupt established channels, it is crucial for top management to implement a highly executable crisis-communications strategy not only externally between businesses and customers, but also internally between businesses and employees. However, this mission does not happen over night, as forward-thinking leaders must devote time and resources, as they do with other dimensions of their business, in order to ensure its successful integration. A strong corporate culture and foundation are essential to gain employee buy-ins ahead of time and help establish, as well as maintain, organizational focus, because management cannot afford to begin communicating its visions and goals during a crisis.

## 2.2 Research Approach

To create a framework for our methodology, we identified literatures in *Enterprise Risk Management: A Manager's Journey* by Spencer K.H. Pickett, *MIT Sloan Management Review*, and *Harvard Business Review* that are helpful in searching for ways to calculate the extra costs of recovering from supply chain disruptions, evaluate current supply chain vulnerabilities, and assess potential supply chain risks. Below are the synopses of these inspiring articles that led to various adaptations in our research.

In his book, Pickett [2006] demonstrates the overview and the practice of Enterprise Risk Management (ERM), which takes a portfolio approach to categorize corporate vulnerabilities and evaluate various risks based on assigned numerical values derived from a scorecard, or what he calls Risk Registers. Pickett emphasizes the importance of a

management-driven approach toward risk, referring to the six stages of risk-management maturity, with “crisis management” being the least developed stage, and “immersed in the business” being the highest level of risk-management maturity.

Pickett asks managers, in his Risk Registers, to rate risks along two dimensions: the likelihood of occurrence and the severity of impact (should a risk event occur). High-likelihood and high-severity risks deserve the bulk of a manager’s attention, while low-likelihood and low-severity risks should be given the least amount of a manager’s attention. The amount of risk a company is willing to take, according to Pickett, depends largely upon the individual company’s risk appetite.

The article by Chopra & Sodhi [2004] breaks down the categories of risk to disruptions, delays, systems, forecast, intellectual property, procurement, receivables, inventory, and capacity, and cross references them in a matrix sorted by supplier-related, internal, and customer-related scenarios to form a supply chain stress test. Using a tailored risk-management tactic, which exhibits the relative cost of risk-mitigating reserve with the level of risk a company might anticipate, management can determine the correct courses of action, such as increase capacity, acquire redundant suppliers, enhance responsiveness, increase inventory, improve flexibility, pool or aggregate demand, and/or boost capability.

Watkins & Bazerman [2003] illustrate that to overcome unexpected events, companies should address their vulnerabilities by actively scanning for and recognizing “predictable

surprises." Realizing why an organization is vulnerable, let it be psychological, organizational, or political can help mitigate its business risks. Prediction can be difficult, but a company can further reduce its risks through the effective implementation of prevention countermeasures such as asking employees to speak up about their concerns, adopting scenario-planning and risk-assessment techniques, performing rigorous risk analyses, establishing cross-company alert systems, and building reliable formal, as well as informal, information networks.

The three actionable takeaways from Pickett, Chopra & Sodhi, and Watkins & Bazerman are:

- With modification to Pickett's Risk Registers, we built a Risk Impact Scorecard that allows us to prioritize key elements to search for applicable past data that could help us find the cost of managing supply chain crises.
- Insights given by Chopra & Sodhi provided us with direction to obtain relevant present data that could help pinpoint weaknesses in the current supply chain of a business.
- Recommendations from Watkins & Bazerman suggest the feasibility of utilizing event indicators and signals embedded in organizational documentations and communiqués that could help us detect potential supply chain disruptions.

# 3 Methodology

Information for the case studies presented in Chapter 1 came from comprehensive interviews conducted with six managers involved in managing the supplier-bankruptcy crisis and the natural-disaster disruption at SpecChem. The following departments participated in our study: Purchasing, Quality, Operations, Product Management, Supply Chain, and Business Development. The interviews were structured with both a set of common questions for everyone, intended for us to better understand SpecChem and its general strategies, and a collection of tailored questions for each manager. These interviews were designed to retrieve details of the events in question, obtain thoughts on lessons learned from the events, and get opinions on SpecChem's current supply chain robustness. A list of interview questions asked can be found in Appendix A. By incorporating and distilling different outlooks of the same incidents, we strove to objectively recount the disruptive incidents.

Data for the analyses and results in Chapter 4 consisted of numerical records collected from surveys and extracted from the SpecChem's Enterprise Resource Planning (ERP) systems archive, tracking daily movements over a period of one year for both events, as well as qualitative records compiled using various reports, detailed timelines and schedules, corporate communiqué, SpecChem's internal supplier-auditing measures, Internet research, and available business documentations, starting up to one year prior to the supplier bankruptcy. Information assembled and analyzed in this stage was used to

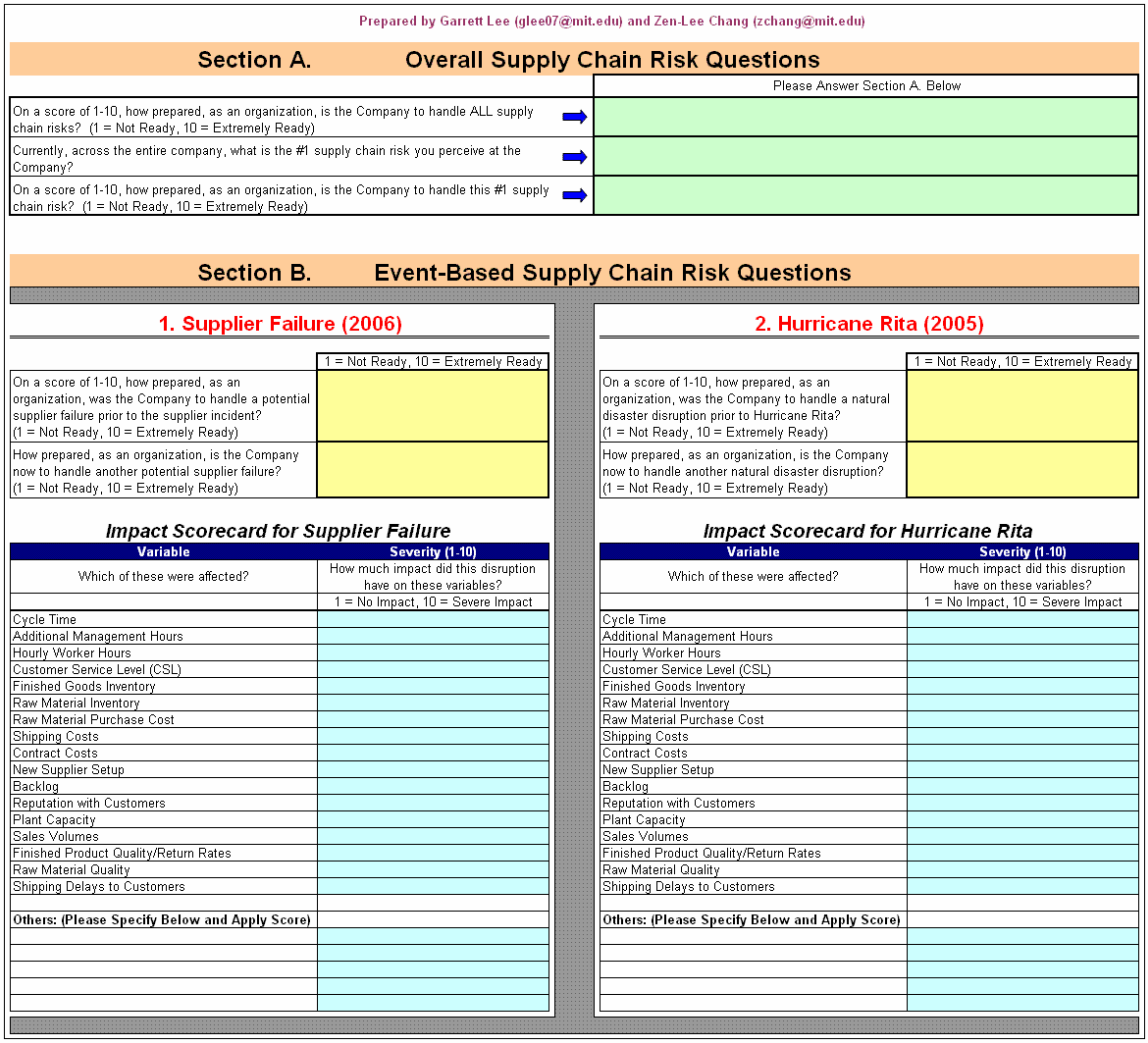
determine the cost of managing supply chain crises, gauge current supply chain vulnerabilities, and appraise potential supply chain risks.

### 3.1 Calculating the Cost of Managing Supply Chain Crises

Using a Risk Impact Scorecard we developed, shown in Figure 3.1, we first surveyed the employees and managers of the six departments mentioned earlier in order to determine the factors that had the most impact on SpecChem's supply chain in both disruptive events.

This scorecard we created presented a number of variables we believe could have been impacted by a supply chain disruption. We then asked managers to rate on a scale of one to ten how severely each variable was impacted by the supplier failure and the natural disaster, with ten being the worst. Once we received scores from all participants, we totaled and averaged the scores. We then deemed any variable with an average score greater than a five as relevant and worth quantifying. After identifying relevant factors, we were then able to request for targeted quantitative data, where available, associated with each factor and put a dollar value on the extra costs SpecChem had incurred when handling supplier failure and natural disaster.

Appendix B shows SpecChem's scoring detail. For instance, Additional Management Hours and Raw Material Inventory both scored more than a five, so we proceeded to estimate the opportunity cost of SpecChem's managers devoting more hours controlling the crises as well as the added cost of ordering and storing extra inventory.



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**Section A. Overall Supply Chain Risk Questions**

| | Please Answer Section A. Below |
|---|---|
| On a score of 1-10, how prepared, as an organization, is the Company to handle ALL supply chain risks? (1 = Not Ready, 10 = Extremely Ready) | |
| Currently, across the entire company, what is the #1 supply chain risk you perceive at the Company? | |
| On a score of 1-10, how prepared, as an organization, is the Company to handle this #1 supply chain risk? (1 = Not Ready, 10 = Extremely Ready) | |

**Section B. Event-Based Supply Chain Risk Questions**

**1. Supplier Failure (2006)**

| | 1 = Not Ready, 10 = Extremely Ready |
|---|---|
| On a score of 1-10, how prepared, as an organization, was the Company to handle a potential supplier failure prior to the supplier incident? (1 = Not Ready, 10 = Extremely Ready) | |
| How prepared, as an organization, is the Company now to handle another potential supplier failure? (1 = Not Ready, 10 = Extremely Ready) | |

***Impact Scorecard for Supplier Failure***

| Variable | Severity (1-10) |
|---|---|
| Which of these were affected? | How much impact did this disruption have on these variables? |
| | 1 = No Impact, 10 = Severe Impact |
| Cycle Time | |
| Additional Management Hours | |
| Hourly Worker Hours | |
| Customer Service Level (CSL) | |
| Finished Goods Inventory | |
| Raw Material Inventory | |
| Raw Material Purchase Cost | |
| Shipping Costs | |
| Contract Costs | |
| New Supplier Setup | |
| Backlog | |
| Reputation with Customers | |
| Plant Capacity | |
| Sales Volumes | |
| Finished Product Quality/Return Rates | |
| Raw Material Quality | |
| Shipping Delays to Customers | |
| | |
| **Others: (Please Specify Below and Apply Score)** | |
| | |
| | |
| | |
| | |
| | |

**2. Hurricane Rita (2005)**

| | 1 = Not Ready, 10 = Extremely Ready |
|---|---|
| On a score of 1-10, how prepared, as an organization, was the Company to handle a natural disaster disruption prior to Hurricane Rita? (1 = Not Ready, 10 = Extremely Ready) | |
| How prepared, as an organization, is the Company now to handle another natural disaster disruption? (1 = Not Ready, 10 = Extremely Ready) | |

***Impact Scorecard for Hurricane Rita***

| Variable | Severity (1-10) |
|---|---|
| Which of these were affected? | How much impact did this disruption have on these variables? |
| | 1 = No Impact, 10 = Severe Impact |
| Cycle Time | |
| Additional Management Hours | |
| Hourly Worker Hours | |
| Customer Service Level (CSL) | |
| Finished Goods Inventory | |
| Raw Material Inventory | |
| Raw Material Purchase Cost | |
| Shipping Costs | |
| Contract Costs | |
| New Supplier Setup | |
| Backlog | |
| Reputation with Customers | |
| Plant Capacity | |
| Sales Volumes | |
| Finished Product Quality/Return Rates | |
| Raw Material Quality | |
| Shipping Delays to Customers | |
| | |
| **Others: (Please Specify Below and Apply Score)** | |
| | |
| | |
| | |
| | |
| | |

**Figure 3.1 Risk Impact Scorecard**

### 3.2 Evaluating Current Supply Chain Vulnerabilities

To investigate SpecChem's current supply chain vulnerabilities of the two chemical products under research, we requested the daily balances of finished goods and raw material inventories. In addition, we noted the number of suppliers and the approximate percentage of raw material each vendor supplied for both compounds before and after the respective crises, as well as the company's supplier qualification procedures.

