Supply Chain Risk: A Utility Company Perspective

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Introduction

Our client is a large multinational utility company servicing the Northeastern United States. They serve over 3 million clients, providing them both electricity and gas.

In 2012, Hurricane Sandy hit the east coast of the United States, resulting in massive damages of more than $50 billion to the economy\(^1\). East coast utility companies experienced widespread power cuts, resulting in revenue losses as well as decreased customer satisfaction and brand image. But weather events don’t affect just the distribution infrastructure, they can also disrupt the company’s operations by affecting its supply-chain. Following the Fukushima Daiichi nuclear plant incident in 2011, Toyota’s midsize car production had to be dramatically reduced because they could no longer receive supplies of key components that had been contaminated\(^2\). A correlation has been evidenced between global warming and the intensity of natural disasters\(^3\).

In an effort to recognize and prepare for the growing number of extreme weather events, our client is trying to assess the risk levels of its different suppliers. Today, it is lacking sufficient information on the susceptibility of its supply chain to climate change and other risks, leaving them vulnerable to disruptions in their service.

Based on conversations with the stakeholders, the primary goal of the project evolved to developing a framework for identifying aggregate supply chain risk associated with sustainability and additional risk (geopolitical, regulatory, market, etc.). We then explored resiliency strategies in response to it. This framework is based on the existing supply-chain literature and discussions with our client’s procurement team, as well as some of its suppliers. Because of limited resources and time constraints, we focused on key areas that impact our client’s supply chain most.

In this report, we begin by describing our approach to the problem and defining what constitutes supply chain risk. We then develop a framework for evaluating risk based on four pillars: identification, quantification, mitigation and response. Additionally, we discuss the limitations of this framework, and provide long-term recommendations for our client. Lastly, we reflect on the challenges we have faced throughout the project, those that illustrate the difficulties of embedding sustainability in a company’s long-term strategy.

Approach

In terms of achieving the end goal of creating a framework that informs the utility company of risk across the various segments of their supply chain, the team first started out by performing

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a literature review of best practices in supply chain risk management. Publications from academia, industry, and other research institutions were considered in terms of applicability to this project. Additionally, the team reviewed a selection of proprietary tools and methods used currently by businesses to quantify supply chain risk (Exhibit A). Based on our findings from the literature review and tools assessment, we developed questionnaires that contained questions aimed at gathering information about the various risks associated with different segments of the supply chain (Exhibit B). In-house utility employees and supplier management staff then completed these questionnaires.

This was followed by phone conversations with representatives from the utility company and their suppliers. The results from the questionnaires were used to identify potential areas of risks within various functions of the supply chain. Simultaneously, the team also worked on locating open source data for visualizing climate change and geopolitical risk (categorized as uncontrollable risks). The data that was eventually utilized consisted of composite values by country. These composite values quantified and aggregated the different elements associated with climate change and geopolitical risk. The visualization of this data was done using ESRI ArcGIS.

Supply Chain Risk

Since the advent of globalization, supply chains have evolved to become increasingly complex, spatially diverse, and interwoven systems. While this has brought advantages in the form of cheap labor, direct access to raw material, and tax incentives, a global supply chain is susceptible to disruptions or risk that can have serious consequences for the company. Companies that are vertically integrated have greater control over the operations of their supply chain but companies that contract suppliers are often lacking in the real time monitoring that allows them to understand and quantify supply chain risk. If unpredictable events such as climate change, natural hazards, and geopolitical unrest disrupt a part of the supply chain, the effects of this can be felt across the various supply chain functions (manufacturing, logistics etc). Lapses within the operations of supply chain can also have a similar effect, and the diagram below succinctly illustrates the varying levels of impact versus controllability of various risk elements.

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The elements of supply chain risk can be categorized by uncontrollable and controllable risk. The descriptions for these various elements are below:

**Uncontrollable Risks**

**Natural Disasters**

Amongst the various factors contributing to supply chain risk, the impact of natural hazards due to global climate change is one of the most impacting and uncontrollable factors. Globalization has led to increasing levels of complexity in the supply chain, thereby raising the potential for disruptions. The earthquake in Japan, and the floods in Thailand best evidence the significance of natural disasters on supply chain\(^7\). Both occurring in 2011, the Japan disaster caused record losses to the economy, and impacted the ability of various industries to manufacture and transport goods. Similarly in Thailand, the massive floods led to a temporary halt in production as well as physical damage to industrial assets. Closer to home, Hurricane Sandy in 2012 caused damage to various manufacturing properties and disrupted supply chains on the east coast\(^8\).

