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Developing a Logistics Risk Assessment Tool

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Abstract

Economies around the world have thrived in the wake of the development and keen understanding of effective supply chain management practices. As a result, organizations have become more dependent on other organizations to move their products and services to completion due to complex sourcing and shipping arrangements that have precipitated from the formation of sophisticated supply chains. A supply chain is in general a flow of products or services. When this flow is disrupted or halted, disastrous consequences can ensue. In the worst cases, such as with a disaster relief organization like the American Red Cross, disruptions in supply chains could mean the loss of human life. Although more supply chain managers recognize that disruptions along supply chains can cause millions of dollars in lost revenue and large losses of goodwill, very few know exactly what risks their organizations are exposed to. The aim of this research is to better understand what risks are present along each point in the supply chain – both internally and externally – and to develop a way to assess those risks. Furthermore, this research aims to understand how to mitigate these risks for organizations. Ultimately, the goal is to employ these findings in the form of a web tool that surveys users about their supply chain, assesses their current levels of risk, and suggests ways to mitigate this risk.

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1 Introduction

Over the past century, technological breakthroughs have occurred at an almost unfathomable rate. Consequently, businesses and manufacturers have been able to take advantage of these breakthroughs and realize tremendous success by producing at ever-increasing levels. This has created the need for long, complex supply chains. Supply chains are channels of distribution beginning with the supplier of materials or components, extending through a manufacturing process to the distributor and retailer, and ultimately to the consumer (Collins English Dictionary, 2015). The development of these supply chains has made a tremendous positive impact on the world, with more consumers satisfied with a wider variety of products than ever before.

While effective supply chain management practices have their advantages, many approaches result in a lack of direct control on when materials for products arrive. This increased reliance on external suppliers can lead to delays in manufacturing and deliveries, and/or low quality levels if the supplier is not performing as expected (Tan et al., 1999). This underperformance could be due to some inherent problem with the supplier or an unavoidable disruption in their business environment, such as a strike or a natural disaster. In the past, competition was amongst organizations, but now it is pitting entire supply chains against each other. The organizations with the strongest supply chains will outperform their less efficient competitors (Li et al., 2006). As the world becomes more reliant on these complex supply chains to which companies owe much of their successes, it will be vital for organizations to know exactly what risks they are exposed to and how to avoid them.

Potentially disastrous consequences can be a result of ignorance of risks along the supply chain. This is clearly evidenced by the fire that consumed large portions of a Philips Electronics

plant in 2000 (Chopra and Sodhi et al., 2014). This plant was a producer and supplier of cellphone chips, perhaps the most integral part of a cellphone. Two of their major customers were Ericsson and Nokia. One would presume that the fallout from this fire hindered both Ericsson and Nokia's abilities to keep producing their cellphones. While both of them were extremely dependent on Philips' cellphone chips, Nokia was able to find another supplier in just a few days. Ericsson, however, spent an entire month attempting to find another supplier, resulting in a loss of $200 million. This led to a downward spiral for Ericsson that they never truly recovered from, while Nokia's profits rose 42% in 2000, despite the incident (Mukherjee et al., 2008). It is important to understand that disruptions of this magnitude can occur in any organization from risks that are both directly and indirectly controlled by that organization.

The previous example was a preventable disaster that could have been completely avoided had the proper infrastructure and systems been in place. Some supply chain disruptions are like this – totally unavoidable if foreseen – while others are not avoidable. The latter type of disruptions is mostly a result of natural disasters, which can have tremendous negative impacts on the world economy.

One such disruption caused by natural disaster was the Great Tohoku Earthquake and Tsunami of 2011. This disaster shut down Tier 1 and 2 automotive parts suppliers and original equipment manufacturers (OEM) such as Toyota for several weeks. Due to this massive disruption, it was estimated that 4 million units of vehicle production were lost (Canis et al., 2011). The month after this disaster occurred, production was down 80% in Japan, 15% outside of Japan, and 13% globally (Robinet et al., 2011). The loss of production had tremendous economic repercussions, but it also resulted in significant social consequences. At the time it was estimated that this disaster could affect almost 400,000 Americans' jobs (Japan Automobile

Manufacturers Association et al., 2011). The automotive industry had just begun recovering from the setbacks of the recession several years prior, and this disruption was a major blow to that progress. That is almost half a million Americans, who could potentially be at risk of poverty due to a single event in a single country.

While this was not a preventable disruption, many of the negative consequences that precipitated from this event could have been mitigated or even avoided with proper planning. Having a diversity of suppliers and transportation providers is critical to a high level of resilience in a situation like this. Many other risk mitigation techniques would have prevented these disastrous results had they been in place. Regardless of whether the event itself is preventable or not, there are always measures that can be taken beforehand to limit the financial and socioeconomic consequences of a disaster.

In order to help organizations foresee risks they would not otherwise, a logistics risk assessment web tool was being designed. The goal of this tool is to rate an organization's current readiness for supply chain disruptions and help them identify the areas with the most potential for improvement. To introduce the framework and logic of the tool, a careful literature review was conducted to understand what the ideal conditions and actions for risk mitigation are and was translated into a logic for organizations' performances to be measured against. This tool is capable of conducting a broad assessment of an organization's capability of handling risks and for relaying the results of that assessment to users.

2 Literature Review

To understand the elements necessary for an effective risk assessment tool, an extensive literature review was conducted. The background information about supply chain risk

management and agreed-upon best practices was one part of the focus of the literature. The other focus was delving into other tools with similar applications to this tool to develop metrics, algorithms, and performance measures for the logistics risk management tool.

2.1 Supply Chain Risk Management

The introduction of this paper focused on disasters that have occurred along certain organizations' supply chains, leading to major disruptions in flow and massive shortages of end product. In this section of the literature review, the focus was on techniques that aim to mitigate the risk associated with such disasters. All of these techniques fall under the umbrella of Supply Chain Risk Management (SCRM) and have the overarching purpose of mitigating the likelihood of disruptions that would interrupt the continuity of normal business operations and processes (Supply Chain Risk Leadership Council, 2011). It should be noted that SCRM is made up of two components: resilience and vulnerability. In this context, resilience is defined as reducing the effects of a disruption, while vulnerability is reducing the likelihood of that disruption from occurring (Zsidisin, 2003).

Many organizations would be tempted to start the SCRM process by identifying their risks and managing those immediately; however, this approach could lead to fundamental misunderstandings of the sources of risk along the supply chain. This misunderstanding would most likely result in a treatment of symptoms rather than finding root causes of problems. In order to avoid this misstep, organizations should start the SCRM process by understanding and pinpointing their internal and external environments (Supply Chain Risk Leadership Council, 2011). They should strive to understand all risks associated with their workforce, internal processes, locations of business activities, etc.

After taking the time to thoroughly understand their environments, organizations can then take on the task of finding risks and mitigating or eliminating them. This process involves the identification of the risk, assessment of its potential impact, and then taking action to reduce the probability of occurrence of this risk (Kilubi et al., 2015).

As is with many other business processes, there are best practices that are established organically through learning and application. Over time, industries gain enough experience to see which practices are successful and which ones are not. As the idea of supply chain management has matured, best practices in SCRM have begun to be solidified. This does not mean that every organization takes part or even knows about all best practices, but it does mean that a fairly comprehensive set of best practices in SCRM has been developed when looking at the business landscape as a whole. The great aspect about best practices is that they have been tried by many different organizations in different industries and have still gained widespread adoption as being the best.

Due to this resilience, best practices seemed like a great framework to base the Logistics Risk Management Tool on. In order to do this, an "ideal" supply chain had to be developed. This meant going through literature to understand best practices along every major part of the supply chain. This process is described in depth in Section 3.1 Best Practice Selection. Creating this ideal supply chain would allow the tool to have something to compare individual organizations against, in order to show them where they fell in SCRM against a supply chain comprised of best practices.

2.2 Similar Tool Review

Through the literature review, no other tools with the same utility and goal as the Logistics Risk Management Tool were discovered; however, many other tools with similar

functionalities were found and reviewed to build a framework for the logic and components necessary to develop such a tool. Literature was reviewed so as to find other tools that used best practices as a basis and then tried to understand the logic of these tools.