Using the number of suppliers and the amount of raw material that each provides, we can assess the company's procurement strategy, in case one of the suppliers for a given product is suddenly down and the others need to fill the void in capacity. Moreover, we examined SpecChem's existing supplier-qualification and auditing procedures, and cross-referenced them with our own risk-appraisal framework.

### 3.3 Assessing Potential Supply Chain Risks

We searched various vendor-related documents, comments from our interviews, and new reports, collected up to fifteen months prior to supplier insolvency, and identified information deemed relevant that potentially signals a supplier's poor financial health.

By documenting these event-based markers, or indicators, we were able to create a basic protocol for predicting possible supply chain risks that may eventually lead to disruptions, based on known events and their respective indicators.

# 4 Data, Analyses, and Results

We begin this chapter by identifying the variables most impacted by the supplier bankruptcy and natural disaster events using our Risk Impact Scorecard. Once identified, we quantify these variables to arrive at a total cost of managing the disruptive events. Then, we explore the differences between these two events and assess current vendor-based vulnerabilities within SpecChem's supply chain. We finish this chapter with recommended supplier selection and monitoring practices, plus a discussion on observing event-based indicators that could reduce overall supply chain risks.

## 4.1 Data from Risk Impact Scorecard

We received seven responses for our Risk Impact Scorecard. The seven respondents represented individuals from the six departments mentioned earlier as well as a seventh respondent from SpecChem's Six-Sigma Black Belt program. See the compiled results of our survey in Appendix B for reference.

### 4.1.1 Data for Sole-Supplier Bankruptcy

The survey results reveal that for the supplier bankruptcy disruption, seven variables on a scale of one to ten received average scores higher than a five, suggesting that respondents perceived these seven variables to be most impacted by the supplier failure. The results can be seen in Figure 4.1 below. In descending order by score, those seven critical variables are raw material purchase cost, additional management hours, raw material

quality, raw material inventory, finished product quality/return rates, hourly worker hours, and finished goods inventory.

***Impact Scorecard for Lignin Supplier Failure***

| Variable | Severity (1-10) |
|---|---|
| Which of these were affected? | How much impact did this disruption have on these variables? |
| | 1 = No Impact, 10 = Severe Impact |
| Cycle Time | **3.67** |
| Additional Management Hours | **8.33** |
| Hourly Worker Hours | **5.17** |
| Customer Service Level (CSL) | **3.57** |
| Finished Goods Inventory | **5.00** |
| Raw Material Inventory | **7.57** |
| Raw Material Purchase Cost | **8.43** |
| Contract Costs | **1.80** |
| New Supplier Setup | **4.71** |
| Backlog | **2.33** |
| Reputation with Customers | **2.33** |
| Plant Capacity | **3.17** |
| Sales Volumes | **2.14** |
| Finished Product Quality/Return Rates | **6.29** |
| Raw Material Quality | **8.14** |
| Shipping Delays to Customers | **3.71** |

**Figure 4.1 Results of Impact Scorecard for Lignin Supplier Failure**

### 4.1.2 Data for Hurricane Rita Disruption

The survey results revealed that for the Hurricane Rita incident, five variables received average scores higher than a five. The results are depicted in Figure 4.2 below. In descending order by score, these variables are raw material inventory, additional management hours, finished goods inventory, shipping costs, and shipping delays to customers.

***Impact Scorecard for Hurricane Rita***

| Variable | Severity (1-10) |
|---|---|
| Which of these were affected? | How much impact did this disruption have on these variables? |
| | 1 = No Impact, 10 = Severe Impact |
| Cycle Time | **3.86** |
| Additional Management Hours | **6.67** |
| Hourly Worker Hours | **3.83** |
| Customer Service Level (CSL) | **3.17** |
| Finished Goods Inventory | **6.00** |
| Raw Material Inventory | **7.43** |
| Raw Material Purchase Cost | **2.33** |
| Shipping Costs | **5.57** |
| Contract Costs | **1.80** |
| New Supplier Setup | **1.33** |
| Backlog | **4.14** |
| Reputation with Customers | **2.50** |
| Plant Capacity | **2.33** |
| Sales Volumes | **1.67** |
| Finished Product Quality/Return Rates | **1.33** |
| Raw Material Quality | **1.33** |
| Shipping Delays to Customers | **5.00** |

**Figure 4.2 Results of Impact Scorecard for Hurricane Rita**

## 4.2 Cost of Managing Sole-Supplier Bankruptcy

In this section, we measure the cost of managing the supplier bankruptcy crisis. Specifically, we examine the impact of five of the seven variables deemed pertinent from the results of our Risk Impact Scorecard: raw material purchase cost, additional management hours, raw material inventory, hourly worker hours, and finished goods inventory. We also quantify the cost associated with switching suppliers. Due to lack of information and their qualitative nature, the remaining two relevant variables from the Risk Impact Scorecard results, raw material quality and finished product quality, will not be discussed.

### 4.2.1 Cost of Additional Raw Material Purchased

Figure 4.3 shows how raw material purchase cost varied over the timeframe under study. Monthly purchase costs ranged from $0.06 per unit to $0.10 per unit. The average purchase cost prior to this crisis was $0.07 per unit. The average purchase cost per unit during the time of this crisis was $0.08 per unit, and post-crisis cost per unit was $0.10.

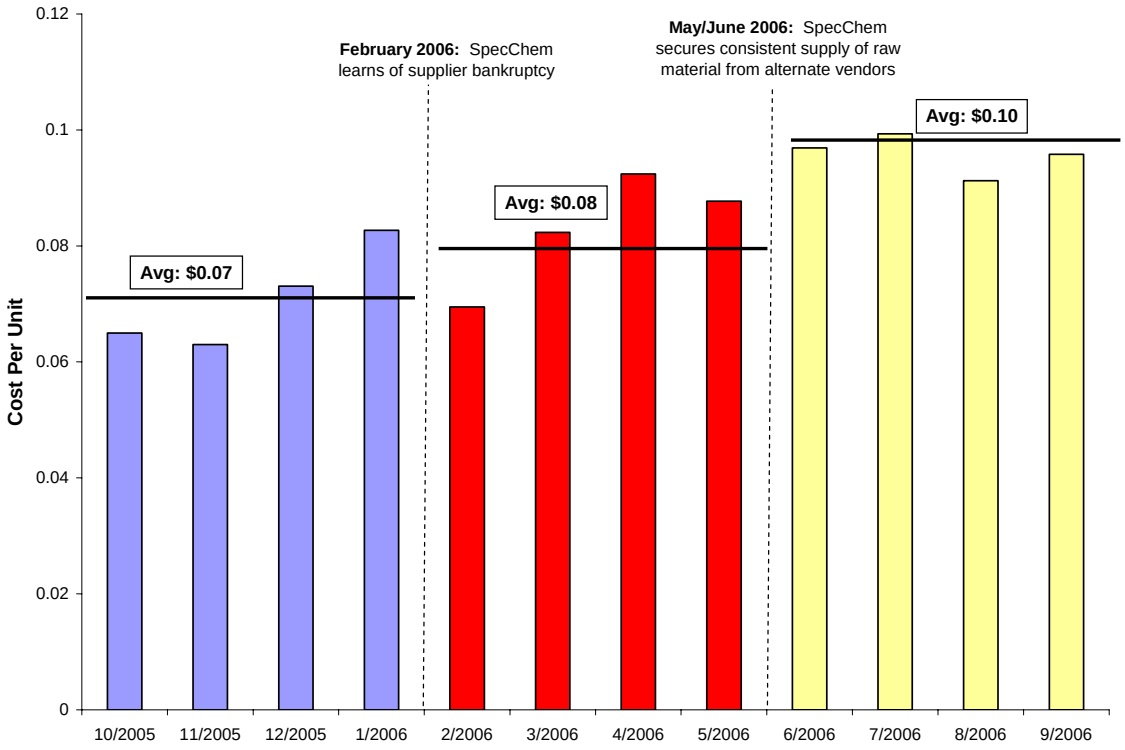


**Figure 4.3 Raw Material Purchase Cost**

SpecChem's moving away from SP and shifting toward other more expensive suppliers for raw material explains this increase in purchase cost. SpecChem's decision to partner exclusively with SP was purely cost-driven, because no other suppliers could compete

with SP's price. After the crisis, raw material costs sharply increased when SpecChem added several higher-priced alternate suppliers to its Lignin vendor list.

Figure 4.4 summarizes the total cost impact as a result of the higher average price of raw material. This figure shows the comparison between SpecChem's total cost of Lignin, had the price remained $0.07 per unit (price per unit of raw material pre-crisis) over the period under research, and the actual total cost of raw material during crisis. As a result of SpecChem's multi-sourcing from alternate suppliers, the raw material costs increased by $279,987.

| Time Period | Units Raw Material | Cost/ Unit | Total Cost | Total Cost @ 0.07 Per Unit | Difference |
|---|---|---|---|---|---|
| Pre-Crisis | 23,649,984 | $0.07 | $1,655,499 | $1,655,499 | $0 |
| Crisis | 27,998,737 | 0.08 | 2,239,899 | 1,959,912 | 279,987 |
| **Total** | **51,648,722** | | **$3,895,398** | **$3,615,411** | **$279,987** |

**Figure 4.4 Total Cost of Raw Material**

### 4.2.2 Cost of Additional Management Hours

The cost of additional management time spent on crisis recovery was estimated based on detailed daily meeting notes recorded by one of the managers during this disruption. These notes include the dates of meetings, topics discussed, duration of the meetings, and meeting attendees. Incorporating the dates and the lengths of meetings, the list of attendees at all of the meetings, and the estimated cost per management hour, we found the total cost of additional management time spent dealing with this crisis to be approximately $150,000.

### 4.2.3 Impact on Raw Material Inventory

The possible shortage of SP's raw material required immediate response from SpecChem's management. Prior to the supplier failure, over 99% of Lignin was sourced from SP, with the remaining 1% served by one other supplier. SpecChem keeps approximately thirty days worth of Lignin supply in inventory, having no formal metrics such as customer service level or item fill rate to determine its inventory levels.

The news of supplier failure was communicated to SpecChem on February 16th, 2006. Figure 4.5 depicts the flow of raw material into the company, corresponding with management's intent to stockpile available Lignin inventory. On February 22nd, 2006, SpecChem received an expedited shipment of 3.1 million pounds of raw material, or roughly 16 times more raw material than normal in a single shipment, from SP. Management at SpecChem placed such a large order of Lignin in an attempt to garner all remaining inventory SP had on hand. SpecChem used this tactic to slow down inventory depletion so that it could locate additional suppliers of this traditionally single-sourced raw material, as well as give new vendors time to ramp up production capabilities and undergo required quality assurance and testing.