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Geopolitical Instability

The political stability of a country and susceptibility to terrorism are another set of challenging factors contributing to supply chain risk. Nick Wildgoose, global head of supply chain at Zurich Insurance remarks - “Interstate conflicts can have a detrimental effect on supply chains and, as new sanctions come into place, businesses may see some of their suppliers affected”. To elaborate on this, the uprisings in Egypt, Libya and Syria are good examples. In addition to causing volatility in crude oil prices and restrictions on suppliers within these borders, this instability also led to the blockage (or delays) in supply shipments. There has been an increase in awareness of geopolitical risk, and as a result has featured amongst the top five risks to supply chain in a report published by World Economic Forum in 2015.

Commodity price volatility

About every organization is exposed to financial risks stemming from commodity price volatility. These risks are either direct, affecting the cost of raw material for manufacturers; or indirect, affecting its support activities such as transportation. They will impact the overall profitability of the business as well as its cash flows and its ability to remain competitive. But they can also cause supply chain disruptions, putting the business at an even greater risk. Typical instances of supply chain disruptions caused by commodities volatility include increased oil prices bankrupting logistics companies, prohibitive pricing of key minerals for electronics components, or food price surges resulting in factory shutdowns from social protests in sourcing countries.

Currency fluctuations

According to a survey by PWC and MIT Forum for Supply Chain and Risk Management, managers view currency fluctuation as the second most important risk to their supply chain, second to raw material prices volatility. Whether supply contracts are expressed in local currency or dollar, the supply chain will ultimately be affected: either the buyer will pay more for its raw and semi-finished goods in the first case or its suppliers will react to decreased profitability by increasing its prices if the contracts are in dollar and their own sourcing in local currencies. With most large and even medium companies’ supply chains tracing back to global markets, virtually no business is exempt from currency risk. Depending on the origin of its main suppliers, a company’s competitive position can be affected by currency risk.

Regulatory

There are different elements of regulatory risk that could stem from a lack of compliance, changed or new regulations, and international trade laws. In regulation for example, the US government is keen to combat the sourcing of conflict minerals. The SEC also has asked for companies to file human rights risks in their supply chain. The risk from compliance can arise if the suppliers are not abiding by local laws pertaining to environment, human rights and labor laws, and as a result are forced to shut down (temporarily or permanently). The lack of compliance in the case of environment or human rights is also closely linked to reputation risk. Finally, international trade sanctions on certain countries can also lead to a disruption in supply chain.15 16

Controllable Risks

Network

Reliable and efficient logistical support is essential to the operation of a company’s supply chain. Changes in transportation mode, port inspections at border crossing, strikes and natural disasters can cause delays in the flow of materials through the supply chain. These delays can often result in large financial losses. A 10 day lock-out of the West Coast Ports in 2012 cause the US economy an estimated $1 billion a day17. If these events are frequent, companies can plan strategies to mitigate the effects of these delays based on historical data. Some of these strategies include maintaining excess inventory and using several types of transportation modes if possible18.

Data security/IT incidents

As companies become more reliable on software and computer networks to conduct business they are making themselves more vulnerable to disruptions resulting from cyber-attacks. The credit card information of 56 million customers of The Home Depot were compromised by hackers using malware which was installed on the company’s systems for months before being detected19. There are several other examples where malicious groups have shut down company websites and compromised databases with sensitive information. These attacks can come from deliberate internal and external sources or through unintentional acts. Thus, having

proper network security thought a business and looking out for cyber security risks especially in the supply chain is of utmost importance.

Customer demand volatility

Often times, suppliers are delivering the same product to several customers. Any number of events may occur which increase the demand from customers. Given limited capacity, a surge in demand results in shortages that reduce the flow of materials through the supply chain. Firms must have contingency plans in place to ensure that their supply of goods of materials is not affected by demand shocks.

Shortages of raw materials or components

Shortages of raw materials or components at all tiers or the supplier level can greatly impact a supply chain, leading eventually to failed provision of completed goods for the end user (i.e., utility company). At each individual supplier level, purchasing and inventory programs are designed to manage some level of certainty in demand, and minimize loss due to excess material that could be destroyed, lost or become obsolete.

Suppliers are cognizant of the “bullwhip effect” which can cause large fluctuations in material supply needs due to uncertainty added to each level of customer ordering in the supply chain process, so for some materials, supply is not always sufficient to cover extreme levels of demand. In addition, coverage of 100% of demand materials or components is often not achievable without keeping large amounts of inventory, and the cost of storage typically prevents this from happening. Access to materials or components and capacity/lead time of production (if applicable) can vary by supplier, as well as the ability (or not) to expedite procurement of additional materials when demand exceeds supply. In order to determine the level of risk associated with shortages in raw materials or components, the client must understand the impact of its contract terms and conditions on purchasing and inventory practices.