One such tool that ended up being a major contributor to the Logistics Risk Management Tool was a tool called the Inventory Management Readiness Assessment Model developed by previous University of Arkansas student. This tool and the research that went into its development laid a great foundation for the methodology that would be used in the development of the Logistics Risk Management Tool. While it was a somewhat different topic of research, the inventory tool was based on best practices and compared specific organizations against best practices (Castrodale, 2014). This was a great basis for how to compile best practices and implement them into quantitative, comparable attributes.

Another important aspect of similar tools that was reviewed was a weighting system that gives different weights to different attributes – or in this case best practices – based on how important they are to the system as a whole. A couple papers highlighted this method in a way that could be translated into the Logistics Risk Management Tool. In an attempt to assess the value of different projects Home Depot could pursue, Feng et al. (2008) developed a matrix with all of the different objectives of a new Home Depot location broken into different categories. They then gave each objective a weight of importance. The weight of each category normalized in such a way that the normalized weights of each of the five categories summed up to 1. They then rated each option on a scale from 0 to 10 in each objective, based on how well each option would perform the objective. These scores were summed up and multiplied by the normalized weights of each objective, which gave the overall score of each option.

While there is really no need to assess multiple alternatives when trying to achieve the minimum level of risk in a supply chain, the model that Feng et al. laid out seemed to be very applicable to rating best practices and their importance in the overall system. Each objective – each best practice in our case – can be given specific value measures, which aid in allocating different levels of importance and in understanding the effects of doing or not doing a best practice.

An important attribute that is not addressed in Feng et al.'s model is the variation in these value measures. Variation is very critical, because it can have a huge effect on the importance of a certain objective. If, for example, it was the best practice to real-time data available for analysis, there could be huge swings in availability of data depending on different situations. To continue with the example, imagine that this best practice was the second most critical best practice in mitigating supply chain risks, but it had by far the most variation in availability and the highest ranked best practice had very low variation. This would make accounting for real-time data analysis the most important practice, because its wild swings in availability could have a larger impact on the system than the highest ranked best practice. This idea of including variation as a component of importance to the decision is the basic premise of more advanced Multiobjective Decision Analysis techniques (Parnell, 2008).

3 Research Methodology

The best practices discovered in the literature review were much larger in quantity than what was actually going to be necessary for the tool. Steps were taken to reduce this number into a concise, yet comprehensive list of best practices that would properly address all aspects of supply chain risk management.

3.1 Best Practice Selection

There are many different areas of SCRM that must be addressed when seeking to eliminate potential disruptions. The literature review had to be broken into five different categories all with the same goal of building resilience in the supply chain to minimize the impact or frequency of disruptions. The aim in splitting the areas of focus up was to find best practices in each of those areas that could late be assessed by the tool. These five areas of SCRM can be seen in Figure 1: Areas of Focus.

The first step taken in this process was to eliminate any redundant best practices. The next iteration was to remove any best practice that could possibly fall into another category or be encompassed by a different best practice. This rendered four best practices in the managerial level, sourcing, warehousing and transportation, and inventory and production areas and two best practices in the information systems area.

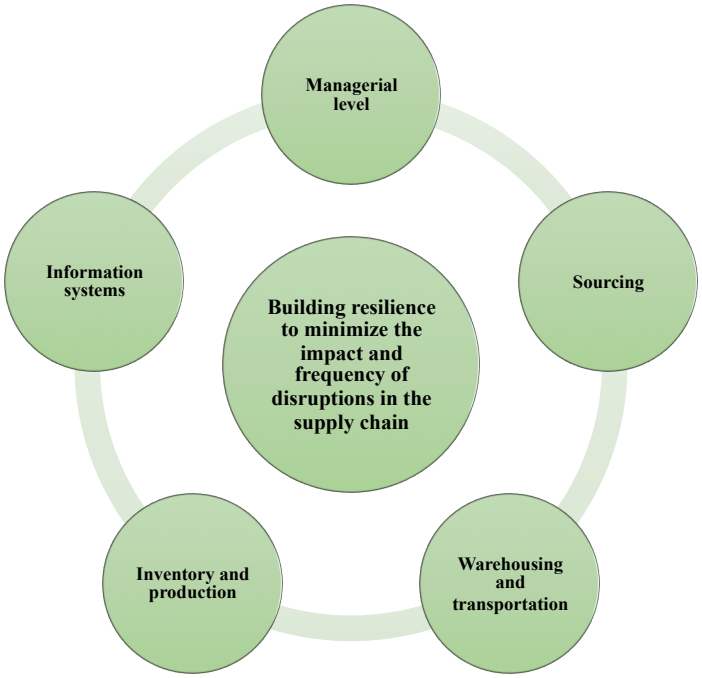

Figure 1: Five Areas of SCRM

3.1.1 Managerial Level

The managerial level area of SCRM focus involves executive level decisions that can be made to directly implement to decrease supply chain disruptions. The first area of focus within the managerial level is focusing on the weakest links in the supply chain, which the following practices highlight. The first best practice discussed in this area was the rehearsing and testing of systems through periodic staged events (Kleindorfer et al., 2005). This practice allows an organization to tangibly see where the disruptions might occur in any given staged event they might think of. The next task organizations could do to mitigate supply chain risk would be to develop methods and metrics of evaluating suppliers and transportation providers (Slone et al., 2007). It is critical that executives be involved in these decisions, because only key performance indicators (KPIs) that could have an effect on the bottom line should be used. These KPIs should measure the impact and likelihood of disruptive events occurring to or because of an organization's suppliers or transportation providers. Another step companies could take would be to evaluate technologies used in-house, upstream, or downstream to assess whether or not they are up-to-date (Slone et al., 2007). One of the easiest and most effective steps executives should be taking to mitigate risk is communicating clearly and regularly with staff to ascertain early warning signs of supplier trouble (lengthening cycle/delivery times, top management changes, etc.) (Institute for Business & Home Safety, 2015).

Another area of focus for managers would be having backup or contingency plans in case unavoidable disruptions occur. One of the most important backup plans is having an extremely reliable insurance company with maximum coverage, so cash flows will not be impeded (Travelers, 2013). In reference to actual product flow, executives want to make sure they have backup plans accounting for all areas of the supply chain.

To ensure buy-in of the entire supply chain, it is a critical practice that executives implement collaborative planning and/or continuous replenishment programs. This involves building deep relationships with suppliers that allow for regular tests, information sharing, and frequent conversations to understand their concerns (Turner, 2011). One of the most effective approaches to accomplish this practice is to use continuous replenishment software that allows users to monitor suppliers' inventories and other metrics (Prud'homme, 2008).

Perhaps the most important task executives should practice in SCRM is involvement. One simple step in this practice is having regular annual or quarterly briefings on supply chain risk exposure and what is being done to mitigate said exposure (Supply Chain Risk Leadership Council, 2011). Another way for executives to stay involved is to have quick access to critical SCRM data through easy-to-reach data dashboards that are updated regularly (Handfield et al., 2011).

3.1.2 Sourcing

Many major sourcing eruptions arise due to an organization's sole-supplier having a disruption; therefore, convention says to have multiple sourcing options to ensure supplies can be sourced even if a catastrophe does occur at one supplier's plant. Not only is it important to have multiple suppliers for one product, but it is also critical to have suppliers for the same material from different geographies and with multiple manufacturing sites (Pochard, 2003).

Another best practice in sourcing is to increase the frequency of monitoring and auditing supplier performance. With proper metrics for evaluation this could provide early indications of underperformance and disruption.

Having clear vendor management policies is critical to success and avoidance of disruptions in the supply chain. These policies should include Service Level Agreements.

Without these agreements, fill-rates and in-stock rates could see major fluctuations, which would be sure to halt the flow of material in the supply chain (Chithur, 2015).

Ideal sourcing should also include the use of incentives and pricing to increase cooperation amongst suppliers. This is much like collaborative planning, but it focuses heavily on suppliers and what can be done to encourage their cooperation. These types of incentives are usually beneficial for everyone and reduce total costs along the supply chain (Vakil et al., 2011).