Raw material inventories remained high for several months following the failure of SP, with several more spikes in raw material inflow keeping inventory elevated above normal. These additional spikes in inventory level were largely a result of pipeline inventory still being delivered to SpecChem by the defunct SP.

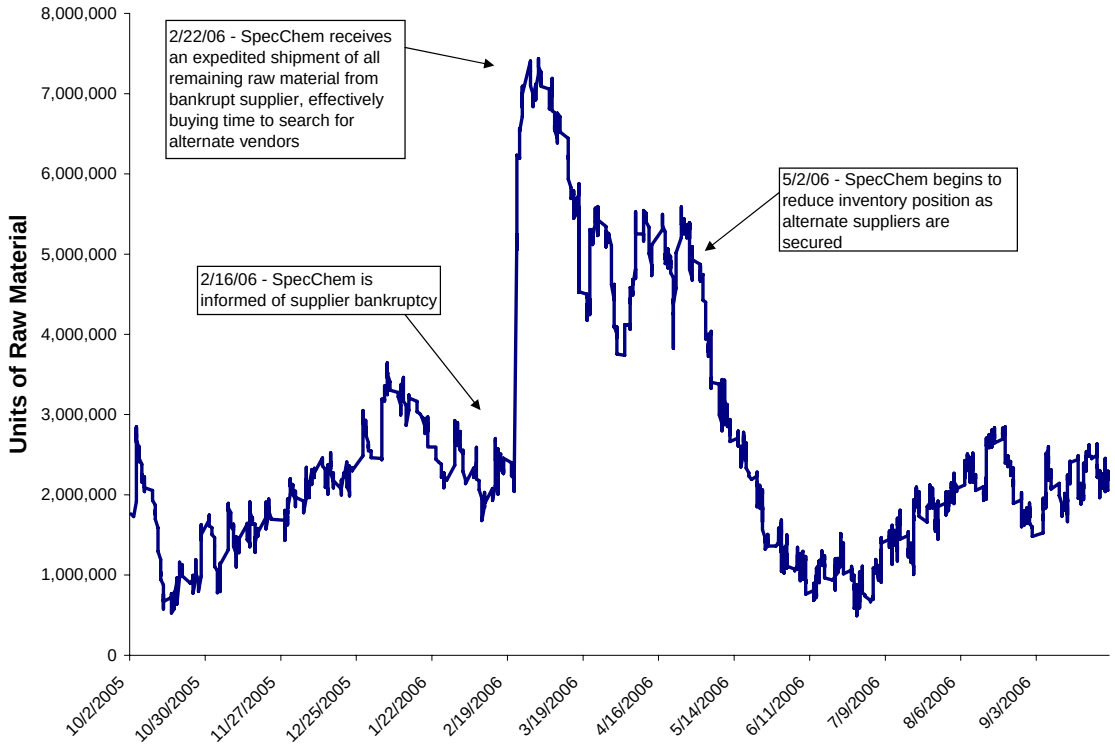


**Figure 4.5 Raw Material Movement**

New sources of raw material were located relatively quickly. TB, a new Lignin supplier, was able to ship raw material within a week. Additionally, SpecChem's previous supplier, BG, who supplied 1% of Lignin, was able to supply SpecChem with more raw material by increasing its capacity. BG was able to channel supply from its current U.S. facility, where it had provided SpecChem with raw material in the past, as well as from a second facility located outside the U.S. However, SpecChem could not immediately convert most of the new suppliers' raw material into saleable finished products, as significant research and development was required to transform the new Lignin into a usable finished product.

Once SpecChem successfully converted the new raw material supplies into stable finished products, the company became more confident that it would be able to source adequate volumes from these suppliers as needed. Therefore, SpecChem in May 2006 began to decrease its raw material inventory position to its previous thirty-day inventory level.

Because SpecChem ramped up its raw material inventory during this crisis, the inventory holding costs increased during this period as well. The average inventory pre-crisis, during crisis, and post-crisis was roughly 2.1 million units, 4.6 million units, and 1.7 million units, respectively. Applying an annual inventory holding cost of 12%, the cost of holding excess inventories was about $100,000 as a result of managing the crisis.

Figure 4.6 illustrates raw material sourcing percentages, by supplier, six months before and six months after the supplier-bankruptcy disaster. As seen in this figure, SpecChem switched from single-sourcing 99% of its Lignin supply prior to the supplier disruption to a more balanced multi-sourcing practice.

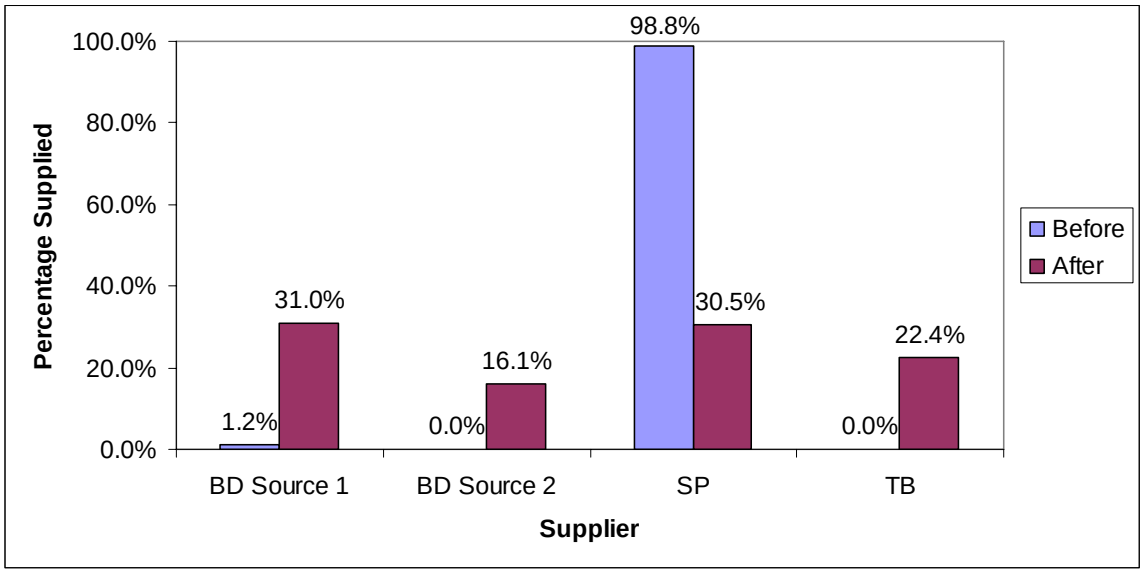


**Figure 4.6 Sourcing Percentages Before and After Supplier Failure**

### 4.2.4 Cost of Additional Hourly Worker Hours

Hourly worker hours were calculated based on management's record of workers' time diverted from normal business operations as well as overtime hours accrued above average business levels. Using this information, it was estimated that the additional hourly worker hours accumulated in this disruption cost SpecChem an extra $30,000.

### 4.2.5 Impact on Finished Goods Inventory

As discussed earlier, SpecChem experienced a significant spike in raw material following the supplier failure. According to our Risk Impact Scorecard survey, managers at SpecChem felt that the supplier bankruptcy would impact finished goods inventories as well. Interestingly, finished goods inventory was actually largely unaffected, as seen in Figure 4.7.

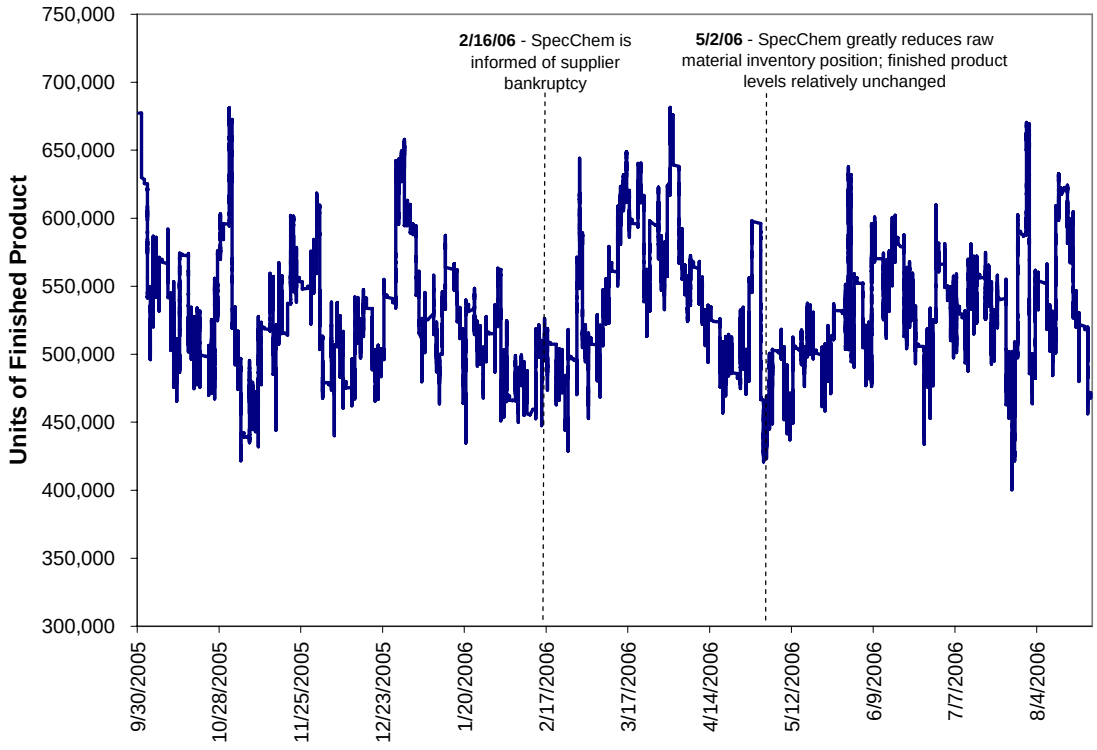


**Figure 4.7 Finished Goods Inventory**

Upon further investigation, this relatively unchanged finished goods inventory position makes logical sense. The disruption only impacted raw material supply. Once raw material supply is secured, hence the spike in raw material inventory, there is no urgency in converting the Lignin into a finished product unless the raw material has a short shelf-life, and it does not. Thus, with the raw material source in hand, the company can produce finished goods using its controlled, normal production schedule, which is what SpecChem followed.

### 4.2.6 Cost of Switching Supplier

The cost of switching suppliers was calculated by taking into account all of the major steps required by SpecChem when setting up new suppliers. These steps include quality assurance and new raw material testing, reformulation, field testing, and other R&D activities. The number of hours spent by R&D to qualify these new suppliers, including the usage of both physical and human resources, translated into a switching cost of $75,000.

### 4.2.7 Total Cost of Managing Sole-Supplier Bankruptcy Crisis

Given the costs described and quantified above, a total cost of managing this crisis can be derived. Figure 4.8 shows that in total, costs increased by $635,000 during the time of this crisis. Interestingly, the Risk Impact Scorecard variables ranked in order of importance by SpecChem's managers were consistent with the variables that were actually impacted by the supplier failure.

| Cost Variable | Amount | Manager Impact Ranking |
|---|---|---|
| Increased Raw Material Costs | $279,987 | 1 |
| Management Hours | 150,000 | 2 |
| Excessive Inventory Holding Costs | 100,000 | 4 |
| Hourly worker Hours | 30,000 | 6 |
| Excessive Finished Goods Inventory | 0 | 7 |
| Supplier Switching Costs | 75,000 | NA |
| | $634,987 | |

**Figure 4.8 Total Cost of Managing the Crisis**

Had a pre-emptive risk-mitigation strategy been in place via multi-sourcing the raw material Lignin, the total cost of such strategy would only have been the cost of switching suppliers and the marginal cost of buying the more expensive raw material, or $354,987. In other words, it cost SpecChem 45% more to have a reactive crisis-management strategy.