Bankruptcy of critical supplier

Over relying on one vendor can significantly disrupt production schedules when this supplier goes bankrupt. In 2001, Ford’s Land Rover was receiving its entire chassis supplier for its Discovery model from UPF-Thomson. As the company went through financial difficulties, it eventually demanded that Land Rover pay for it to maintain its chassis unit. After months of disruption in its supply chain, Ford settled to buy the collapsed components of UPF-Thomson\textsuperscript{20}. Companies should be cautious when pressuring their critical suppliers, so as not to send them into bankruptcy\textsuperscript{21}.

Safety & quality incidents

Gaps in safety and quality can lead to unanticipated events that shut down a portion or all of the supply chain associated with a particular supplier. Programs associated with safety are often configured based on government regulations, and regulations can vary greatly by location. The market on the other hand, often dictates quality programs, and what industry


determines is sufficient. Both programs involve initial investments, as well as continuous efforts to ensure compliance. If continuity of achieving safety and quality standards is not a priority for a supplier, the chance of an event taking place that greatly impacts operations beyond the original risk level becomes higher than had these programs been performed as designed.22

Fires/strikes.tech problems at supplier sites

Incidents caused by man-made conditions such as fires, strikes or technical problems can occur at supplier sites and have a major impact on the supply chain. A supplier’s time to recover (TTR) from each type of incident is therefore critical information needed by the customer (i.e. utility company) so that contingency plan(s) can be put in place, and disruption to the end user can be avoided or at least minimized to the extent possible.23

There are various challenges associated with companies striving for improvements to mitigate supply chain risk24. As described previously, there are wide sources of risk that a company needs to understand and mitigate. It is not sufficient to understand just the primary layer of the supply chain, but also the secondary and tertiary layers. This compounds the difficulty in identifying and mitigating supply chain risk. Moreover, companies that have been in business for years have spent considerable time and effort to optimize and reduce costs in their supply chain. Many companies have recognized the importance of understanding their supply chain, and ensuring that disruptions don’t affect their ability to deliver a product or service. Accenture conducted a quantitative survey of 446 organizations in 2013, one of the questions being the level of importance given by the organization to supply chain risk25. The study reported that 98% of the respondents said that there was an increase in perceived importance of risk management. This is encouraging, since the negative effects of unpredictable climate change, natural hazards or political events will require a flexible, responsive and resilient supply chain.

Risk Evaluation Process

The supply chain risk evaluation process can be divided into four main categories: identify, quantify, mitigate and respond. The S-Lab team has conducted a literature review of the best practices in each activity area that is elaborated in the following sections. There are a plethora of approaches to supply chain risk management. What is listed here is not intended to serve a comprehensive survey of all practices but to present a general framework from which one can glean ideas, expand and develop their own approach.

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To create an effective supply chain risk management (SCRM) program, an organization must begin by exploring the relationships and interdependencies between themselves and the other firms with which they interact and identifying the possible risks their supply chain may experience. A dedicated SCRM team can conduct this process of risk identification. The team should comprise of a diverse and cohesive mix of senior management and leadership from the organization who will be engaged throughout the entire SCRM program development process. The Supply Chain Risk Leadership Council (SCRLC), a consortium of companies from diverse industries, have developed a set of guiding principles to investigate SCRM and recommends that an effective team should be formed from leaders in the firm with the following functions:

- Business continuity
- Engineering and design
- Enterprise risk management
- Finance
- Governance
- Import/export compliance
- Logistics
- Manufacturing
- Procurement
- Quality
- Security
- Supplier management

Once the SCRM team has been formed, they could then begin the risk identification process. To get started, the team can use a myriad of tools such as brainstorming sessions, surveys, visual mapping of the supply chain and pre-existing risk assessment reports among others.

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Initial brainstorming sessions can be used to get all the ideas and perspectives from the various stakeholders within the company related to potential risks that the supply chain. The team should dedicate ample time for sessions and create an environment for open dialogue where members will not feel daunted. The team can use multiple approaches to begin the thought process. SCRLC suggests identifying risks internal to the firm versus external risks. Another method that is becoming more popular is Simchi-Levi's approach of categorizing risks based on predictability and controllability that was addressed in the preceding section. External subject experts may be consulted during brainstorming activities as well.

SCRLC has also published a detailed report on emerging risks to the supply chain that can provoke discussion during brainstorming sessions.

Initially, the scope may be limited to Tier 1 suppliers or even a subset of Tier 1 suppliers and extended later on to Tier 2 and higher. Other factors which should be considered are number and origin of shipments, contractual terms defining responsibility for shipping, modes of transport and routes for shipments, other logistics providers or partners involved in the supply chain.

Informed by the above recommendations and other literature, the S-Lab team has developed a set of questionnaires, maps and other to help the client better understand the relationship between themselves and their suppliers, and begin to identify the resulting vulnerabilities.