3.1.3 Warehousing and Transportation

One of the most critical practices in warehousing and transportation is to have high visibility of products and their movements at all times. RFID and GPS technology are musts for maximum visibility of products. As technologies develop and advance though, it is critical that management stay up-to-date on technologies, always using the ones allowing for the highest visibility (Prest, 2012). This allows management to know instantaneously when a disruption has occurred, so that a contingency plan can be quickly implemented.

Another important step that must be taken in warehousing and transportation is to diversify transportation modes as much as necessary. This means using not only different carriers, but also a variety of modes of shipment, such as truckload, less than truckload, rail, etc. This is critical, because it allows organizations to send more critical shipments on quicker modes of transportation. Another method of diversification is to own at least a small fleet for the most critical components or products to be shipped on. These practices keep non-critical products from taking up space and impeding flow of critical products on the way to the customer (Urciuoli, 2015).

In the same way that suppliers should be monitored and audited so should shippers. Many of the same steps must be taken here as should be taken with the auditing suppliers. One of the

distinctions between suppliers and shippers though, is that security is a much larger concern with shippers. Due to this, it is necessary that policies for security are employed, strictly enforced, and carefully monitored to mitigate the risk of lost, stolen or broken items in transit (Ellison et al., 2010).

Another critical practice in warehousing and transportation is maximizing the security of products. Sometimes it is difficult to know which transportation providers can be trusted to secure and safely transport an organization's products. In this case, one helpful task to ensure security is to do careful background checks on service providers, particularly if these are foreign providers (Federal Bureau of Investigation, 2016).

3.1.4 Inventory and Production

Inventory and production disruptions could involve any number of incidents. An example of a disruption in production would be a critical stamping machine breaking down and requiring maintenance. Likewise, an inventory disruption could occur if there was some sort of damage, such as fire damage, the inventory underwent. It is therefore vital that organizations use best practices to try to avoid or mitigate the impacts of these occurrences. One way to do this would be to pick an inventory management system capable of forecasting demand and tracking inventory to the degree appropriate for the organization's product portfolio.

Another way to accomplish risk mitigation in inventory and production is to minimize quality-related issues. Use Total Quality Management principles to reduce the number of products recalled or reworked (Sparta Systems). To avoid equipment breakdown, it is also critical that organizations perform scheduled maintenance on all machines that are remotely necessary to the production process (Carbonara et al., 2014).

Much like warehousing and transportation and sourcing, it is necessary that inventory and production be continuously and regularly monitored and scored on critical KPIs that can be indicative of possible disruptions.

One of the most critical practices in inventory and production is to maintain flexibility in production. Operating at 100% utilization may be efficient, but it leaves no room for error when a disruption in the process occurs. It is recommended that production runs always operate under 100% efficiency (Lapide, 2008). This practice also involves the shifting of resources to increase flexibility. Flexibility increases when production levels are spread out across all production lines and facilities fairly evenly (Tang et al., 2008).

3.1.5 Information Systems

Information systems are becoming ever more ubiquitous and critical to the flow of products through the world's supply chains. With this still being a new area to manage risk within the supply chain relative to the four other areas, there is great potential for improvement and impact. The Big Data movement over the past few years has shown the power of mining raw data and translating it into meaningful models and solutions and how that power can transform organizations financially. This same tactic can be used to transform the way risks are identified and mitigated throughout supply chains.

One way to reduce disruptions along the supply chain is to invest resources into ensuring all computing systems are properly secured. Almost all parts of an organization are tied to a computing system. If some sort of attack or disaster were to affect the function of these computing systems and an organization was not properly prepared, disastrous consequences could ensue. It is best practice to ensure a thorough background check is run on anyone and

everyone who is granted access to any computing system within the organization (Swanson, M. et al., 2010).

Security measures are absolutely necessary to preventing disruptions in supply chains, but the use of Big Data provides a more progressive – rather than reactive – approach to identifying risks. One way this can be done is by utilizing huge data warehouses kept by governments or other public institutions. Organizations can use this data to assess risks associated with certain properties they own or are looking to acquire or global hazards that might be eminent (Kelly et al., 2010). Another technique that could lend well to mitigating disruptions is social media and other live web data. Utilizing this data could provide insight into global events occurring in areas relevant to an organization's operations long before the news would have made its way to the organization otherwise, allowing them extra time to implement a contingency plan (Inbound Logistics, 2012). Big Data has also been being widely used in predictive analytics with great success. Government entities have already been researching and revealing great potential in using Big Data to mitigate the impact of natural disasters (Tellman et al., 2015). These same techniques could prove very useful in analyzing past supply chain disaster and predicting future disasters through key triggers in data.

3.2 Expanding the Utility of the Identified Best Practices

Supply chain risk management is an extremely broad topic that is not bound by industry boundaries or geographical constraints. At the outset of the project, the goal was to send out this list of best practices to industry partners to have them verify, validate, and even offer other best practice solutions. Upon further review, it became clear that this approach might yield misleading results. Due to the broad nature of SCRM, many different industry partners in various industries would have to be sampled. Individuals from different corporations would most likely

rank best practices differently than others, making it difficult to ascertain what the actual and/or most important best practices were.

The next step in the process of compiling these best practices was to ensure that each one of them would contribute to the overall goal of building resilience in the supply chain to minimize the impact and frequency of disruptions. In order to do this, each best practice had to be verified as fitting into the category it was preliminarily placed in. In order to do an analysis of these best practices later, directions such as “increase”, “decrease”, “maximize”, or “minimize” had to be assigned to each one. The result of this process was a concise list of best practices that encompass all five categories of importance in SCRM: managerial level, sourcing, warehousing and transportation, inventory and production, and information systems. All of these best practices also can be assigned quantifiable numbers or functions, because they have been assigned directions in which it is advantageous for a company to follow the direction of that best practice. The figure below describes these best practices with their associated directions included.