## 4.3 Cost of Managing Hurricane Rita Disruption

In section 4.3 and its subsections, we quantify the impact of this natural disaster on raw material inventory, additional management hours, and finished goods inventory. Shipping delays and shipping costs, the two other variables deemed relevant from our Risk Impact Scorecard, are not quantified due to the inaccessibility to such information.

### 4.3.1 Impact on Raw Material Inventory

Figure 4.9 shows the aggregate raw material flow before, during, and after Hurricane Rita. Management at SpecChem never perceived Hurricane Rita's disruption of its suppliers in the Gulf Coast as a crisis. Figure 4.9 seems to support management's perception of this disruptive event. While there was some change in inventory levels, it was nowhere near the same magnitude as that of the supplier bankruptcy incident, both in scale and in time. As it does with Lignin, SpecChem keeps on average thirty days of inventory of the raw material Polycarboxylate. Because SpecChem viewed this supplier downtime as temporary, the company did not see the need to drastically increase raw material inventory.

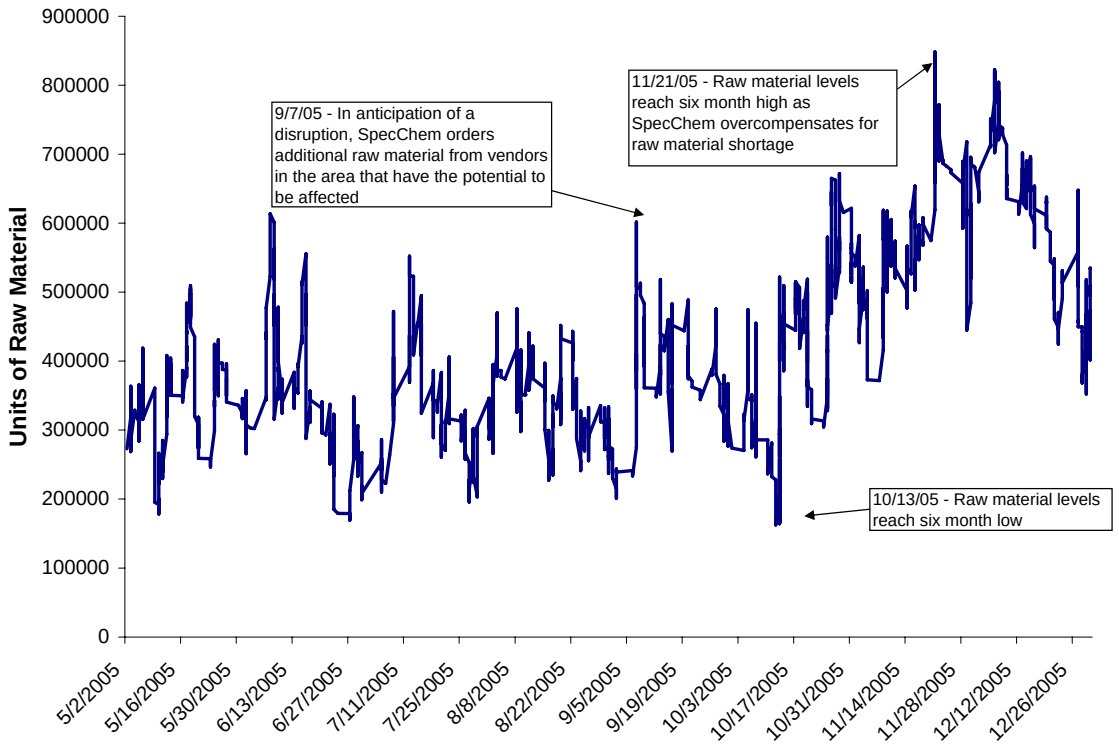


**Figure 4.9 Raw Material Inventory Levels**

Hurricane Rita swept through the Gulf Coast in September 2005. It was not until October that SpecChem began to be concerned about its Polycarboxylate raw material inventory levels. On October 13th, 2005, raw material inventory dropped to its lowest level of the entire year, but then it quickly came back as pipeline inventory arrived and the suppliers became operational once again. In fact, mirroring the classic "bullwhip" phenomena, inventories actually reached an excessive high on November 21st, 2005, prompting management to slow down ordering, bringing the inventory back to its normal level.

Figure 4.10 shows the supplier sourcing percentage breakdowns before, during, and after Hurricane Rita. Polycarboxylate was multi-sourced before this incident, and not a lot

changed in the way SpecChem sourced its raw material immediately after this disruptive incident. The suppliers restarted production after a few weeks, and business was back to normal for SpecChem.

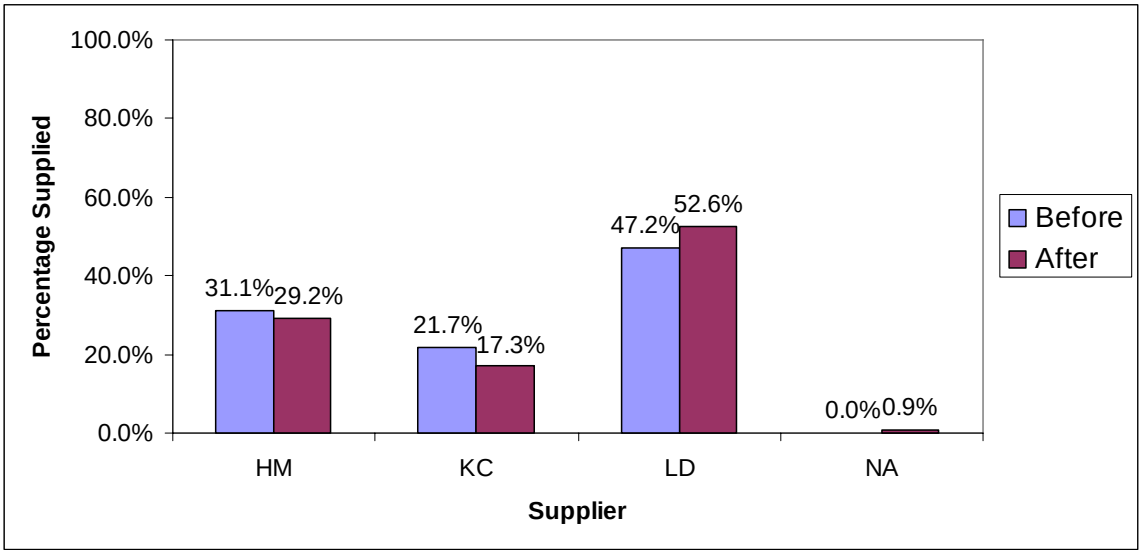


**Figure 4.10 Sourcing Percentages Before and After Disruption**

### 4.3.2 Cost of Additional Management Hours

The cost of management time spent recovering from Hurricane Rita was estimated based on detailed daily meeting notes taken by one of the managers during the disruption. These notes included the dates of meetings, topics discussed, duration of the meetings, and meeting attendees. Using the dates and lengths of meetings, the list of attendees for all meetings, and the estimated cost per management hour, the additional management time spent recovering from this disruptive event cost SpecChem $30,000.

### 4.3.3 Impact on Finished Goods Inventory

Finished goods inventory followed the same pattern as raw material inventory, but without the "bullwhip," with a large dip in mid-October followed by the return to normal levels as the disrupted raw material suppliers came back online. Figure 4.11 illustrates this impact.

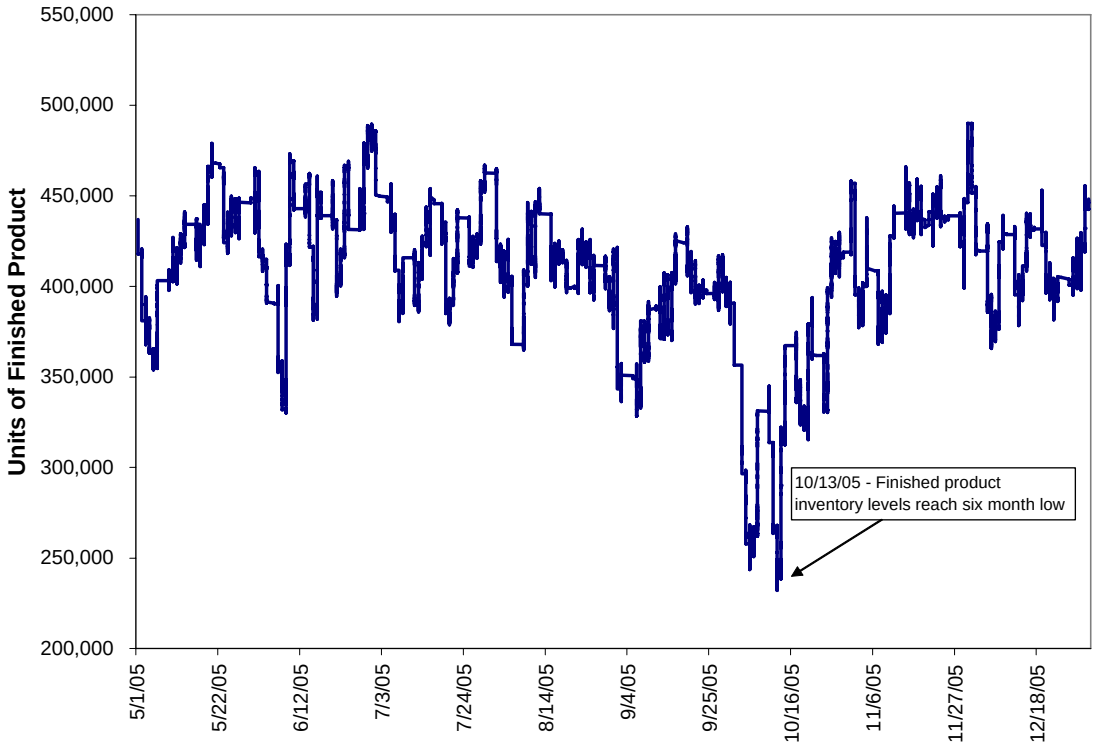


**Figure 4.11 Finished Good Inventory Levels**

### 4.3.4 Total Cost of Recovering from Hurricane Rita Disruption

In total, the cost of managing this supply chain disruption was really only the cost of additional management time spent during this time period, or roughly $30,000. This raw material was already multi-sourced prior to the incident and as a result, the other

suppliers kept the disruption of raw material inflow to a minimum. SpecChem was confident that the suppliers would once more be operational after Rita; thus, minimal resources were further allocated to manage this event.

It may appear that there was no crisis in this instance; however, prior to the suppliers' resuming normal business in October, both raw material and finished product inventory levels had dropped to the lowest of the year, and SpecChem became alarmed at that point. Had the suppliers been down for another month, there was a very good chance that this incident would have reached crisis level. No other existing suppliers would have had the capacity or the required product formula to step in and make up this lost volume, and SpecChem would have had to look for alternative suppliers as it did during the supplier bankruptcy crisis.

### 4.4 Compare and Contrast: Sole-Supplier Bankruptcy vs. Hurricane Rita

Both the supplier bankruptcy and the Hurricane Rita events involved losing suppliers. With no formal risk-management process in place, why was one a crisis and the other one not? In this section, we examine the differences between these two events.

#### 4.4.1 Actions Taken Based on Prior Information

Before SP went bankrupt, there were warning signs that hinted a potential problem, but SpecChem did not act on the information. When Hurricane Rita was approaching, SpecChem saw the warning signal of an impending disaster and used this information to better prepare the company for the disruption by coordinating specific action plans and

alerting suppliers and customers in advance. Recognizing and acting on warning signs made a difference in the way these two events were handled, as seen clearly from the respective impacts.