Surveys & Spider Plots

In order to gauge relative risk levels within the utility company’s supply chain, a set of surveys was developed with the intention of sending one questionnaire to all suppliers for completion by the client manager, and the second questionnaire to utility company representatives that interact most with the individual suppliers. Due to variability in how different products are procured and used by the utility company, the questionnaires were designed to be associated with a single product or product line, meaning all questions were to be answered according to that one product or product line. In some cases, question pairings were developed so that risk could be determined by comparing the response from the supplier with that of the utility company. Inconsistent responses may identify an area of risk.

The list of questions were limited to a single page, and grouped according to the process step (manufacturing, product design, logistics etc.) most closely impacted by a potential disruptive event. Questions were developed based on the internal and external risk factors described above (see Exhibit B for question mapping against the different risk factors and categories), and were mostly multiple-choice on a scale of 1-5, with a few questions left open-ended. As seen in Exhibit B, the answers corresponding to the 1-5 scale were either qualitative in nature with scales ranging from “Strongly Agree” to “Strongly Disagree” forwards or backwards, or somewhat quantitative, with pre-determined ranges estimated from the team’s experience and understanding of equipment procurement.

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28 During the S-Lab project, three suppliers were identified for review. The questionnaires were distributed, and at the time of this report, one set of questionnaires had been filled out by both the utility company and the supplier. Phone conversations had covered select questions for the other two suppliers, but the forms were generally incomplete.
Upon discussing the individual questions with suppliers and utility representatives and reviewing the initial questionnaire responses, it became evident that several adjustments needed to be made. These changes included the following:

- Open-ended questions should either be eliminated, or example responses should be provided to reduce uncertainty.
- Adjustments to the pre-set ranges of certain questions: The time and volume ranges provided in the questionnaires were found to be insufficient for one of the three suppliers queried. The values had been based on one teammate’s experience in procuring equipment for environmental remediation projects, and during conversations with two of the three suppliers, it was found that these ranges did not completely cover their operations, and should be adjusted.
- For two out of the three pairings, the suppliers were reluctant to provide specific information regarding locations and specific forms transportation (both open-ended questions). Trust may be a consideration, so these questions may require additional follow-up by the utility company representative managing the relationship.
- Questions should be direct and avoid ambiguity so that responses can be used in the supplier evaluation.

In addition to feedback from the questionnaires, it was also realized that the rating structure (1-5) of questionnaire questions might not be constant across all companies, depending on the sensitivity to certain types of risk. For the purposes of this evaluation, the ratings were kept as whole numbers spanning the full 1-5 range, though for future more evaluations, it is recommended that the utility company carefully review the ratings and adjust as needed according to their own risk acceptance profile. It should be noted that for graphing reasons, the 1-5 order was reversed for certain questions so that “high” risk was always assigned a value of 5, and “low” risk was always assigned a 1. Values that did not follow the standard set of responses were either represented as the “worst” case, considered to be a more conservative approach when more than one response was circled, or assigned a value of 5 for future follow-up if the response was unclear.

Visual Mapping (Exhibit D)

In order to gain a visual perspective on climate change and geopolitical risks for supplier locations, the team utilized ESRI ArcGIS as the mapping software. In the first map, the numbers for climate change vulnerability originate from the University of Notre Dame’s GAIN Index\(^{30}\). This index provides composite values that combine many different elements. For example, the vulnerability to climate change is an aggregate number, and obtained by adding numbers from ecosystem services, food, health, human habitat, infrastructure, water, adaptive capacity, exposure and sensitivity. The Index also provides an aggregate number for readiness, which is essentially a measure of how capable a country is to mitigate the effects of climate change. Both these numbers were mapped onto separate maps. The numbers for the political stability and absence of terrorism were extracted from the worldwide governance indicators published by the World Bank\(^{31}\). These numbers were also then mapped in the GIS software. From the graphs, the team could glean that majority of the supplier locations were located in US, Canada, and Europe, and these countries were the least vulnerable to climate change risk. Although there are some locations are in South East Asia and South America,

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where the locations are susceptible to a medium level of risk to climate change. Similarly for political stability, the supplier locations in US, Canada, and Europe are less threatened by political and violence risk. On the other hand, the South East Asian and South American countries are in the medium to high-risk category.

Quantify

Quantifying supply chain risk is a complex process, and requires a more exhaustive data collection program in order to achieve a high level of detail for each potential source of risk. As this project was limited in schedule and resources, the following approach was designed around data obtained from the questionnaires, follow-up conversations, publicly available climate change vulnerability, preparedness and geopolitical hazards as described above, and information obtained from the supplier website(s)\(^{32}\), and represented in a dashboard format (Exhibit C). The dashboard provides a high-level screening of risk areas so that when additional resources become available, they can be assigned towards investigating the “flagged” areas in more detail.