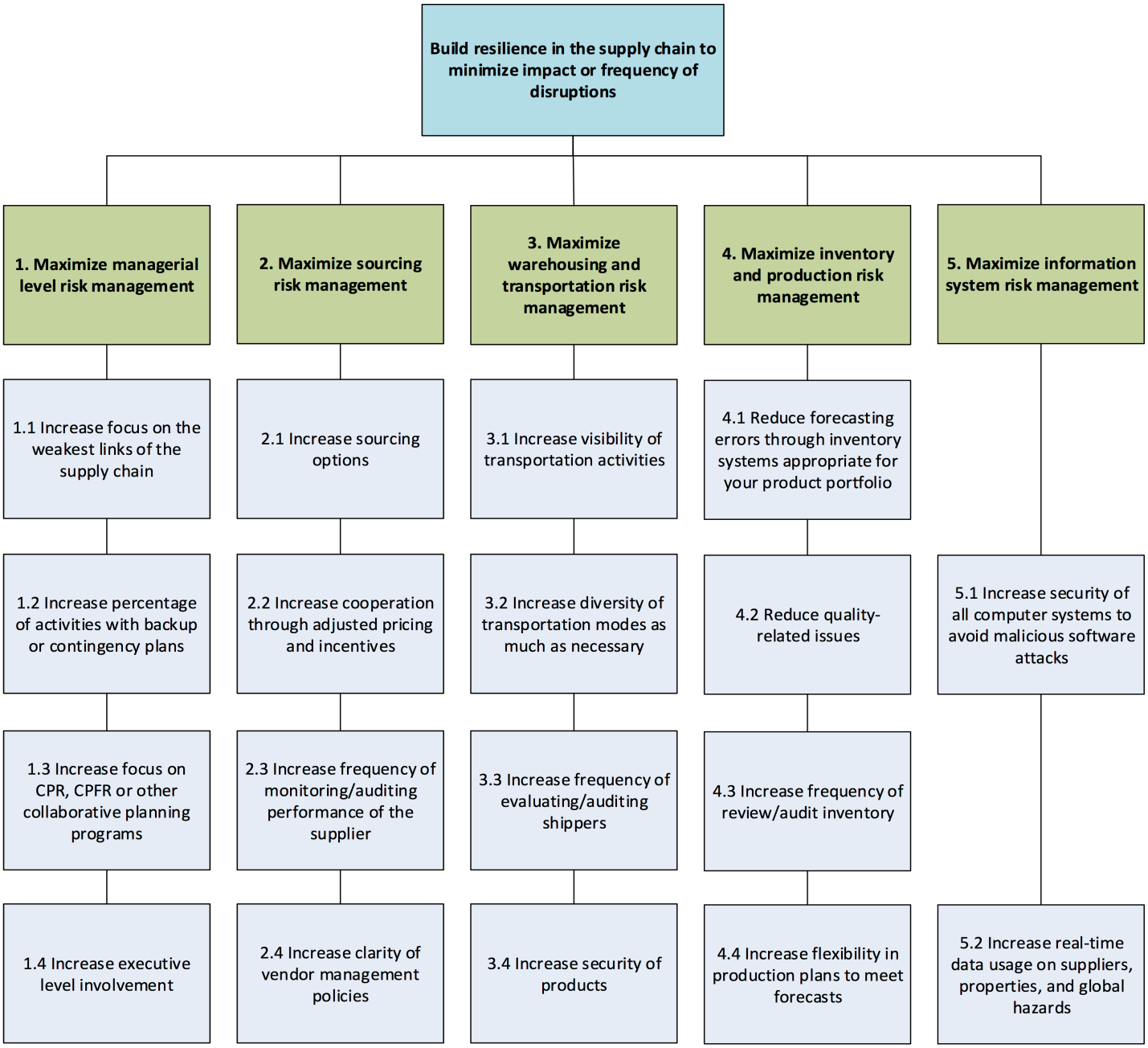

Figure 2: Best Practices in Five Focus Areas

3.3 Best Practice Component Compilation

While these best practices were carefully separated into distinct groups and were meant to be very specific, they might still not be in the form necessary to accurately assess organizations' adherence to these policies. For example, if an organization was asked whether or

not they take part in collaborative planning or to what extent they do, it would be difficult for them to accurately answer. The next step then was to review literature for component activities contributing to the extent to which each organization adheres to best practices.

The goal in finding these components of the best practices was to find tasks essential to the successful adherence to each best practice. Additionally, they also needed to be tasks that could be transformed into yes or no questions, so organizations could easily and clearly answer them in the assessment tool. After careful review of many components of each best practice, a final list was formed through the elimination of components that did not adhere to the aforementioned requirements. This process yielded four component activities for each of the best practices shown in Figure 2, and the complete list can be found in the Appendix.

4 Logistics Risk Assessment Tool

This section describes the process of the development of the logistics risk assessment tool that allows users to identify and assess risks across their supply chains. Many tools similar to this are built in Excel, but there are many advantages to building tools are hosted in other environments, including ease of access and user friendliness. For these reasons, the tool was developed as a web-based tool. Building an entire website for this tool allows for increased flexibility and ability to scale as opposed to many traditional Excel-based tools. The tool utilizes databases to capture and store all pertinent information from surveys while still allowing users to interface with the tool in a very easy fashion.

4.1 Excel Prototype Development

While a web-based tool was chosen as the instrument for the final version of this tool, building an Excel-based prototype of this tool is an extremely beneficial practice in laying the framework and the logic for the web tool. This is due to the immense amount of research that has already been done in decision analysis with accompanying Excel tools, such as the Multiple Objective Decision Analysis tool referred to in the literature review and written about in the *Wiley Handbook of Science and Technology for Homeland Security* (Parnell, 2008).

As was laid out by the research methodology there are five areas of SCRM, each with a group of best practices (a total of 18 best practices), and those best practices are made up of different component activities that collectively encompass the entire best practice (72 of those in all). The basic idea for the tool is to allow users to answer 'Yes' or 'No' to whether or not they do each of the 72 component activities. The collection of the answers about the component activities of each best practice represents to what extent the organization utilizes each best practice.

The first step in this process was to decide how critical each best practice is in preventing disruptions along the supply chain. Factors to consider for the criticality of these are the magnitude of disruptions it would prevent, the frequency of disruptions it would prevent, and the importance of its position along the supply chain. In order to quantify the criticality of the best practices, we decided to assigned importance in two different ways, but both ways would assign an importance level from 1 through 10 to each best practice. One way was to decide on the importance of each best practice from the vast amount of information compiled in the literature review. Another way of assigning importance that could be implemented would be allowing the users of the tool to decide on the importance of each best practice depending on the needs of

their particular organization. While this leaves companies vulnerable to blind spots and without a fresh perspective, it was a suggestion made by industry partners at a research conference. The former ranking option of each best practice in the tool is displayed in Figure 3.

Managerial Level	**Rank**
Increase focus on the weakest links of the supply chain	3
Increase activities with backup or contingency plans	5
Increase focus on CPR, CPFR or other collaborative planning programs	7
Increase executive level involvement	8
Sourcing	
Increase sourcing options	6
Increase frequency of Monitoring/auditing performance of the supplier	3
Increase clarity of vendor managemenet policies	2
Increase cooperation through adjusted pricing and incentives	1
Warehousing and Transportation	
Increase visibility of transportation activities	4
Increase diversity of transportation modes as much as necessary	6
Increase frequency of evaluting/auditing shippers (3PL and own fleet)	3
Increase security of products	4
Inventory and Production	
Reduce forecasting errors through inventory systems appropriate for your product portfolio	5
Reduce quality-related issues	6
Increase frequency of review/audit inventory	3
Increase flexibility in production plans to meet forecast	4
Information Systems	
Increase security of all computer systems to avoid malicious software attacks	8
Increase real-time data usage on suppliers, properties, and global hazards	6

Figure 3: Ranking of Best Practices

The next step in the process was to assign weights to each best practice regarding the variability in the practice. This is an extremely vital step, because variability can make low ranking practices more important in a system if variability is large enough in magnitude. The more a component can vary the more critical it is to the system that managers pay attention to it.

For this tool, the variability was estimated in large part to the magnitude of each best practice. For example, using real-time data involves using thousands of metrics and statistics, so naturally it will have a higher variability than the practice that reduces forecasting errors with different inventory systems. The number of different inventory systems available for an organization's product portfolio will be limited to just a few, so the variability in that best practice would be very low. The variability that was assigned to each best practice is shown below in Figure 4.

Managerial Level	**Variability**
Increase focus on the weakest links of the supply chain	10
Increase activities with backup or contingency plans	80
Increase focus on CPR, CPFR or other collaborative planning programs	60
Increase executive level involvement	30
Sourcing	
Increase sourcing options	50
Increase frequency of Monitoring/auditing performance of the supplier	40
Increase clarity of vendor managemenet policies	15
Increase cooperation through adjusted pricing and incentives	20
Warehousing and Transportation	
Increase visibility of transportation activities	25
Increase diversity of transportation modes as much as necessary	50
Increase frequency of evaluting/auditing shippers (3PL and own fleet)	40
Increase security of products	50
Inventory and Production	
Reduce forecasting errors through inventory systems appropriate for your product portfolio	10
Reduce quality-related issues	30
Increase frequency of review/audit inventory	40
Increase flexibility in production plans to meet forecast	60
Information Systems	
Increase security of all computer systems to avoid malicious software attacks	65
Increase real-time data usage on suppliers, properties, and global hazards	90

Figure 4: Variability Assignments for Each Best Practice

The next step was to normalize each weighting, including the variability assignment and the importance factor of each. It is necessary to normalize these weights, so that an accurate comparison can be made across each best practice and so the aggregate score of all best practices has intrinsic value. In order to do this, variability and importance were summed up and each best practice's variability added to its importance score was divided by adding the total variability and total importance together. With this type of normalization, all the normalized weights of best practices add up to 1 and each area of SCRM has a calculated weight between 0 and 1 depending on the variability and importance numbers of each category. This process is illustrated in the following example and was modeled after another Multiple Objective Decision Tool (Feng et al., 2008).

$$Total\ Raw\ Weight\ Importance = \sum_{i=1}^{18} Raw\ Weight\ Importance(Best\ Practice_i) = 84$$

$$Total\ Variability\ Assignments = \sum_{i=1}^{18} Variability\ Assignment(Best\ Practice_i) = 765$$

Best practice being weighted: Increase sourcing options

Raw Weight Importance: 6

Variability Assignment: 50

$$Calculated\ Normalized\ Weights = \frac{Raw\ Weight\ Importance + Variability\ Assignment}{Total\ Raw\ Weight\ Importace + Total\ Variability}$$

$$Calculated\ Normalized\ Weights = \frac{6 + 50}{84 + 765} = 0.07$$

Subsequent to this process, the survey that would capture the extent to which each organization did each best practice had to be created. This was done by translating each of the 72

component activities of the 18 best practices into yes or no questions that organizations could easily answer without much discrepancy. Each best practice has 4 component activities, so each activity makes up 25% of the value of the entire best practice. Therefore, if an organization answered yes to 3 out of the 4 components of a best practice, they would be awarded 75% of that practice's value. An example of this survey is shown in Figure 6.