### 4.4.2 Length of Downtime

While managers at SpecChem claimed that they did not view the Hurricane Rita disruption as a crisis, as mentioned earlier, they did agree that had the effects of Hurricane Rita caused their suppliers to shut down indefinitely, they would have had a crisis on their hands. This demonstrates that the length of downtime was a key factor in why supplier bankruptcy (indefinite downtime) was a crisis and Hurricane Rita (finite downtime) was not.

### 4.4.3 Sourcing Strategy Prior to Disruptive Events

When SP declared bankruptcy, it was essentially the sole source of raw material for SpecChem. When Hurricane Rita hit and closed operations of SpecChem's suppliers in the Houston area, SpecChem still had one other supplier that could support the flow of raw material. Had SpecChem been sole-sourcing Polycarboxylate as it had been with Lignin, the severity of Hurricane Rita's impact would have been greater.

## 4.5 Current Supply Chain Vulnerabilities

We revisited the two distinct product families examined in the case studies above to assess how vulnerable SpecChem's supply chain currently is to similar disruptions, should another one occur in the future.

Lignin was particularly vulnerable when the crisis occurred because of SpecChem's decision to single-source, and we saw the shift to a multi-sourcing strategy post crisis. Has SpecChem continued with this multi-sourcing strategy? Figure 4.12 shows the comparison of the percentage breakdowns between raw material sourcing in the six months following the crisis and raw material sourcing during the first quarter of 2007. With the exception of reversing the percentages sourced locally versus internationally from the same supplier, SpecChem continues to order in relatively the same percentages from its suppliers as it did immediately following the supplier bankruptcy. We should note that SP reemerged from bankruptcy in August 2006, and SpecChem once again uses it as a supplier. However, learning from the past crisis, SpecChem has not gone back to single-sourcing all of its Lignin volume from this lower-priced vendor.

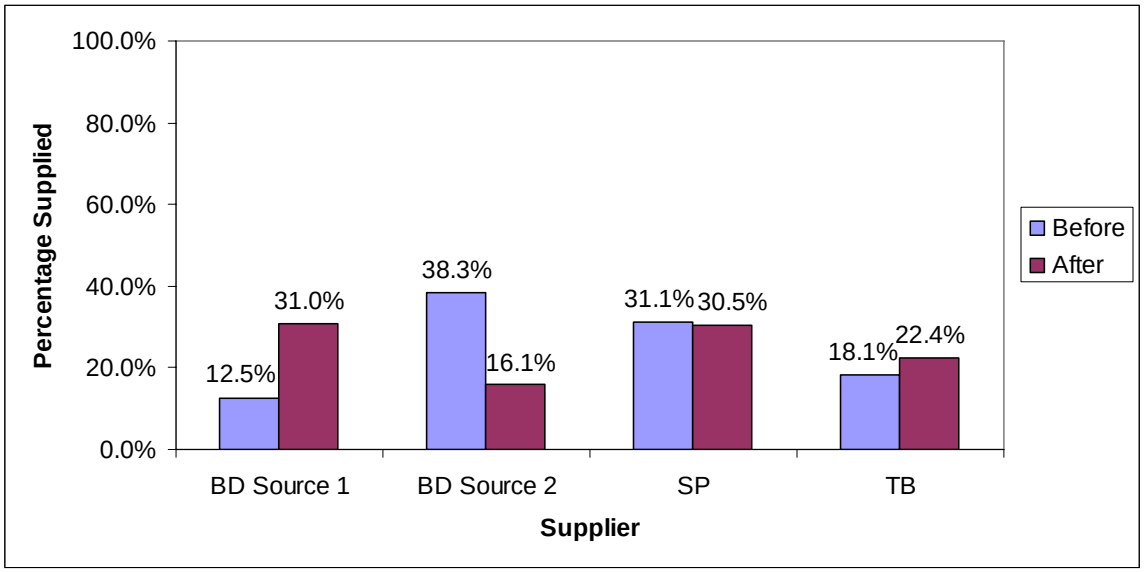


**Figure 4.12 Sourcing Immediately After Crisis vs. Current 2007 Sourcing**

Based on this information, SpecChem is engaged in multi-sourcing Lignin in order to significantly mitigate the impact of another potential disruption. While it is true that the negative impact of a supplier failure right now would probably be diminished, crisis is not necessarily averted merely because of this new multi-sourcing strategy.

A crisis could be averted only if the following were true:

- The other two SpecChem suppliers have enough combined excess capacity to fill the raw material void that the failed supplier had left behind.
- The alternate suppliers can produce this extra raw material in a timely fashion with minimal delay.
- This additional raw material can be purchased without an excessive premium added to the current price.

All three of these conditions must be met in order for this to be a true risk-mitigation strategy. Based on our discussions with SpecChem, these conditions do not necessarily hold. SP has proven in the past that it has the capacity to provide SpecChem with enough raw material to supply the entire product line. Yet, of all the suppliers that may be risky, SP's history would place it as the most likely candidate to fail. Indeed, this is the reason that SpecChem has not returned to sole-sourcing. SpecChem may be able to secure enough Lignin should one of the other two suppliers, other than SP, go down, but it is unclear whether the other two suppliers would be able to make up for the loss in capacity should SP go out of business again. Nonetheless, it seems that while SpecChem is still

vulnerable, the company is in a better position now with multiple suppliers than it was prior to SP's bankruptcy.

When examining the current raw material sourcing strategy for the product family related to Hurricane Rita, we noticed that a slight shift in strategy has taken place. Figure 4.13 shows the comparison of the sourcing percentages for raw material pre- and post-disruption through March 2007.

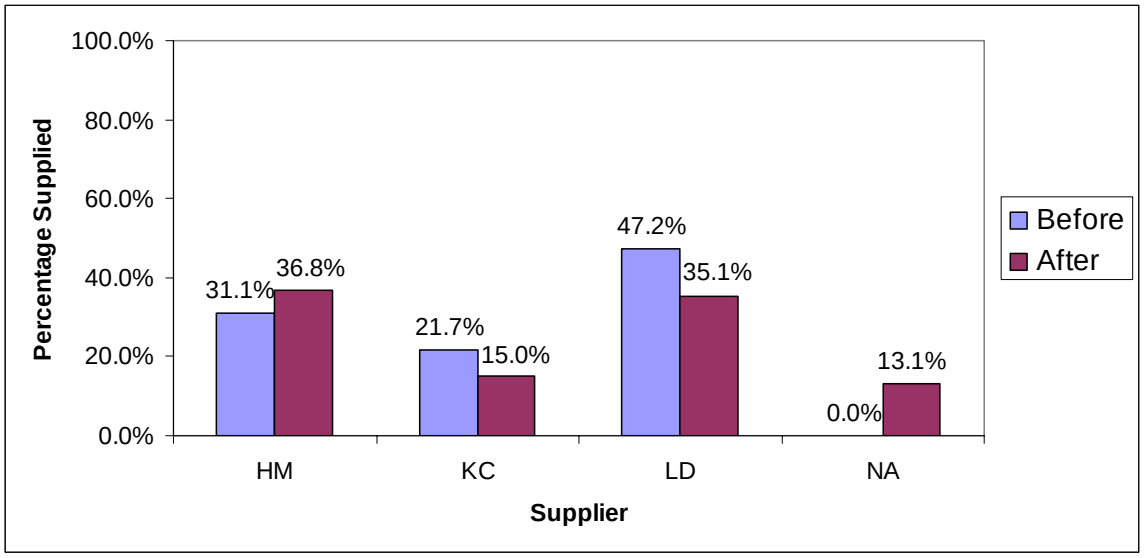


**Figure 4.13 Sourcing Pre- and Post-Disruption**

Since the disruption, SpecChem has added an additional supplier, NA, who has since shouldered a significant portion of raw material inventory for the overall product family. Similar to the Lignin example earlier, whether or not this new strategy reduces overall vulnerability depends largely on the ability of other suppliers to fulfill required capacity

should one supplier go down. But again, vulnerable or not, SpecChem appears to be in a better position when compared with its situation prior to the Rita disruption.

### 4.6 Supplier Evaluation Procedures

Another important task that could help manage risks is to ensure the quality of a company's suppliers. Currently, there is no formal protocol at SpecChem for selecting its suppliers. Moreover, the method for monitoring the suppliers' performance, product quality, and financial health has also been exercised on an ad hoc basis.

Incidentally, the quality of potential as well as existing suppliers is measured differently by case, posing a high risk of disruption in the supply-side of the chain, as no unified rules are in place to set the bar and/or provide the Purchasing Manager at SpecChem with a succinct way to compare and contrast his options and decisions. Ultimately, the decision could be cost-driven rather than value-driven, when the urge to save money in the short-run overrides the objective to benefit the company in the long-term. We shall examine several supplier-evaluation procedures used at SpecChem below. We also emphasize that SpecChem's supplier evaluation process is not consistent, as each of the steps presented in this thesis may not always be applied in qualifying every supplier.

#### 4.6.1 Supplier Selection Process

When evaluating a potential supplier, managers from SpecChem's Purchasing, Quality, and Operations departments usually work together to qualify the supplier's product, making sure that it meets SpecChem's specifications.

When a new supplier is required, the Purchasing Manager typically relies on a chemical directory that lists available producers of a specific product in need, followed by request for information from promising vendor(s). An initial screening tool, comprised of matching product specifications using datasheet, observing suppliers' compliance with governing laws, surveying suppliers' available capacity, and analyzing suppliers' company health using reports such as Dun and Bradstreet, is generally deployed to pare the number of potentials. Geographical location is also considered, as the Purchasing Manager prefers local suppliers for commodity raw materials, whereas product availability dominates the decision process for specialty raw materials, which often require joint development between SpecChem and its vendors. SpecChem then engages those selected in a request for proposal, which is subject to verification through on-site visits, quality audits, and supply chain interviews, further narrowing down candidates.

Next, the Quality Department collaborates with R&D to test material samples obtained from the remaining supplier candidates. Based on test results and product performance, Operations and Product Management evaluates the candidates' technical abilities and willingness to provide support before sending back their approval. Finally, all the managers make the decision to award business based on the recommendations, costs, and the outcomes of negotiation with different prospects. Trade-offs between quality and price are sometimes made given the variability in market conditions. In many cases, there are no contracts involved. Instead, SpecChem adopts a level of commitment from the suppliers, who gets paid according to preset raw material quantities, even when

demand for SpecChem's products falls, requiring less of the raw material. A supplier selection process could sometimes take up to two years to complete.

### 4.6.2 Supplier Monitoring Process

Continuous monitoring of supplier performance at SpecChem is fairly passive, and is normally observed only when severe quality issues arise, even though the Quality Manager conducts occasional supplier-quality audits. The postmortem analysis is frequently incomplete after recovering from a crisis.

To maintain vendor-customer relationship, the Purchasing Manager arranges phone calls with general, readily replaceable vendors every month, and once a week with suppliers critical to SpecChem's operation. He also tries to organize face-to-face meetings with those critical suppliers about once per quarter. Teleconference summaries and trip reports are submitted after each engagement, as well as stored in the company archive. Furthermore, the Purchasing Manager periodically visits the suppliers' plants, gathers information about his vendors, and references documentations written about the suppliers to monitor their financial health. However, a supplier's business situation, along with its strategic and financial conditions, is often not well-understood.

The Operations Manager keeps in touch with the suppliers by sharing SpecChem's forecast information, and works with the vendors to prepare for demand fluctuations as well as supply issues. Vertical integration of key suppliers have been contemplated by upper management in the past; however, the notion is often dismissed, as there is a

considerable amount of know-hows behind each chemical technology and capital investment required that prevented SpecChem from moving forward.

### 4.6.3 Benefit of a Standardized Supplier Evaluation Protocol

One detail worth noting here is that SpecChem has had a standard Supplier Scorecard for evaluating its suppliers. The Supplier Scorecard provided the managers with a checklist of action items for selecting and monitoring suppliers. However, the protocol was ultimately abandoned years ago for no satisfactory explanation.

