Application of Supply Chain Risk Management through Visualization and Value-at-Risk Quantification

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Summary: This project attempts to bridge the gap between isolated risk mitigation plans and a comprehensive approach for corporations to deploy supply chain risk management ("SCRM") on an enterprise scale. Through the use of supply chain visualization and value-at-risk modeling, we have developed a SCRM strategy for a pilot supply chain of a large multi-national chemical company ("GlobalChem").

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KEY INSIGHTS

1. Supply chain risk can be quickly analyzed through visualization.
2. The value-at-risk for each node in a supply chain network can be quantified using a risk exposure index and location-based disruption probability data.
3. GlobalChem can reduce its supply chain risk by either increasing inventory or adding new suppliers for components with a high VaR index.
4. This methodology can be expanded from our pilot product line to an enterprise scale for more comprehensive risk analysis.

Introduction

Many companies fail to mitigate supply chain disruptions effectively because they lack an integrated, practical approach for SCRM that can be implemented on an enterprise scale. According to a 2013 World Economic Forum report, share prices are estimated to drop by 7% on average for companies that suffer a major supply chain disruption. To mitigate this risk, companies need a well-established strategy for supply chain resilience that incorporates a cross-functional risk management process, an integrated monitoring system, and close cooperation with upstream and downstream supply chain partners. Our SCRM solution is developed on Sourcemap.com, a web supply chain mapping platform that will interface with current enterprise resource planning ("ERP") systems. Thus, in the future the solution can be applied broadly across all of GlobalChem's product lines.

Framework

Our methodology for supply chain risk management involves the visualization of GlobalChem's supply chain and the quantification of the value-at-risk ("VaR") at each node in the company's supply chain. This approach will give our sponsor company an

unbiased approach toward quantifying the amount of risk in their supply chain network.

Visualization of the supply chain is equally as important as risk quantification. Studies have shown that the human brain interprets visual data more quickly than textual and numeric information (M. Parkinson). When a supply chain is captured in a well-designed map or tree diagram, managers can quickly grasp the degree of complexity in their network as well as gain some general understanding of the risks inherent in its design.

For most geographical locations, there is historical frequency and severity data collected by public organizations such as the U.S. Geological Survey and private organizations such as Applied Insurance Research (AIR, Inc.). When mapped, we may view the hazards in risk heat maps, which can quickly convey the likelihood of such disruptions in any particular region of the world. **Figure 1** shows a risk heat map of earthquakes in the U.S.

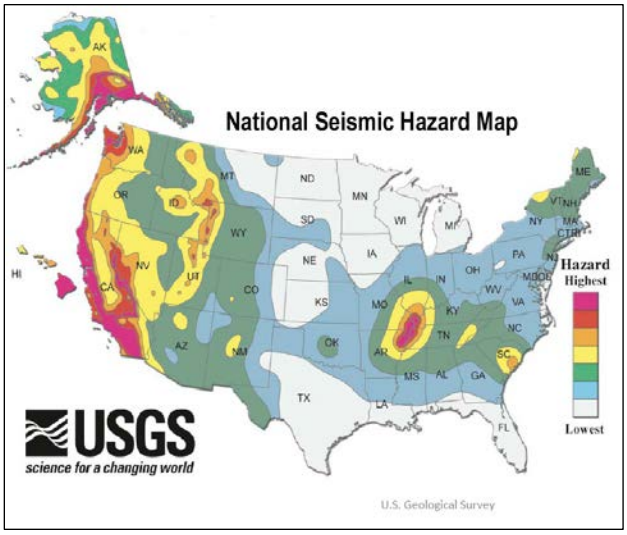

Figure 1: Earthquake Risk Heat Map (Source: U.S. Geological Survey)

Taken a step further, this information can be combined with a risk exposure index to calculate a VaR for every node in a supply chain network. Risk exposure is a measure of the maximum loss potential should a disruption event occur. For our purposes, this would mean the amount of revenue lost should a node be removed from the supply chain network. For each node in our network, we defined this risk exposure amount to be equal to the daily revenue dependent on this supplier, multiplied by the difference in recovery time and the days of inventory positioned between the supplier and the customer,

*REI = Daily Revenue * (Recovery Time – Inventory Days).*

The purpose of VaR is to be an unbiased measure of risk. It is not particularly useful on a stand-alone basis, but is more useful as a comparison tool across time or physical dimensions. In our project, VaR is used to calculate the expected value of loss due to natural catastrophes. Specifically it is the product of risk exposure index and the probability of disruption,

*VaR = Risk Exposure Index * Pr(Disruption).*

Exceedance probability ("EP") curves from AIR, Inc. allow us to identify the probability of novel events that may greatly exceed normal losses, which the insurance industry would then categorize as a "catastrophic event." In the example shown in **Figure 2**, we can see that there is a 1.3% probability of a catastrophe creating more than $1,000 of damage per $1 million of assets, which we defined as our disruption threshold.