Managerial Level

1.1 Increase focus on the weakest links of the supply chain

Do you rehearse and test systems through periodic staged events?
No
Do you develop methods and metrics of evaluating each supplier and transportation provider?
Yes
Do you evaluate technologies used in all parts of the supply chain to assess whether or not they are up-to-date and encouraging changes if no
Yes
Do you communicate regularly with staff to understand the early warning signs of supplier trouble?
Yes

1.2 Increase percentage of activities with backup or contingency plans

Have multiple plants manufacturing your product in case there is a disruption at one
Yes
Work with insurance companies to pick the right coverage to at least ensure that a disruption in cash flow will not happen
No
Have a backup plan for a disruption involving any of your suppliers or transportation providers
No
Have proper safety stock levels of inventory and try not to depend on only one supplier for any material
Yes

Figure 5: Sample Survey Questions

The final step in this development was to translate organization's answers to the surveys into a number that could be compared against an 'ideal' organization. As mentioned previously, whether or not a company performs none, some, or all of the component activities of each best practice determines the percentage of value awarded to that organization for that best practice. These scores are out of 10 and the 'ideal' organization has a 10 in every best practice. If an organization practices 3 out of 4 component activities in a certain best practice, they would then be awarded 7.5 points for that best practice. While this gives the value for each best practice, it is important that a way of aggregating all of these values is derived. In order to do this, I multiplied

the organization's score in each best practice (the percent of component activities practices times 10) by the corresponding calculated normal weight of each best practice and then summed these values for each area of SCRM. This gives the score of the organization in each of the five areas of SCRM. To obtain the total system score, I then added each of the scores from the five areas of SCRM of the organization, obtaining a value between 1 and 10.

Partial Objectives Hierarchy for Supply Chain Risk Mitigation	Comparison	
	Your Organization	Ideal
Build resilience in the supply chain to minimize im		
1. Maximize managerial level risk management		
1.1 Increase focus on the weakest links of the s	7.5	10
1.2 Increase percentage of activities with backu	5	10
1.3 Increase focus on CPR, CPFR or other collab	2.5	10
1.4 Increase executive level involvement	10	10
Section Scores	**1.26**	**2.39**
2. Maximize sourcing risk management		
2.1 Increase sourcing options	7.5	10
2.2 Increase frequency of Monitoring/auditing p	5	10
2.3 Increase clarity of vendor managemenet po	10	10
2.4 Increase cooperation through adjusted pric	7.5	10
Section Scores	**1.13**	**1.61**
3. Maximize warehousing and transportation risk n		
3.1 Increase visibility of transportation activiti	10	10
3.2 Increase diversity of transportation modes	2.5	10
3.3 Increase frequency of evaluting/auditing sh	5	10
3.4 Increase security of products	7.5	10
Section Scores	**1.24**	**2.14**
4. Maximize inventory and production risk manage		
4.1 Reduce forecasting errors through inventor	5	10
4.2 Reduce quality-related issues	10	10
4.3 Increase frequency of review/audit invento	10	10
4.4 Increase flexibility in production plans to m	7.5	10
Section Scores	**1.58**	**1.86**
5. Maximize information risk management		
5.1 Increase security of all computer systems t	2.5	10
5.2 Increase real-time data usage on suppliers,	7.5	10
	1.06	**1.99**
Overall Value	**6.3**	**10.0**

Figure 6: Best Practices Evaluation with Values

As depicted in Figure 6, the user can compare his or her organization's total score to the ideal of 10, but the user can also compare the organization to the ideal in the five areas of SCRM as seen in the lines titled "Section Scores". To further illustrate the gaps, a summary page with two different visualizations was created as the results page of the tool. This summary page

allows industry members to see quantitatively how far they are away from the ideal, but also graphically displays the magnitude and location of these gaps

Partial Objectives Hierarchy for Supply Chain Risk Mitigation	Calculated Weights	Calculated Normalized Weights	Variability	Please Place Raw Weights of importance of practice in this column (from 1 to 10)	Comparison	
					Your Organization	Ideal
Build resilience in the supply chain to minimize impact of frequency of disruption						
1. Maximize managerial level risk management						
1.1 Increase focus on the weakest links of the supply chain	0.24	0.02	10	3	7.5	10
1.2 Increase percentage of activities with backup or contingency plans		0.10	80	5	5	10
1.3 Increase focus on CPR, CPFR or other collaborative planning programs		0.08	60	7	2.5	10
1.4 Increase executive level involvement		0.04	30	8	10	10
Section Scores					**1.26**	**2.39**
2. Maximize sourcing risk management						
2.1 Increase sourcing options	0.16	0.07	50	6	7.5	10
2.2 Increase frequency of Monitoring/auditing performance of the supplier		0.05	40	3	5	10
2.3 Increase clarity of vendor managemenet policies		0.02	15	2	10	10
2.4 Increase cooperation through adjusted pricing and incentives		0.02	20	1	7.5	10
Section Scores					**1.13**	**1.61**
3. Maximize warehousing and transportation risk management						
3.1 Increase visibility of transportation activities	0.21	0.03	25	4	10	10
3.2 Increase diversity of transportation modes as much as necessary		0.07	50	6	2.5	10
3.3 Increase frequency of evaluting/auditing shippers (3PL and own fleet)		0.05	40	3	5	10
3.4 Increase security of products		0.06	50	4	7.5	10
Section Scores					**1.24**	**2.14**
4. Maximize inventory and production risk management						
4.1 Reduce forecasting errors through inventory systems appropriate for your product portfolio	0.19	0.02	10	5	5	10
4.2 Reduce quality-related issues		0.04	30	6	10	10
4.3 Increase frequency of review/audit inventory		0.05	40	3	10	10
4.4 Increase flexibility in production plans to meet forecast		0.08	60	4	7.5	10
Section Scores					**1.58**	**1.86**
5. Maximize information risk management						
5.1 Increase security of all computer systems to avoid malicious software attacks	0.20	0.09	65	8	2.5	10
5.2 Increase real-time data usage on suppliers, properties, and global hazards		0.11	90	6	7.5	10
					1.06	**1.99**
Overall Value	1.00	1.00	765	84	**6.3**	**10.0**

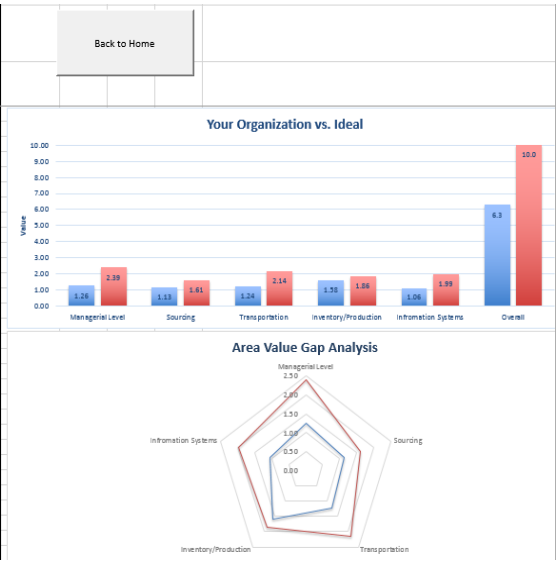

Figure 7: Summary Page of Excel Prototype Tool

4.2 Case Study

In this research, both variability and importance of each best practice were assigned a value based on a literature review and not necessarily on expert knowledge of the subject. In order to verify and validate that this tool was working as it should be and that it came to reasonable conclusions, we reached out to industry partners at a manufacturing company.