Supplier dashboard creation approach:

1. Finalize application of 1-5 rating system for each question on the set of questionnaires
2. Identify question pairings, where input was provided by both the supplier and the utility company
4. Present questionnaire data on a series of three radial plots so that areas of inconsistency (among pairings) or high potential risk (measured with a value of 5) area identified. Question pairings were aligned to the extent possible.
5. Summarize findings from supplier website review in a text box directly beneath the supplier ID.
6. Reference the climate change vulnerability and preparedness maps and the geopolitical instability map for risk values by location.
7. Present data in a matrix that lines up areas of risk with the segments of the supplier and utility company supply chain, and color-code based on the initial value.

As indicated above, the resulting dashboards are intended to identify potential areas of risk that should be explored in further detail first by the utility company to determine if the flag is a risk that is within our outside of their targeted risk profile, and then by the the risk evaluation team and/or an outside consultant.

Mitigate

Mitigating supply chain risk is about building greater resilience into the supply chain, so that potential disruptions are minimized. It is different from supply chain breakdown response, which is explained in the next section.

\(^{32}\) Information gathered from supplier website(s) includes references to risk identification and management and mitigation measures associated with health and safety, their own supply chain risk, sustainability, etc.
According to the SCM World study, effective supply chain risk mitigation strategies include the following set of 4 actions: Active inventory tracking, reducing reliance on single components, increasing the use of standard component designs, and segmenting and regionalizing supply chain strategies. Other studies also emphasize the need for insurance solutions and the use of inventory buffers for risky and critical components, while reasserting the importance of contracting with alternative suppliers and regionalizing supply chain strategies.

Active inventory tracking

According to SCM World CSCO survey data, active inventory tracking and dual sourcing are the most popular risk mitigation strategies used by supply chain managers, with 45% rating them as “highly effective”. Active inventory tracking helps to identify the higher-risk suppliers/products, while allowing for a leaner procurement process.

Reducing reliance on sole and single sourced parts

Reliance on single sourced parts is pointed out as a major source of risk in all the studies that the team has found. An eloquent illustration of it is given by S. Chopra: in 2000, a fire in a Philips Electronics plant in New Mexico interrupted the supply of critical phone chips for two clients: Nokia and Ericsson. Nokia quickly responded by switching its supply to other plants while Ericsson lost one month worth of production since it was using a single source. Dual or multiple sourcing is an effective way to mitigate tier 1 supply risk. However, as pointed out in the SCM World study, company should look for independent alternatives. It often happens that two suppliers will have the same network of tier 2 to tier 3 suppliers. This means that a disruption in one of them could affect both suppliers equally, therefore rendering the dual sourcing strategy completely inadequate and costly.

Increasing use of standard component design

Standardizing the design of components so that they can be used across product lines and sourced from multiple suppliers brings the double benefit of cost reduction and risk mitigation. It also leaves a greater margin for inventory buffers, since the value of the inventory decreases. Few managers actually use this tactic because it requires large reorganization to streamline operations.

Segmenting and regionalizing supply chain strategies

Regionalizing the impact of a disruption helps to contain the impact of the disruption within the region. While it avoids the risk of global shutdown from one region’s extreme event, it also reduces overall costs of transportation. It offers more flexibility to better serve different markets by locating manufacturing closer to distribution center, reducing customers’ delivery time. Strategies to regionalize supply chain can be based on markets’ geographic distribution or level of risk associated with the different components.

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Insuring the supply chain

Although not recognized as a major tool for risk mitigation, supply chain professionals view insurance as very effective. Insurers and companies have aligned incentives to avoid disruption and subsequent claim settlement. Therefore, insurance companies can bring in their expertise to help companies implement risk mitigation strategies. Effective insurance contracts will not only provide settlements in case of extreme events, they will also incentivize clients to decrease risk by adopting suggested risk mitigation tactics.

Overestimating supply chain risk

Supply chain managers have an incentive to underestimate risk in order to increase short-term profitability. But underestimating risk has proven to be far more destructive than overestimating it and bearing the subsequent additional costs because the loss incurred from a disruption generally overwhelm these costs.

Respond

Supply chain disruptions happen even with the most thorough mitigation strategy in place. Unsurprisingly, effective response depends on the level of preparedness of the company. Effective contingency plans are quick to detect disruptions, quick to implement, adapted to each product and supplier, and regularly audited and reviewed. Companies that manage to quickly respond to supply chain disruptions often have a centralized data-gathering unit. This helps the company to be well informed, and institute response plans quickly. For example, when the tsunami struck in 2011, Nissan had a Global Disaster Control Headquarter as well as a recovery committee already in place. While the industry slipped 25% that year, Nissan recorded just 3.8% decrease in activity. Having specific plans for each supplier also increases the effectiveness of the overall contingency strategy, especially when dealing with different regional sub-supply chains. Lastly, contingency plans should be flexible and constantly monitored and reviewed by the mean of stress tests, simulations, and aftermath reflection.