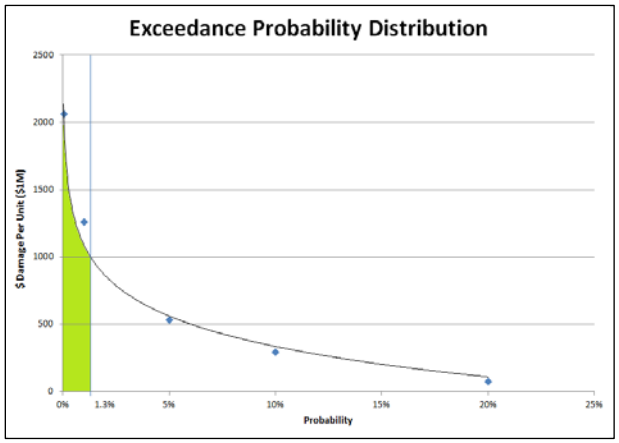

Figure 2: Exceedance Probability Curve ("EP Curve") – Data from AIR, Inc.

After calculating the VaR of each node in the network, we integrated the information into our supply chain map in Sourcemap, which color-coded our network based on the relative VaR of each node. Such visualization helped GlobalChem to identify the nodes that had the highest concentration of risk.

Figure 4: Supply Chain Map with VaR Overlay

Findings

We mapped an end-to-end supply chain of selected product lines, quantified the amount of risk at each node in the network, and demonstrated the new supply chain set up with risk mitigation (Figure 3). As a result of our study, we mitigated the VaR from single-source vendors with moderate disruption probabilities and primary vendors with high disruption probabilities. The strategies were developed for the specific operations and industry but they could also be applied more broadly with adjustments.

Single-Source Vendors

While more multi-national organizations seek lean strategies such as reducing the supply base, their supply chains become more vulnerable to any type of disruptions that occur around the world. Multiple sourcing is effective in mitigating disruptions from single sources. It is also critical to keep the sources geographically scattered, so that the supply chain is more flexible in response to unpredictability. Given the high cost associated with multiple sourcing, an internal target is necessary to keep a balance between risk mitigation and cost control.

Additional time and costs need to be taken into consideration because vendor qualification is often determined by cross-functional teams. Many single sources are in essence sole sources because no other vendor in the market is capable of meeting the internal standards of product quality, process reliability, and regulatory compliance. The strategy is still to diversify the supply by either investing in the enhancement of other vendors' capabilities or to negotiate for the vendor's geographic expansion.

Upstream Strategic Partners

Our model has identified enormous risks with a primary supplier situated somewhere with high disruption risk probability. The mitigation strategy is to lessen the company's dependence on the risky primary supplier. One way is to adjust the split of supply among

vendors, as is experimented in the model. In reality, companies can also sign option contracts with other vendors to reserve excessive capacity that deals with any type of disruptive events occurring to the primary supplier.

The other way to mitigate risks associated with a risky primary supplier is to increase inventory of certain raw materials in central warehouses. This is effective for the materials that are needed in many product lines, but in small quantities.

A More Integrated Platform

Over the course of the project, we have identified a few areas for improvement in the enterprise to facilitate a more automated data collecting and processing platform in future. One key recommendation is to more explicitly document procurement strategies. Following the current practice, the metrics that evaluate vendor performance or development plans that capture sourcing strategies could hardly be translated into any single value of estimate to determine disruption risks. We suggest some key operational aspects be documented by procurement including supplier's factory location, recovery time, capacity, sourcing splits and inventory.

Conclusion and Further Research

When corporations are able to quickly visualize their supply chains, assessments of risk exposure and mitigation solutions will surface more quickly. Yet, there will be questions about which solution would be most cost effective and provide the most risk mitigation. The scope of our project includes risk identification and quantification, but a natural extension of our research would have been to include scenario planning and stress testing.

When we showed GlobalChem the key risk in its supply chain, the next step was to find an appropriate response to reduce that risk. However, there were questions whether the best response was to find additional suppliers and, if so, how many were adequate. To address this question, our visualization and VaR quantification methodology can be applied to hypothetical situations. The scenario tests can be used in conjunction with a cost-benefit analysis to determine the best course of action. Finally, we can stress test our supply chain to understand resiliency. By simulating disasters, we can identify weak spots in our supply chain that our calculation missed.

After reviewing our project with our sponsor and hearing their feedback, we noted potential additions to our SCRM strategy that could further enhance value for organization. First, live real-time alerts from monitoring organizations could provide risk managers with warnings of upcoming disasters. Second, an intercompany visualization platform could connect the company with external suppliers and distributors, which would create a vertically integrated and resilient supply chain.

Furthermore, there are areas of improvement for this approach to SCRM. First, the model for risk exposure can be further improved by incorporating vendor capacity. Second, operating risks at vendor level can be built into the model. Finally, the threshold for disruption at some nodes can be differentiated when more data is available about construction quality or other risk factors.

Business organizations that have focused on cutting costs by aggregating orders to fewer suppliers have also concentrated the risks in their supply chains. In order to balance risk and efficiency, we recommend that organizations examine our approach for risk identification, evaluation, and mitigation. We hope that our research will help organizations like GlobalChem to find a balance in building an economically resilient supply chain and to create a sustainable system for all stakeholders.