The advantage of having a supplier evaluation protocol is that selecting and monitoring procedures are standardized, controlled, and systematically organized, eliminating discrepancies and variations created by unequal or ad hoc practices. SpecChem's evaluation methods, listed in sequence in the above subsections, are in fact sound and reasonable, involving interdepartmental efforts to ensure continuous supplier quality. Nonetheless, the current process is not readily repeatable, as evaluating managers may forget or intentionally skip steps under different circumstances, such as giving preferential treatment to existing suppliers. Therefore, SpecChem should reinstate and enhance the Supplier Scorecard to provide managers with clearly detailed instructions on how to select and monitor suppliers and exactly what to do, resulting in tighter decision control measures and eliminating unexpected process errors. In addition, a protocol that constantly monitors raw material quality and supplier financial health could help SpecChem prepare for and/or prevent impending disruptions with warning signals.

After the Lignin crisis, SpecChem now prefers Lignin suppliers with redundant capacities that can ramp up production in case another source becomes unavailable. SpecChem also resists the inclination to allow the lowest-cost supplier to undercut others and become its dominant source for raw materials, even if the company's new-found persistence were more expensive. These crises have brought employees closer together, as departments shared resources and broke out of the organizational silos to work toward a common cause.

### 4.7 Indicators of Supply Chain Disruption

Before Hurricane Rita forced two main Polycarboxylate suppliers, HM and LD, in the Gulf Coast into emergency shutdown, managers at SpecChem vigilantly tracked the storm's progress, and had two weeks to request an increase in production from both suppliers in order to stockpile raw material inventory. The devastation caused by Hurricane Katrina merely a month prior impelled SpecChem to become well-prepared for a possible disruption in its supply chain. Nevertheless, SpecChem realized that unless Rita permanently shuts down both suppliers, an unlikely scenario since the plants were designed to withstand inclement Gulf Coast weather, it would only be a matter of time before production resumes.

In the instance of Hurricane Rita, live weather updates alerted SpecChem in advance, serving as a warning signal for the company to seek alternatives and launch countermeasures. This is in contrast with the Lignin supplier bankruptcy, where the sole supplier could have been down indefinitely. In the latter example, with no way of

knowing when the supply would become available again, were there any observable signs, or indicators, that could have alarmed SpecChem to get ready for the disruption? If so, where could SpecChem's managers acquire those indicators?

Supplier's financial reports, public records, Dun and Bradstreet for private firms, Moody's Industry Review, Standard & Poor's, trip reports from on-site visits, internal communiqués pertaining to the supplier, relevant meeting summaries, and news about the supplier are all excellent literary sources for learning about a supplier and/or monitoring a supplier's overall health. Indicators such as management change, workforce reduction, impasse with union representatives, closing of plants, prolonged financial losses, etc. represent alerts that are worth probing and paying attention to when evaluating a supplier.

In search of warning signs that led to SP's insolvency, we scanned documents, journals, and news reports, and eventually found a local newspaper of SP's home city that has a comprehensive archive on-line, complete with an interactive message board and a section for community voices. Since SP is a major employer in that area, it is often the center of attention of that local paper. We began our investigation of the company's state of affairs fifteen months before SpecChem was notified of SP's bankruptcy, examining archived editorials and community columns starting in December 2005. SpecChem's Purchasing Manager also provided some behaviors about SP that had roused his suspicion, which was noted in his trip report, of the supplier's financial instability and its potential inability to stay in business.

Below is a sample chronological compilation of indicators, reiterated using a mix of paraphrased passages and direct quotes from the local newspaper and the Purchasing Manager, that could have prompted SpecChem to prepare for potential disruptions in raw material supply. The events go beyond SP's bankruptcy to demonstrate how SpecChem could continue monitoring these indicators to further gauge severity and adapt its strategy. For a list of additional supply chain disruption indicators, see Appendix C.

*December 26, 2004, Community Voice*

"In recent months, [SP] has continually cut the hours of their employees. Some are only working 16 hours in a week. So now in order to atone for their thoughtlessness, they decided to schedule us to work Christmas Eve. It is wonderful working for a family-oriented business."

- Potential-Disruption Indicators
  - Company continually reducing employee work hours
  - Some employees working only 16 hours per week
  - Company scheduling make-up hours during Christmas holidays
  - Sarcastic remark showing employee's discontent

*March 17, 2005, Editorial Column*

"[SP] announced three operations appointments at [the city's] manufacturing center and headquarters on Wednesday."

New operations appointments at SP: Vice President of Manufacturing, Vice President of Production Control/Planning and Logistics, and Operations Manager.

- ❖ Potential-Disruption Indicator
  - o Changes in top-management positions at key sites

*April 1, 2005, Community Voice*

"[T]here are many men and women that did take pay cuts at [SP]."

- ❖ Potential-Disruption Indicator
  - o Company mitigating financial difficulty by reducing worker wages

*January 16, 2006, Editorial Column*

"The man injured in an industrial accident at [SP] Sunday morning remains in critical condition, a company spokeswoman said Monday afternoon."

"According to the [local fire department], which also refused to identify the man, emergency workers found him just before 8:30 a.m. Sunday morning at the finishing end of the paper manufacturing line with his arm and chest stuck in the rollers."

- ❖ Potential-Disruption Indicators
  - o Unsafe work environment resulting in a serious accident
  - o Plant could be shutting down for investigation and repair

- Raw material delivery could be delayed

*February 2, 2006, SpecChem Purchasing Manager's Trip Report*

SP has requested for a dramatic increase in raw material price to cover its rising costs. The supplier also indicated that it would be cheaper for SP to buy raw material from its competitors and sell to SpecChem than to produce the material itself, hinting sustainability issues. Additionally, SP had some unresolved matters with the worker's union.

- Potential-Disruption Indicators
  - Company not doing well financially, losing margins due to high costs
  - Competitors performing better than sole supplier at a lower cost
  - Company having disputes with the union

*March 19, 2006, Editorial Column*

"[SP] has announced it is closing a Wisconsin mill and implementing a strategy to focus on manufacturing [locally]."

"The company cited the high costs of energy, wood fiber, transportation and logistics."

- Potential-Disruption Indicators
  - Company shutting down an unprofitable mill
  - Company acknowledging high operating costs

*March 22, 2006, Editorial Column*

"[SP], one of the city's largest employers, filed for bankruptcy in Delaware Tuesday seeking shelter from between $50 million and $100 million in debt as the company reorganizes. The filing follows an announcement over the weekend that [SP] would be discontinuing operations at its [Wisconsin] pulp and paper facilities just more than a year after purchasing the mills from a Canadian company."

- ❖ Potential-Disruption Indicators
  - o Company declaring bankruptcy
  - o Company losing production capacity by closing manufacturing plant

*March 22, 2006, Editorial Column*

"It's a surprise. We knew that they had run into problems, and we were waiting to see what the outcome would be. There is some concern. There always is when a company files for Chapter 11. But this could also mean that the company is willing to work through this financial adversity."

- ❖ Potential-Disruption Indicator
  - o Community recognizing company's financial trouble before bankruptcy

*April 28, 2006, Editorial Column*

"[SP] has asked a U.S. Bankruptcy Court judge to allow it to pay an unusually high rate of medical insurance claims dating back before the company filed for Chapter 11 reorganization."

- Potential-Disruption Indicator
  - High cost of employee benefits plagued the company prior to bankruptcy

*May 2, 2006, Community Voice*

"I AM TIRED of paying the gas and electric bills and for the clean-up for places like [the local steel mill] and [SP]. Let them move out of town. Who needs them? Their employees have bragged for years about all the money they've made. Now they can get a job at Wal-Mart like the rest of us. Down with the unions."

- Potential-Disruption Indicators
  - Community exhibited outrage for paying the company's utility bills
  - Community showed contempt toward the company's employees and union
  - Community gloated in the company's downfall
  - With diminished local support, the company may have difficulty tapping into qualified local workforce in the future

*June 21, 2006, Editorial Column*

"[SP] purchased the [Wisconsin] pulp and paper mill from [company FP] in February 2005. According to court documents filed this week with the [potential buyer's] purchase agreement, problems with the Wisconsin operation largely led to [SP] filing for Chapter 11 bankruptcy in March."

- Potential-Disruption Indicators
  - Signs of company's financial troubles could have been traced back to the acquisition of new mill
  - Source of financial burden identified and confirmed

*August 19, 2006, Editorial Column*

"Officials in [SP's home city], which operates its own waste water utility, noticed cash flow changes at the paper mill earlier this year, [Deputy City Manager] said.

"'We were experiencing late payments from [SP] in the first quarter of the year,' [Deputy City Manager] said. 'During that first quarter we made the conscious decision, based upon our fears that there could be something wrong, to fill those positions pending what happens with [SP] because it could be a big hit to the general fund if they don't make it.'

"Since filing for chapter 11 bankruptcy in March, [SP] has made good on its utility payments. However, the company still owes the city $266,033 plus $40,000 in late charges for overdue waste water bills from the first quarter, [Deputy City Manager] said."

- ❖ Potential-Disruption Indicators
    - o City officials noticed that the company struggled financially before declaring insolvency
    - o Company was late on utility payments
    - o Company continues to owe utility charges and overdue penalties, suggesting financial instability

*October 18, 2006, Editorial Column*

"[SP] has a new owner, but employees at the bankrupt plant are still worried about the company's future. 'They haven't told us much,' said [a] machine operator [at SP's mill]. 'There is a lot of concern whether we'll still be here.'

"Among those were technology and customer service problems, rapidly input costs while low-end uncoated paper prices were going down, and a clash over trading terms with raw materials suppliers."

- ❖ Potential-Disruption Indicators
    - o No clear communications from upper management at the company, keeping workers in the dark with speculations that may lead to unfavorable rumors
    - o Company experiences service issues, cost increases, and supplier disputes

*November 28, 2006, Editorial Column*

"A fire was reported at [SP] Monday night. The fire broke out about 7:50 p.m. at [SP's No. 2 Mill], dispatchers said."

- Potential-Disruption Indicator
  - A disaster at the plant could indicate disruption of production and delay in supply
  - The mill could have been sabotaged by employees

As seen above, SpecChem could have benefited by periodically monitoring its suppliers, assessing its potential supply chain risks and planning preventive measures accordingly. The indicators specified after their respective passages can provide the managers with another powerful tool to determine the precautionary steps necessary to circumvent possible disruptions. By digesting these warning signs collected over time into a coherent summary, managers can present clear, substantiating evidence in a logical and compelling manner that warrants executive management's attention, aiding executives in constructing a sound response.

Although we concentrated on exploring the tell-tale signs of poor supplier financial health, the same technique is flexible enough to be applied to other event-based supply chain disruptions. As the Hurricane Rita example illustrated, supply chain disruptions threatened by natural disasters could be observed and alleviated by paying attention to weather reports and surveying supplier plants' structural integrity. To guard against

disruptions caused by accidents, a company could examine its suppliers' histories, and periodically audit manufacturing sites as well as accident records; to prepare for disruptions caused by strikes, a company could learn about the relationships between the suppliers and their unions, plus scan news reports and even message boards to identify possible tensions and record grievances filed. These are just several tactics that can be used to assess supply chain dangers, and prevent or mitigate potential disasters using event-based disruption indicators.

# 5 Conclusion

In examining the events surrounding the bankruptcy of SP, we showed that managing a crisis cost SpecChem 45% more than managing a risk. The difference amounted to nearly $300,000 over a four-month period, a significant figure that warrants managerial attention. Moreover, since $60 million in revenues were at risk, the gravity of the situation was clearer: the cost of managing a crisis is high. Risk management, albeit not free, makes economic sense.

Applying risk-management practices correctly is extremely difficult. Based on our research, it is a sound idea to have multiple suppliers for any given raw material. SP's bankruptcy was seen as a crisis because the raw material was sole-sourced, while Hurricane Rita was not because the raw material was multi-sourced.