Recommendations

As realized throughout this S-Lab project, evaluating supply chain risk in a comprehensive fashion is an extremely resource-intensive process. To build off of the high level screening evaluation framework provided herein, it is recommended that best practices be applied to this project, beginning with the creation of a dedicated cross-functional team. Once the team is developed, the company should design a program targeted at gathering the required data in the most efficient means possible. Depending on the required skillset and the available staff, it can be determined if resources are available in-house to perform significant data collection associated with a select number of suppliers, or if an outside consultant should perform this.

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step as well. We also recommend looking at the following tools that are available on the market, as well as joint research opportunities with the MIT Operations Research Center (Exhibit A):

- Cisco dashboard
- Llamasoft website originally developed by D. Simchi-Levi
- Ecodesk Sustainability in Supply Chain Mapping

While obtaining visibility in the supply chain beyond Tier 1 suppliers would allow the company to better prepare for shocks to the supply chain, it is not an easy process because suppliers are often unwilling to disclose their own suppliers’ list and information. Entering in an NDA agreement could remove this obstacle though the most effective strategy remains to nurture a high level of trust between organizations and suppliers which can only be developed over time and through continuous engagement on the criticality of having visibility in the supply chain.

Challenges

Consistent with struggles that sustainability focused teams face in convincing broad participation for sustainability initiatives, the team faced several challenges throughout the project. One of the challenges that underscored the evolution of the project deliverables was the disconnect between the requirements of the sustainability manager and the executive level team. While the former was more interested in the sustainability dimensions of supply chain risk, the latter wanted an assessment of the broader level risks the company needs to consider. The project deliverables thus changed from quantifying and visualizing supply chain risk specific to climate change, to a framework that the company could use to assess broader risk categories in their supply chain. This transition occurred late in the project timeline, which resulted in the team scrambling to integrate previous work, and conduct research for the framework. Another challenge that slowed the progress of the teams’ work stemmed from the many discussions with suppliers and company representatives. In a time constrained project timeline such as 15.915, having to rely on the responsiveness of the parties involved in filling out the questionnaires strongly impacts the data collection process.

As previously discussed, the data collection and analysis process was an iterative process that, additional time and revisions would have improved the level of details, the accuracy and the reliability of data. Throughout the process of reviewing best practices, the team realized that to completely understand the company’s supply chain risk requires extensive time commitments, access to specific and real-time data, cooperation within the internal and external network of the client company, and perhaps a culture change that recognizes the importance of supply chain resilience and robustness.
Exhibit A: Existing Tools Quantifying Supply Chain Risk

See attached PDF
DHL Resilience 360 Dashboard
http://www.dhl.com/Resilience

Sourcemap
http://www.sourcemap.com/
LLamasoft ® Logic-Tools: www.logic-tools.com

Part I - Visibility

Part 2 - Scenario Analysis

Part 3 - Rapid Response
BSI Supply Chain Risk Exposure Evaluation Network (SCREEN):
Ecodesk™ Supply Chain Footprinting and E-Chain™ Supply Chain Integrated Solution:
https://www.ecodesk.com/footprinting

Oracle Rapid Planning provides full analysis of alternative scenarios

Oracle Advanced Planning Command Center
Ohio State University Supply Chain Resilience Assessment and Management Tool (SCRAM)

http://resilience.osu.edu/CFR-site/scram.htm

**Capability #6 --- Adaptability:** "Ability to modify operations in response to challenges or opportunities."

<table>
<thead>
<tr>
<th>C6 - Our organization is highly adaptable to changes in the market.</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither agree nor disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>C6.1 - We can quickly reallocate orders to alternate suppliers and reallocate jobs between different production facilities.</td>
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<td></td>
</tr>
<tr>
<td>C6.2 - We use strategic gaming and simulations to design more adaptable processes.</td>
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</tr>
<tr>
<td>C6.3 - We excel at seizing advantages from changes in the market.</td>
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<tr>
<td>C6.4 - We develop innovative technologies to improve operations.</td>
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</tr>
<tr>
<td>C6.5 - We continually strive to further reduce lead-times for our products.</td>
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<tr>
<td>C6.6 - We effectively employ continuous improvement programs.</td>
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</tr>
</tbody>
</table>

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Risk Exposure Index Example (following Simchi-Levi approach)

- Time-to-recovery (TTR) is the time it takes to recover to full functionality after a disruption
- Financial impact (FI) is lost sales during TTR
- The Risk Exposure Index (REI) is the maximum FI over all nodes in the supply chain