As discussed in Section 4.1 Excel Prototype Development, there were two different options for evaluating the importance of each best practice. One was deciding on the importance based on research and our own understanding of the supply chain and its inherent risks. In this case, the tool would just be a two-step process where the company would answer whether or not they do each component activity and then review their results based on our rankings of importance. The other was allowing companies to rank the importance themselves when they use

the tool. In this case the tool would be a three-step process where the organization ranks the importance of each best practice, answers whether or not they do the component activities of each best practice, and finally review how they rank against the 'ideal' organization.

In order to understand if there were any discrepancies between the two options, we asked two industry partners from a manufacturing company to use the tool both based on our own importance of best practices ranking (the two-step process) and their rankings of importance (the three-step process).

4.2.1 Results of Tool Based on Research Rankings of Importance

Based on our rankings the order of importance of the five SCRM areas from greatest to least was warehousing and transportation, managerial level, information systems, sourcing, and inventory and production. This is important to note, because it will have a large impact on the organization's score. The gap analysis from our use case showed that our users had a gap of 3.7 points away from the ideal overall. It also showed that the area with the largest gap was managerial level risk management. This was the second most important area and the users had their worst score in this area, so the managerial level area had a huge impact on their overall score. The results are depicted in the following two visualizations.

Figure 8: Organization vs. Ideal When Importance is Ranked by Research

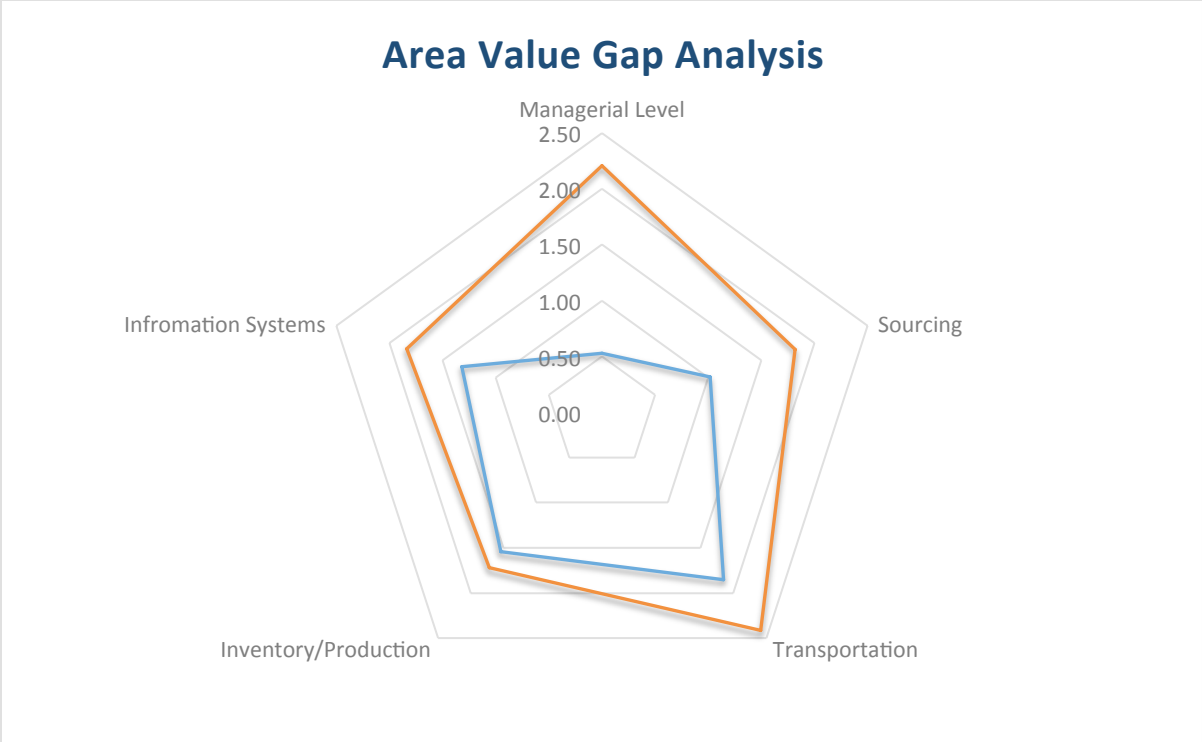

Figure 9: Area Value Gap Analysis When Importance is Ranked by Research

4.2.2 Results of Tool Based on Organization's Own Rankings of Importance

Based on manufacturing company's rankings the order of importance of the five areas of SCRM from greatest to least was warehousing and transportation, managerial level, information systems, sourcing, and inventory and production, which was the same exact order as the rankings from the previous approach yielded. The users' worse performance was still in the managerial level of risk management. Finding that there was not a large difference in the importance of the five areas of SCRM helped to validate the fact that either approach could probably be used and yield similar results. The results from this version of the assessment are highlighted in the following two figures. The only differences between this version of the tool and the previous version were slight discrepancies in the values of each SCRM area, but they were not large enough values to show a discernable difference between the two approaches.

Figure 10: Organization vs. Ideal When Importance is Ranked by the Organization

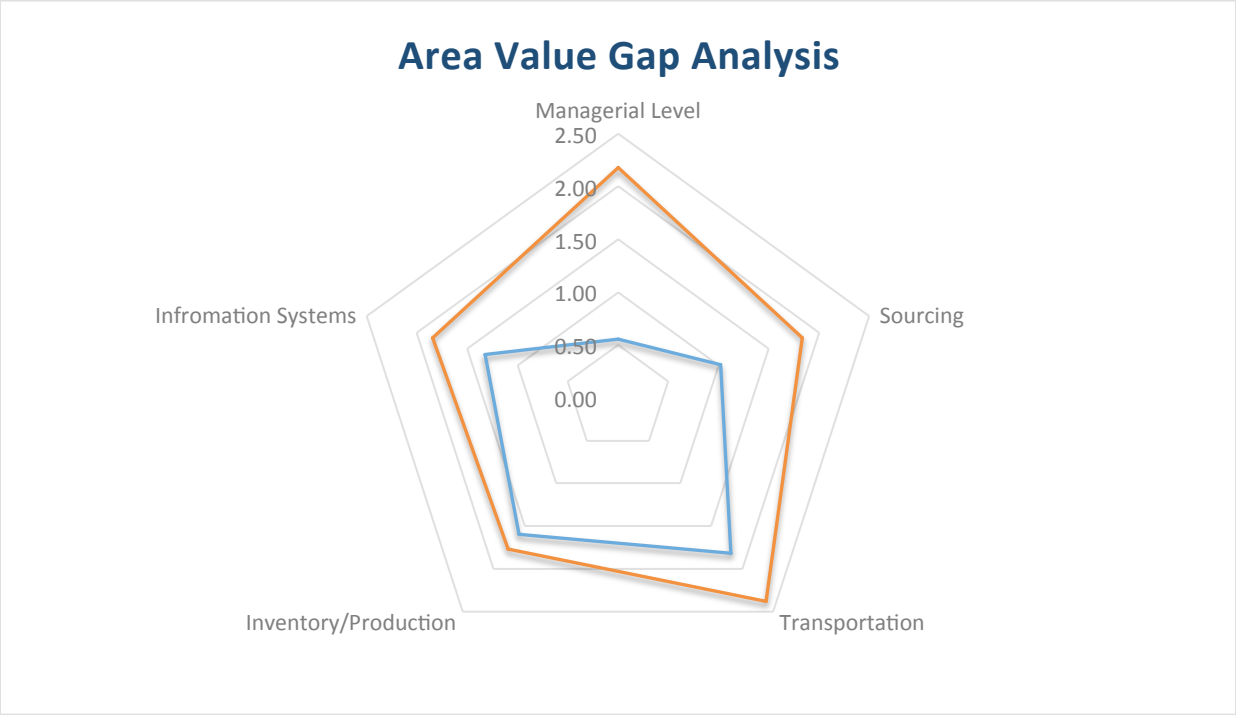

Figure 11: Area Value Gap Analysis When Importance is Ranked by the Organization

5 Conclusion

The culmination of this research work is the Logistics Risk Management Tool. This tool can be used to evaluate both hidden and apparent areas of risk in an organization's supply chain by providing a gap analysis against an 'ideal' organization. This type of tool can be very useful to logistics and supply chain managers in different industries, because it can help give them a different perspective than they might currently have to provide a possible paradigm shift and allow them to see threats that might have been hidden before.