But even if a company were to sole-source a raw material, there is still a way to mitigate some of the risks. A company that decides to single-source should make sure that it has a deep relationship with this supplier. Frequently checking-in with the supplier, scanning local news, scanning reports such as Dun and Bradstreet are all examples of ways to monitor the health of a supplier. However, monitoring alone is not enough. Managers must heed the warning indicators and take actions to prevent potential disruptions. It is also important to note that while the risk of single-sourcing can be mitigated by supplier intimacy, a company that both multi-sources and has deep relationships with all of its suppliers has effectively strengthened its risk-management position.

Another differentiating factor between the supplier bankruptcy and Hurricane Rita was the length of downtime. While a company may not be able to control the length of a supplier's downtime, it can control its impact. In conjunction with multi-sourcing, selecting suppliers with the ability to ramp up production in a short timeframe can lessen the impact of supplier downtime. If one supplier becomes unavailable and a second can fill the gap right away, crisis is averted.

It is easy to point out the flaws in a policy, a strategy, and the decisions made postmortem, because hindsight is always twenty-twenty. In this thesis, we provided our insights on how preventive measures could lessen the likelihood of similar future disruptions, at a fraction of the cost of managing the crises later. A good company learns from its past mistakes and changes for the better. An excellent company cleverly learns from other companies' oversights and takes precautionary steps to avoid those same mistakes.

SpecChem has gotten smarter and has evolved. The company has decided to continue multi-sourcing both Lignin and Polycarboxylate. Can SpecChem do more? We believe so. The managers at SpecChem seem to agree as well. In our Risk Impact Scorecard, we asked managers on a scale of one to ten how prepared they felt the company was prior to the supplier bankruptcy event and how prepared they feel they are now to handle similar events (1 = not prepared, 10 = completely prepared). The average score was 3.29 before

the disruption and 4.14 after the disruption, a positive change that nonetheless has ample room for improvement.

SpecChem has gotten smarter in its sourcing decisions of the raw materials that were impacted by these events, but it is not clear though that this risk-mitigation strategy has been generalized across all product families. In fact, SpecChem had a major quality issue in early 2007 with one of its other products that uses a sole-sourced raw material. Needless to say, crisis management ensued.

Unfortunately, most companies do not readily change in the absence of a crisis. Mueller-Lehmkuhl, a West Germany producer of apparel fasteners, examined its costs only after losing customers to a Japanese competitor, who was able to undercut Mueller's prices by 20%. Lacoste, a French apparel company, made a long-run positioning and branding error but did not do anything about it until it was faced with rapidly declining profits that forced it to reexamine its marketing and distribution strategy in the late 1990's.

When not faced with an impending crisis, most companies just stay put, even if there were warning signals. Mueller-Lehmkuhl may have seen their competitor's prices but until it started losing customers, the firm did not see a reason for change. Lacoste may have ignored the gradual erosion of its premium-brand image until the company was faced with falling profits and impending insolvency. These examples are no different from the story of SpecChem, the chemical company examined in this thesis that chose to use a sole supplier for a critical raw material because it was 20% cheaper to do so. If

there were no crisis, what is the problem? Can a purchasing manager really rationalize and communicate to his/her boss why he/she had turned down a 20% discount to prepare for an event that may or may not take place?

How do companies get out of this complacent and reactionary mindset and build a system of staying one step ahead of a crisis? The change must be top-driven. Reward systems need to be in place to encourage risk-mitigation initiatives and practices. A manager whose bonus/reward system is tied largely to reducing costs is going to elect to sole-source from a supplier whose price is 20% cheaper than the competition's price. It is a rational choice for that manager, given the incentive structure in place. Until it becomes board-driven and directed, risk-management practice will be ad-hoc at best.

Supply chain risk management, up to a certain level, can be cost effective, as quantified in our thesis, but it is not costless. Having intimate relationships with multiple suppliers is more time consuming and costly than having an intimate relationship with only one supplier. Likewise, the cost of adding or switching vendors to mitigate supplier risks is not cheap. Choosing the right level of risk management in place involves a cost-benefit trade-off, and where a company is on the risk spectrum depends largely on an individual firm's risk appetite, but crisis management should never replace risk management. If applied properly, risk management can not only save a company a lot of money, but also make the difference in a company's ability to survive.

# 6 Recommendations for Future Research

As supply chains become more complex and interdependent, organizations face ever-increasing risks. This thesis has provided a framework, from which management can reference, to find the additional costs incurred from managing a vendor-related disruption, analyze current sourcing strategy strengths and weaknesses, anticipate future vendor risks, and refine the results into conveyable strategies. But, there are many more areas in supply chain risk that we feel deserve further and more in-depth analysis. We have summarized below our suggestions for future research.

*Risk-Communication Protocol*

Risk communication is mentioned in our thesis, but it really is deserving of further analysis. How can a company successfully implement a risk-communication protocol that places emphasis on transparency to better prevent future disasters and minimize response time?

*Team Synergy*

As employees depart through career change, attrition, or retirement, their knowledge and experience in battling previous supply chain disruptions, if not well-documented, usually leave with them. Furthermore, team synergy developed in the past could very well vanish when the next group of colleagues gathers to manage risks or crises. How can a company successfully ensure that knowledge stays with a company even when some of its people leave?

*Supplier Contracts*

Instead of relying on a supplier's level of commitment for production capacity, a company should collaborate with its supplier to draft a flexible contract that strives for a win-win situation. In addition to the usual terms and agreements, a contract should include contingency plans in case of a supply chain emergency, clearly delineating each party's operational as well as financial responsibilities. For example, a dynamic contract could define the monetary accountability of each partner in the event of a disaster, supplier switching procedure and alternative options in case of supply interruption, and rewards from cost-saving initiatives and penalties for discretionary expenses incurred. Unless a supplier goes out of business and its customers must find other ways to compensate for the disruption, in-depth research specifically pertaining to supplier contracts is another avenue that further studies could explore.

*Vendor Relationship*

Establishing a long-term relationship with vendors is crucial in achieving non-zero-sum game, maximizing profitability for all partners in a supply chain. Deep customer-vendor relationship is especially important when a firm only has one or two suppliers of a critical component. In any case, a company can gain a competitive advantage by building tighter relationships with its suppliers and viewing them as business partners. How can companies effectively build and maintain these mutually beneficial relationships?

*Vendor Locations*

Selecting suppliers that are dispersed geographically or choosing a supplier that owns multiple manufacturing sites in different regions that are far apart could also help minimize the chance of a total supply disruption, as capacity can be promptly shifted to other plants to avoid material shortage. How should a company optimally configure its vendor networks?

*Communication Metrics*

Solid risk-communication practice requires immense discipline, and has to be top-driven by management; otherwise, any initiative would be difficult to implement due to lack of employee buy-ins. With strong management support, a communication metrics can promote change-management.

However, there are inherent risks within communication that management has to heed and overcome; therefore, these risks should also be addressed:

- Risk homeostasis – employees may become too comfortable with a situation and take a certainty for granted: as people rely more heavily on technology to communicate risks, knowing that messages can be conveyed instantaneously, employees may lose initiative to take charge even after observing the tell-tale signs of disruption.
- Cry-wolf syndrome – an overactive communication channel may cause the employees to ignore important risk information. What level of risk

communication is the right amount? How should employees be trained to determine what is critical or pertinent in case of information overflow?

- Corporate culture – how could the importance of risk prevention be imbedded as part of corporate DNA so that synergy and responsiveness still exist even when members of previously-involved crisis team had left the company?

*Non-Vendor Supply Chain Risks*

This thesis explores the risks a company faces when selecting and sourcing from vendors. There are many other areas within a supply chain that can pose risks, including customers facing supply chain risks, transportation risks, and risks posed by a sourcing strategy of a supplier's suppliers.

*Logistical Regression Analysis*

Based on data gathering and quantitative analysis, future risk-management researchers could find a logistical regression equation that determines a product's risk level using key contributing factors, and ultimately integrate it into a comprehensive risk metrics. The risk level can be approximated by assigning a score, a probability, or a monetary value. To maintain objectivity, this research requires an extensive, pre-determined set of data for a given disruptive event that has happened many times over the years within a company, or a similar set of data collected across a sizable number of firms in an industry for the same disruption. Researchers can reference risk-evaluation methodologies used by credit card companies to compute an individual's credit rating, insurance companies to figure out the price of policy for a customer, and banks to calculate interest rates for a loan.

*Disruption-Indicator Detection Algorithm*

Using data-mining techniques, future risk-management researchers could develop a detection algorithm that automatically scans relevant documentations for disruption indicators, appraises the level of threat, calculates the probability of occurrence, measures the intensity of impact, and summarizes the findings in a presentable format to alert management.

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# Appendix

## Appendix A: SpecChem Interview Questions

Goal of interviews: To better understand the company as well as relevant information surrounding two specific events in question (Sole-Supplier Failure, Hurricane Rita).

### Common Questions for All Managers

- What are your responsibilities at SpecChem?

- Were you with the company when Rita and supplier failure occurred?
    - When did you hear?
    - What did you do? Are there any formal protocols in place?
    - Observations of actions of people you worked with?
    - When did things return to "normal"?
    - Do you think it was handled well? In retrospect, do you think something could have been handled in a better/more efficient way?
    - Could the problems from these events have been avoided? Do you think the company could have had something in place that would have lessened the impact of these events?
    - Do you think there were lessons learned by the company? Is anything done differently now because of these events?
    - Have similar events happened over the past? Natural disasters? Supplier bankruptcy? What other kind of disruption events?
        - A few quick comparison questions for the Lignin issue that happened in 2001:
            1. What was the nature of the issue (summer shortage, supplier-related, etc.)?
            2. Was it the same magnitude as the recent Lignin event?
            3. What was the solution (had enough inventory and safety stock, supplier purchased Lignin from other companies, found other temporary suppliers, etc.)?
            4. How long did it take to resolve and recover?
            5. Any lessons learned? Anything helpful that was applied to the recent crisis?

- In your opinion, how is supply chain risk currently viewed at SpecChem? Would you say it is a top priority, or addressed on an as-needed basis (i.e. reactionary versus precautionary)?
    - Given a potential supplier failure, on a scale of 1-10, how prepared do you think the company currently is to respond? Explain.

- For our analysis, we would like to consider the following independent variables:

- Inventory:
  - Inventory level and policy of Lignin and Polycarboxylate.
  - Supplier lead-time of Lignin and Polycarboxylate.
  - SpecChem turnaround lead-time of Lignin and Polycarboxylate (from processing raw material to delivery).
- Supplier:
  - Decision on number of suppliers.
  - What is the supplier production capacity for each raw material?
  - What kind of quality variation is there for each raw material? What is the tolerance for each?
  - Suppliers' financial health? On-time delivery and quality?
- Sales:
  - Sales data over the past 5 years for each product.
  - Forecast data.
- Customers (do they practice forward-buying to hoard inventory in anticipation of shortage in supply?); Competition; Vertical Integration (partnership with suppliers); Business Climate; Backup Plans (labor, political, production, transportation); Audits (prevention); Postponement Considerations (if at all a possibility).

- What other data do you think we should consider or is relevant?

## 1. Purchasing/Commodity Manager

Our understanding of the position: Individual responsible for coordinating or approving the purchase of a specific item or class of items from vendors. Has direct interaction with suppliers.

- Give more details about raw material vendors
  - Are you able to/how do you gauge the relative health of your suppliers?
  - How do you go about sourcing/finding your suppliers?
  - How are your relationships with your suppliers?
  - How much communication is there between you and your suppliers? Daily? Weekly? Monthly? Or as-needed basis?
  - Is there flexibility in the amount your suppliers can supply you? Capacity limit?
  - Do your suppliers have other customers for the same materials they supply you with and if so, do you know how they decide to ration their capacity to satisfy demand?
  - Knowing there is a potential risk associated with having only a few suppliers, do you actively search to partner with more suppliers to reduce this risk?
  - Is vertical integration a viable possibility?
  - Do you visit all your potential suppliers' physical sites?