Source: Professor David Simchi-Levi, MIT

Exhibit B: Questionnaire

Mapping Risk Categories to Questions (by type of risk)

LEGEND:
- Regulatory
- Supplier
- Combined Utility Co. & Supplier
- Process Time
- Criticality
- Contracting
- % Business
- Regulations
- Communications
- Redundancy
- Past Performance
- Logistics
- Manufacturing
- Purchasing
- Business Strategy
- Product Design
- Product Selection
- Network
- Demand
- Geographic
- Locations

Climate Change Preparedness
Geopolitical Instability
Sourcing
Past Performance
Inventory
Redundancy
Communications
Regulations
% Business
Contracting
Criticality
Delivery
Validation & Verification
Capacity
Contingency Planning
Customization
Process Time
Utility Company Questionnaire

Company Name: ______________________________
Date: ______________________________
Supplier Name: ______________________________
Product Model ID: ______________________________
Product Name: ______________________________

For each of the following questions, please provide an answer on a 1 to 5 scale. If possible, use the Explanation column for actual values, ranges, etc.

<table>
<thead>
<tr>
<th>Product selection</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>The product we are purchasing is critical to our business</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>Regulations are affecting our work on a daily basis</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>Purchasing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>We have multiple possible sources from which we can acquire the product</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>This supplier has a good track record of reliability, quality and responsiveness</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>We maintain high levels of inventory (finished goods) of the product in-house</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>We have multiple alternatives that could be used in substitution of this product</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>We frequently speak with our supplier on the status of our order</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>List the locations of suppliers (manufacturing and distribution center) for this product</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>Regulations are affecting our use of this product</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>Which are the other main risks impacting your day to day work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logistics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How much time does it take to acquire the product once the product has been ordered?</td>
<td>0-1 week</td>
<td>1-2 weeks</td>
<td>2-4 weeks</td>
<td>4-8 weeks</td>
<td>&gt;8 weeks</td>
<td></td>
</tr>
<tr>
<td>Business Strategy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What percentage of your spend goes to this supplier?</td>
<td>0-5%</td>
<td>6-10%</td>
<td>11-20%</td>
<td>21-30%</td>
<td>&gt;31%</td>
<td></td>
</tr>
<tr>
<td>How much do terms and conditions vary between contracts?</td>
<td>Not at all</td>
<td>Very Little</td>
<td>Somewhat</td>
<td>Quite a bit</td>
<td>A great deal</td>
<td></td>
</tr>
</tbody>
</table>
## Supplier Questionnaire

**Supplier Company Name:**

**Date:**

**Product Model ID:**

**Product Name:**

For each of the following questions, please provide an answer on a 1 to 5 scale. If possible, use the Explanation column for actual values, ranges, etc.

<table>
<thead>
<tr>
<th>Product Design</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>The product we are designing is specialized</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>Regulations are affecting our work on a daily basis</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>Which are the other main risks impacting your day to day work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Purchasing</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>The materials we need for our product are not easily available</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>Our suppliers have a good track record of reliability, quality and responsiveness</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>We maintain high levels of inventory (raw materials) to the product we are sourcing</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>We perform regular and thorough quality control on the products we are sourcing from our suppliers</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>We have multiple possible sources from which we can acquire the necessary components for this product</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>We frequently keep our customers updated on the status of their orders</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>The lead times of suppliers (components and raw materials) for this product</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>Which are the other main risks impacting your day to day work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Manufacturing</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulating the work on a daily basis</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>Which are the other main risks impacting your day to day work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In terms of percentage, how much of the capacity level is being built?</td>
<td>1-20%</td>
<td>21-40%</td>
<td>41-60%</td>
<td>61-80%</td>
<td>81-100%</td>
<td></td>
</tr>
<tr>
<td>What is the quantity of inventory of finished product at the manufacturing facility?</td>
<td>1 wk. demand</td>
<td>1-2 wk. demand</td>
<td>2-4 wk. demand</td>
<td>5-8 wk. demand</td>
<td>&gt;8 wk. demand</td>
<td></td>
</tr>
<tr>
<td>We have contingency plans in place for times when unforeseen circumstances such as geopolitical unrest or natural hazards will occur</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>How customized is the manufacturing process for this product (on a per order basis)?</td>
<td>Standard, not custom</td>
<td>Partial custom</td>
<td>Fully custom</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How much time does it take to manufacture an individual product from the time you receive the order?</td>
<td>0-1 day</td>
<td>1-5 days</td>
<td>5-10 days</td>
<td>10-15 days</td>
<td>&gt;15 days</td>
<td></td>
</tr>
<tr>
<td>We perform regular and thorough quality control on the products we manufacture</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Logistics</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>How long does it take to deliver the product once the product is manufactured?</td>
<td>0-1 week</td>
<td>1-2 weeks</td>
<td>2-4 weeks</td>
<td>4-8 weeks</td>
<td>&gt;8 weeks</td>
<td></td>
</tr>
<tr>
<td>How is the product delivered from the manufacturing location to National GHS?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regulations are affecting our work on a daily basis</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
<tr>
<td>Which are the other main risks impacting your day to day work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What percentage of product unit cost is associated with transportation?</td>
<td>0-5%</td>
<td>6-10%</td>
<td>11-20%</td>
<td>21-50%</td>
<td>&gt;50%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Business Strategy</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>How much longer do you anticipate offering this product?</td>
<td>10+ years</td>
<td>5-9 years</td>
<td>3-6 years</td>
<td>3-5 years</td>
<td>0-2 years</td>
<td></td>
</tr>
<tr>
<td>What percentage of your suppliers do you select on an annual basis?</td>
<td>0-5%</td>
<td>6-10%</td>
<td>11-20%</td>
<td>21-50%</td>
<td>&gt;50%</td>
<td></td>
</tr>
<tr>
<td>What percentage of your business comes from National GHS?</td>
<td>0-5%</td>
<td>6-10%</td>
<td>11-20%</td>
<td>21-50%</td>
<td>&gt;50%</td>
<td></td>
</tr>
<tr>
<td>How much do terms and conditions vary between contracts?</td>
<td>Not at all</td>
<td>Very little</td>
<td>Somewhat</td>
<td>Quite a bit</td>
<td>A great deal</td>
<td></td>
</tr>
</tbody>
</table>
Exhibit C: Dashboard