The tool in its current state is a prototype that is meant to act as a foundation for the full tool that will continue being developed. The current assessment model asks very general questions without getting into organizations' size, demographics, or other specific factors;

therefore, it gives a very broad overview of the areas that are at highest risk of facing major disruptions. It does not however provide insight into the possible economic consequences of disruptions in those areas or risk mitigation techniques specific to that assessment. These types of results are the goal of the research though, which will continue for the foreseeable future.

The basis of this tool is a collection of best practices in SCRM from an extensive literature review. The literature was reviewed in many different layers. The first layer was understanding what SCRM was, the second layer was defining the major areas of SCRM, the third layer was studying the best practices in each of those areas, and the fourth layer was finding the individual activities that companies could partake in that comprise those best practices. This meant reading and rereading some of the same papers to get a more thorough understanding of how to structure this collection of thoughts into an actionable tool.

In the beginning of the research, there was a very heavy emphasis on what questions should be asked to gather good, quantitative data from users. This was very difficult, because we had not built a framework for exactly the types of questions we would want to ask organizations, so the first collections of survey questions for the tools ended up being very inconsistent, with some being very specific and cost-based, while others were very broad and covered many categories of SCRM. A better way to have gone about this would have been to start with understanding what SCRM is and what the major areas of SCRM are.

Despite the difficulty in starting this research, the end result was a tool that performed very well in a real use case. While only one user was able to try it, it still helped validate that the process used to score organizations was formulated in a very practical, yet valuable way. The users were pleased with the analysis, the logic, and the user interface. It was also very helpful to see that both ways of approaching ranking importance levels yielded the same importance

rankings for the five areas of SCRM. This helped show that either or both of the processes could be applied moving forward.

There is great value to organizations in periodically assessing their risk exposure. The more often risk exposure is considered the less likely massive disruptions are to occur. This tool should allow managers a good overview of their organization's current state of risk exposure and risk preparedness by showing them the areas in which they are deficient in utilizing SCRM best practices. While it is a very broad overview, little steps go a long way in eliminating risks from the supply chain. Simple "What if?" thoughts help to provide scenarios that could cause disruption and think of ways to mitigate them. The aim of this tool is not only to show the gaps in SCRM techniques, but also to catalyze managers' thought processes about supply chain risks to ultimately give them a broader perspective on the types of risk they may be vulnerable to.

6 Future Work

As mentioned in the conclusion of this paper, this tool is very useable and valuable in its current state, but it is at its foundational level at the moment. Research will continue on this tool to help not only provide the general gap analysis to each organization, but also a cost/benefit analysis tailored to the needs and makeup of the organization. The aim is to allow organizations that want to take action to mitigate risk a way to quantify whether it would be a worthwhile endeavor or not.

Another critical component of future work for this research is translating the Excel prototype into a web-based tool. In Section 4 Logistics Risk Assessment Tool, the advantages of a web-based tool over an Excel based tool were introduced. First of all, Excel user interfaces are usually cumbersome, especially for those with little exposure or regular interaction with Excel. The user interface is not near as intuitive as a website can be, and the chances of corrupting files

or formulas on accident is very high. Distributing an Excel tool to potential users is also difficult, and you may not ever receive any feedback on that information. People are much more familiar with websites and, for the most part, interact with them more often than they do Excel. This would allow users to easily navigate a website housing this tool with far less explanation or training. Websites are also much more robust than Excel tools, so distribution would be much more automatic. Once a web tool is hosted on a domain, it is instantly distributed to the world, rather than having to distribute Excel files and have organizations save them on their local machines.

One of the main advantages of a web tool over Excel files is the ability to store information in a database. An Excel tool, if used, would most likely be sent off to an organization never to be seen again. They might use it for their own purposes, but the likelihood of them reporting back with their results is unlikely. Even if they did report back and a database was used, the results would have to be input to the database manually. A web tool, however, would instantly store all users' information, responses, and results to its database while they are using the assessment. It may not seem all that useful to store data and results from each user, however, the "Wisdom of Crowds" theory could really be applicable here. The Wisdom of Crowds theory is simply the idea that, collectively, bad or wrong ideas are filtered out and the good ones remain (Surowiecki, 2005). It is likely that, individually, a researcher's idea of importance of a best practice or what is the best practice is just as wrong as an individual at an organization's ideas of these principles. With a web tool, when enough organizations have used the tool, the hope is that importance levels and maybe even some not so good best practice levels could be fleshed out.

With all of the data of each user's run through the tool saved in a database, it would be simple to compile importance data of each best practice by industry and use that in the analysis of company's supply chains rather than an individual's ideas of what that importance level should be. The online tool could also ask each user to suggest other best practices or suggest the removal of some of the best practices. If a significant enough portion responded with the same answers, it might be safe to assume that a best practice should be added or deleted from the list. With an Excel tool, these sorts of insights and the robustness of these analyses would simply not be possible to achieve, or they would not be scalable even if they were achieved.

Work has already been started on this web tool with a large portion of the initial framework having been completed. The website has been set up on a server within the Department of Industrial Engineering, so it is not available to the public but can be accessed from on campus. The database has been set up to make the website fully functional.

The basic setup of the current website is a login page, a home page, and two survey pages. The two survey pages contain information and response options identical to those within the Excel prototype. The first survey page allows users to rank the importance of each of the 18 defined best practices. The second survey prompts users to respond 'Yes' or 'No' to whether or not they do the component activities that make up the best practices just like the Excel prototype. The next page that should be built is a page that calculates and displays results in a fashion very similar to the Excel prototype. The following figures illustrate the login page, home page, and the importance ranking survey of the website and the user friendly interface they are housed within.