- The Supply Chain Manager explained that there was enough inventory in the pipeline for both Rita and supplier bankruptcy incidents. Could you expand on exactly what constitutes those pipelines?

- How much safety stock was in each of the pipeline?

- Could depleting those pipelines have a negative impact several months after?

- How much longer would SpecChem have lasted with pipeline inventory and others?

**2. Quality Manager**

Our understanding of the position: Responsible for insuring the quality of the product and processes from raw material stage all the way through to final product.

- What is the shelf-life of Polycarboxylate and Lignin products?

- How do you measure quality?
  - When sourcing suppliers, how do you determine their quality is up to your standards?

- Do you ever have to make decisions/trade-offs at the expense of quality (i.e. lower cost supplier) or is quality always the top priority?

- How closely are you involved with supplier sourcing? How much do you interact with suppliers?

### 3. Western Region Operations Manager

Our understanding of the position: Responsible for all operational activities in the western region.

- Generally, what is your inventory policy?
    - Are you able to easily monitor the amount of inventory (both raw and finished) you have in your system at any given point in time?

- Can you tell us more about the physical locations/infrastructure (plants, warehouses, etc.) that SpecChem Performance Chemicals currently operates?
    - Do these different facilities perform different functions, or are they all regional hubs performing the same functions?

- How many different stages of work in process (WIP) do you have? Is it just raw materials and finished products, or are there other stages?

- Do you keep finished products AND raw materials in inventory, or just finished products? If both, how do you decide how much raw versus finished to keep?

- Can you tell me about the flow of products from raw materials stage to finally reaching the end customer?

- How closely do you work with suppliers? What kind of relationship do you generally have with your suppliers?

- Are your suppliers quick to respond to your capacity needs?

- What do you generally worry about the most or concerns you the most about your operation?

- What risks do you see in your operation?

## 4. Director of Operations

Our understanding of the position: Responsible for overseeing all operational activities.

- Generally, what is your inventory policy?
    - Are you able to easily monitor the amount of inventory (both raw and finished) you have in your system at any given point in time?

- Can you tell us more about the physical locations/infrastructure (plants, warehouses, etc.) that SpecChem Performance Chemicals currently operates?
    - Do these different facilities perform different functions, or are they all regional hubs performing the same functions?

- How many different stages of work in process (WIP) do you have? Is it just raw materials and finished products, or are there other stages?

- Do you keep finished products AND raw materials in inventory, or just finished products? If both, how do you decide how much raw versus finished to keep?

- Can you tell me about the flow of products from raw materials stage to finally reaching the end customer?

- How closely do you work with suppliers? What kind of relationship do you generally have with your suppliers?

- Are your suppliers quick to respond to your capacity needs?

- What considerations go into selecting a supplier?

- What do you generally worry about the most or concerns you the most about your operation?

- What risks do you see in your operation?

**5. Business Director**

Our understanding of the position: Oversees all business activities throughout the organization – Product Manager, Quality Manager, Operations Manager, and Commodity Manager report directly to him.

- How are risks handled at the corporate level? What are the protocols?
- As business director, how do you coordinate and communicate between all the different business units/departments?
- Who makes the decision? Who are the process owners? How is risk communicated, and to whom? Who makes the decision on the cost trade-off?
- Do all departments interact/meet on a regular basis? What are the forms of communication?
- Are there ever conflicting priorities among different groups? How are these resolved?
- How are suppliers selected? Is vertical integration feasible?
- How quickly is information communicated between groups? Between physical locations?
- As business director, what issues currently concern you the most?
- What (if any) risks do you currently see in your operation?

## 6. Product Manager

Our understanding of the position: Responsible for the day-to-day management and welfare of a product or a family of products at all stages of their product lifecycle, including their initial development and marketing.

- Can you tell me more detail about the products that are comprised of Polycarboxylate and Lignin?
- How do you determine what are viable products/technologies?
- How do you market new products to customers?
- How do you decide when to phase out a product and introduce a new one? Do you do this at all?
- Do you find suppliers that currently produce the chemicals you are searching, or do you work closely with suppliers in developing new chemicals?
- The Supply Chain Manager explained that there was enough inventory in the pipeline for both Rita and supplier bankruptcy incidents. Could you expand on exactly what constitutes those pipelines?
- How much safety stock was in each of the pipeline?
- Could depleting those pipelines have a negative impact several months after?
- How much longer would SpecChem have lasted with pipeline inventory and others?

# Appendix B: Aggregate Risk Impact Scorecard Results

Prepared by Garrett Lee (glee07@mit.edu) and Zen-Lee Chang (zchang@mit.edu)

## Section A. Overall Supply Chain Risk Questions

| | Please Answer Section A. Below |
|---|---|
| Number of Respondents | 7 |
| On a score of 1-10, how prepared, **as an organization**, is your company to handle ALL supply chain risks? (1 = Not Ready, 10 = Extremely Ready) | 4.86 |
| Currently, across the entire company, what is the #1 supply chain risk you perceive at your company? | 1. The number one risk, generally, is catastrophe at a strategic supplier. Which supplier varies by business: SCC: NSK, SBM: Valeron.<br>2. Continued availability of Lignin and Carboxylate raw material.<br>3. Transportation disruptions from main distributor.<br>4. Dependence on sole sources, and the lack of approved alternatives.<br>5. Single sourcing of raw materials.<br>6. Single sourcing of raw materials (identical answer from two respondents).<br>7. Supplier Disruption for Single Sourced Items. |
| On a score of 1-10, how prepared, **as an organization**, is your company to handle this #1 supply chain risk? (1 = Not Ready, 10 = Extremely Ready) | 4.29 |

## Section B. Event-Based Supply Chain Risk Questions

### 1. Lignin Supplier Failure (2006)

| | 1 = Not Ready, 10 = Extremely Ready |
|---|---|
| On a score of 1-10, how prepared, **as an organization**, was your company to handle a potential supplier failure prior to the lignin incident? (1 = Not Ready, 10 = Extremely Ready) | 3.29 |
| How prepared, **as an organization**, is your company now to handle another potential supplier failure? (1 = Not Ready, 10 = Extremely Ready) | 4.14 |

***Impact Scorecard for Lignin Supplier Failure***

| Variable | Severity (1-10) |
|---|---|
| Which of these were affected? | How much impact did this disruption have on these variables? |
| | 1 = No Impact, 10 = Severe Impact |
| Cycle Time | 3.67 |
| Additional Management Hours | 8.33 |
| Hourly Worker Hours | 5.17 |
| Customer Service Level (CSL) | 3.57 |
| Finished Goods Inventory | 5.00 |
| Raw Material Inventory | 7.57 |
| Raw Material Purchase Cost | 8.43 |
| Shipping Costs | 5.71 |
| Contract Costs | 1.80 |
| New Supplier Setup | 4.71 |
| Backlog | 2.33 |
| Reputation with Customers | 2.33 |
| Plant Capacity | 3.17 |
| Sales Volumes | 2.14 |
| Finished Product Quality/Return Rates | 6.29 |
| Raw Material Quality | 8.14 |
| Shipping Delays to Customers | 3.71 |
| | |
| **Others: (Please Specify Below and Apply Score)** | |
| | |
| | |
| | |
| | |
| | |

### 2. Hurricane Rita (2005)

| | 1 = Not Ready, 10 = Extremely Ready |
|---|---|
| On a score of 1-10, how prepared, **as an organization**, was your company to handle a natural disaster disruption prior to Hurricane Rita? (1 = Not Ready, 10 = Extremely Ready) | 4.29 |
| How prepared, **as an organization**, is your company now to handle another natural disaster disruption? (1 = Not Ready, 10 = Extremely Ready) | 4.86 |

***Impact Scorecard for Hurricane Rita***

| Variable | Severity (1-10) |
|---|---|
| Which of these were affected? | How much impact did this disruption have on these variables? |
| | 1 = No Impact, 10 = Severe Impact |
| Cycle Time | 3.86 |
| Additional Management Hours | 6.67 |
| Hourly Worker Hours | 3.83 |
| Customer Service Level (CSL) | 3.17 |
| Finished Goods Inventory | 6.00 |
| Raw Material Inventory | 7.43 |
| Raw Material Purchase Cost | 2.33 |
| Shipping Costs | 5.57 |
| Contract Costs | 1.80 |
| New Supplier Setup | 1.33 |
| Backlog | 4.14 |
| Reputation with Customers | 2.50 |
| Plant Capacity | 2.33 |
| Sales Volumes | 1.67 |
| Finished Product Quality/Return Rates | 1.33 |
| Raw Material Quality | 1.33 |
| Shipping Delays to Customers | 5.00 |
| | |
| **Others: (Please Specify Below and Apply Score)** | |
| | |
| | |
| | |
| | |
| | |

**Appendix C: Additional Indicators of Supply Chain Disruption**

*December 11, 2004, Community Voice*
Some SP employees are missing work hours, and are apparently bitter about the company, especially when they have to work during Christmas holidays. Some employees are "talking about the union sitting down with the company."

- ❖ Potential-Disruption Indicators
  - o Unhappy employees
  - o Employees shirking duties and cutting work
  - o Unsatisfactory holiday work schedule
  - o Imminent union involvement

*May 1, 2005, Editorial Column*
"With incentives from the state already on the table, [city] officials are considering ways to further entice [SP] to keep its growing headquarters at its [current] location. The company, which doubled the size of its operations earlier this year when it purchased [another company, FP's] operations, is eligible to receive a state tax credit to expand its [current] headquarters."

- ❖ Potential-Disruption Indicators
  - o Company considering to relocate
  - o City officials enticing company to stay by offering incentives
  - o Company recently doubled in size, suggesting financial burden

*March 23, 2006, Editorial Column*
"Although they have been told it should be business as usual, workers at [SP] are uneasy following the company's recent filing for bankruptcy. News of the filing, combined with the announcement last week that [SP] was closing its [Wisconsin] operations has fueled countless questions for members of [the local union], which represents about 360 hourly workers at [the] paper mill."

- ❖ Potential-Disruption Indicators
  - o Workers displaying anxiety about the company's future
  - o Questions remaining unanswered, lack of communication from the top

*March 24, 2006, Editorial Column*
"A series of legal orders were entered this week in U.S. Bankruptcy Court following [SP's] filing for Chapter 11 reorganization Tuesday. The orders generally allow [SP] to move forward with bankruptcy financing and to pay some debts: U.S. Bankruptcy Judge Christopher Sontchi signed an order allowing [SP] to get secured loans, advances and other financing on an interim basis from Wachovia."

- ❖ Potential-Disruption Indicators
  - o Company facing debts and legal issues
  - o Company borrowing money to pay off debts, increasing financial burden

*April 4, 2006, Editorial Column*
"[One of SP's creditors] is scrambling to get back almost $1 million in supplies shipped to [SP] in the month and a half before the company filed for Chapter 11 bankruptcy. The city has also asked the bankruptcy judge presiding over the case to force [SP] to set aside more money than the company has suggested is adequate to ensure [SP] can pay its utility bills."

- Potential-Disruption Indicators
  - Creditors eager to get back money owed
  - Company struggling to pay for basic operational necessities

*April 11, 2006, Editorial Column*
"Chapter 11 bankruptcy isn't the best time for a labor issue to come up, but it looks to be the case for [SP] and the 360 members of the [union] employed there."

- Potential-Disruption Indicators
  - Labor issues rising amid uncertainty
  - Possible union intervention

*November 29, 2006, Editorial Column*
"Monday night's fire at [SP] broke out in a propane fueled forklift while a person operating the machine was unloading a boxcar full of paper pulp in a covered loading dock, fire officials said Tuesday."

- Potential-Disruption Indicator
  - Similar accidents could repeat in the future if no actions were taken to amend the root cause