Supplier A

Product: Gas Circuit Breaker
Summary of Use: These high voltage circuit breakers are ordered as needed.
Type of projects: Short-duration & Long-duration projects; initial serviced by product: installation and maintenance

Supplier Company Type: Large multi-national
Supplier Company Size: >100,000 Employees
Manufacturing Location: Pennsylvania, United States

Website References:
Health & Safety X Website, 2014 Annual Report
Supplier Compliance X 2014 Annual Report
Sustainability X Website, 2014 Annual Report
Performance Metrics X 2014 Annual Report
Risks to Business X 2014 Annual Report
Financial Stability X 2014 Annual Report
Business Sectors X 2014 Annual Report, 25% to Energy & Electric Systems

<table>
<thead>
<tr>
<th>Metric</th>
<th>Supplier A</th>
<th>Supplier B</th>
<th>Supplier C</th>
<th>Supplier D</th>
<th>Supplier E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Change Vulnerability</td>
<td>1.10%</td>
<td>1.09%</td>
<td>1.11%</td>
<td>1.12%</td>
<td>1.13%</td>
</tr>
<tr>
<td>Climate Change Preparedness</td>
<td>2.00%</td>
<td>1.99%</td>
<td>2.01%</td>
<td>2.02%</td>
<td>2.03%</td>
</tr>
<tr>
<td>Geopolitical Instability</td>
<td>3.94%</td>
<td>3.93%</td>
<td>3.95%</td>
<td>3.96%</td>
<td>3.97%</td>
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<tr>
<td>Breach</td>
<td>2.0</td>
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<tr>
<td>Past Performance</td>
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<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
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<tr>
<td>Inventory</td>
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<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
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<td>Redundancy</td>
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<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
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<td>Communications</td>
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</tr>
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<td>Regulations</td>
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<td>4.3</td>
<td>4.4</td>
<td>4.5</td>
<td>4.6</td>
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<td>Percent Business</td>
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<td>2.3</td>
<td>2.3</td>
<td>2.3</td>
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<td>Contracting</td>
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<td>Criticality</td>
<td>2.1</td>
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<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Validation &amp; Verification</td>
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<td>2.2</td>
<td>2.2</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Capacity</td>
<td>3.3</td>
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<td>3.3</td>
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<td>Contingency Planning</td>
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<td>Customization</td>
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<td>Process Time</td>
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<td>2.0</td>
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<td>Delivery</td>
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<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
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</tr>
</tbody>
</table>

Matrix Notes:
1. Values obtained from ND-QUAL and WGI datasets (see attached maps for country values).
2. Values determined based on questionnaires responses.

Date: 9/3/15 Initial
Exhibit D: ArcGIS Maps

Vulnerability: Exposure, Sensitivity, And Ability to Adapt to Climate Change

Source: University of Notre Dame ND-GAIN Index, 2013
Political Stability and Absence of Violence/Terrorism

Source: World Bank Worldwide Governance Indicators, 2014 Update
Readiness: Portions of Economy, Governance and Society That Affect Adaptation Projects

Source: University of Notre Dame ND-GAIN Index, 2013