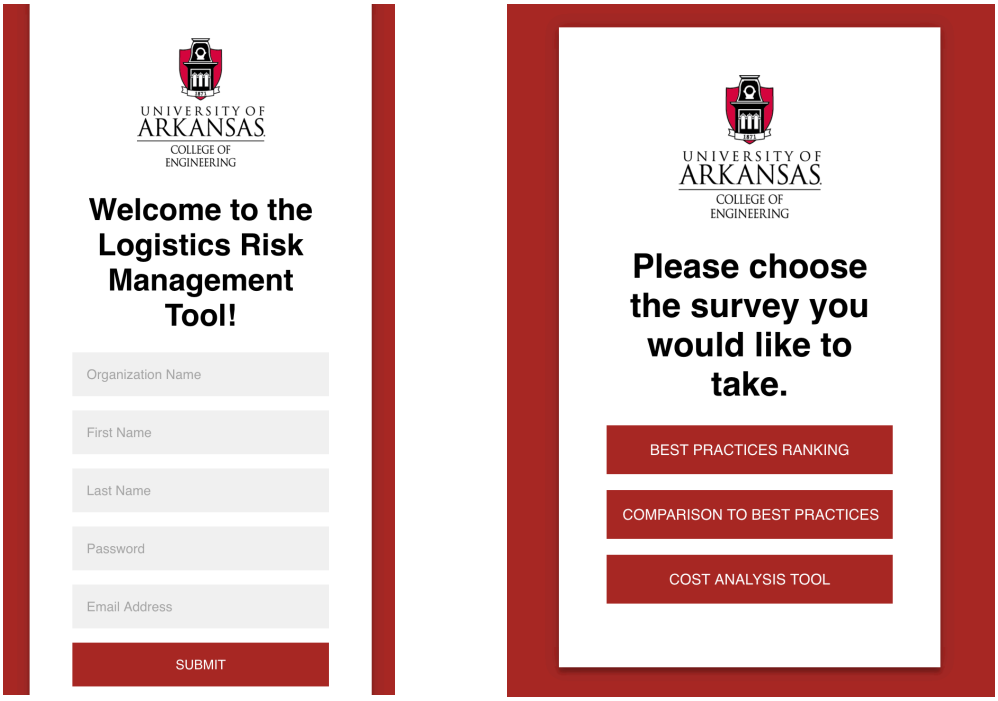

Figure 12: Login and Home Pages of Logistics Risk Assessment Web Tool

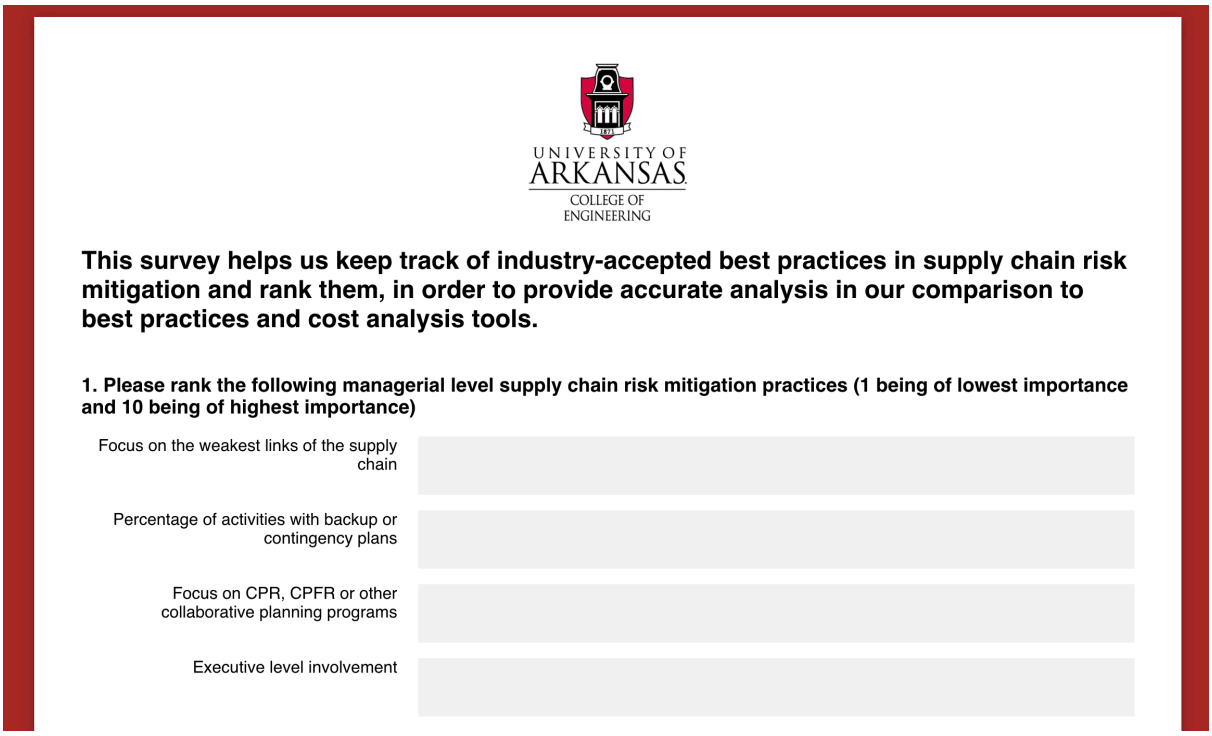

Figure 13: Importance Ranking Survey of Logistics Risk Assessment Web Tool

While it may seem redundant to produce a website that uses the same logic as the Excel prototype, we believe it is invaluable to the success of this research and the resulting tool. Housing this tool on a website immediately increases the usability, utility, functionality, flexibility, and robustness of the assessment.

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Appendix

List of Component Activities that Make Up Each Best Practice

Managerial Level

Increase focus on weakest links of the supply chain

- Rehearse and test systems through periodic staged events (Kleindorfer et al., 2005)
- Develop methods and metrics of evaluating each supplier and transportation provider (Slone et al., 2007)
- Evaluating technologies used in all parts of the supply chain to assess whether or not they are up-to-date and encouraging changes if not (Slone et al., 2007)
- Communicate regularly with staff to understand the early warning signs of supplier trouble (lengthening cycle/delivery times, top management changes, etc.) (Institute for Business & Home Safety, 2015)

Increase percentage of activities with backup or contingency plans

- Work with insurance companies to pick the right coverage to at least ensure that a disruption in cash flow will not happen (Travelers, 2013)
- Have a backup plan for a disruption involving any of your suppliers or transportation providers (Keenan, 2006)
- Have proper safety stock levels of inventory and try not to depend on only one supplier for any material (Christopher, 2003)
- Have multiple plants manufacturing your product in case there is a disruption at one (Christopher, 2003)

Increase focus on CPR, CPFR, or other collaborative planning programs

- Regular tests of supply chains that include all relevant parties (Turner, 2011)
- Information sharing with key suppliers (Turner, 2011)
- Frequent conversations with suppliers to understand their concerns (Turner, 2011)
- Have ability to monitor suppliers inventory and variability in inventory (Prud'homme, 2008)

Increase executive level involvement

- Executive sponsor, who is skilled in the area of greatest risk for the company, involved in the mitigation (Council, 2011)
- Briefing executive board in quarterly meetings on risks and what is being done to address them (Council, 2011)
- Allow quick access and visibility of any indicators of supply chain disruption risk to all executives (Event Planning Systems) (Handfield et al., 2011)
- Minimized gaps between customers, production, and executive leadership (geographically and in communication) (Cross et al., 2010)

Sourcing

Increase sourcing options

- As supplier or other risks increase, have multiple options to source the same supply (Ho et al., 2015)
- Source the same supplies from different geographical regions, both local and foreign (Pochard, 2003)
- Use a multi-tiered demand-based approach of purchasing a fixed amount of material from a single supplier, a variable amount from another supplier, and the spot market if demand exceeds the previous two (Pochard, 2003)
- Use suppliers with multiple manufacturing sites (Pochard, 2003)

Increase frequency of monitoring/auditing performance of the supplier

- Identify suppliers that have the most impact on your business (Kelly et al., 2010)
- Compare key performance indicators (plans and service levels) to other suppliers in the industry (Deloitte, 2013)
- Always have up-to-date information on suppliers to do these performance audits (Deloitte, 2013)
- Well developed set of performance metrics to perform these reviews of companies on (McBeath, 2013)

Maximize clarity of vendor management policies

- Maintain documentation of all ongoing and due diligence and monitoring (Chithur, 2015)
- Have well-thought out and criteria based service level agreements (SLAs) (Chithur, 2015)
- Audit policy is clearly set up and strictly enforced (Ellison et al., 2010)
- Policies for security employed and strictly enforced for suppliers (Ellison et al, 2010)

Increase cooperation through adjusted pricing and incentives

- Careful and accurate assessment of changes in pricing and how those affect demand of products (could cause understock or overstock of inventory if incorrect) (D&B, 2011)
- Ensure that incentives are both focused on short term and long term goals (Vakil et al., 2011)
- All levels of the organization are incentivized, not just top or lower level (Vakil et al., 2011)
- Offer incentives to suppliers for information sharing (Agiwal et al., 2008)

Warehousing and Transportation

Maximize visibility of transportation activities (e.g., GPS)

- High level of data and information sharing (Network, 2011)
- Up-to-date, such as GPS, technology used to monitor where materials and products are at all times (Prest, 2012)
- RFID tracking on all products (Prest, 2012)
- High level of visibility on not only shipments but requirement schedules (Christopher et al., 2004)

Maximize diversity of transportation modes as much as necessary

- If additional transport capacity is critical, own at least a small fleet (Urciuoli, 2015)
- When designating shipments you have the option to use different modes of transportation (Urciuoli, 2015)
- Using transportation providers with diverse array of routing options (Ruske et al., 2011)
- Minimize concentration of high value products on vehicles or in a storage facility at any given time to avoid piracy (Ruske et al., 2011)

Increase frequency of evaluating/auditing shippers

- Maintain documentation of all ongoing and due diligence and monitoring (Chithur, 2015)
- Have well-thought out and criteria based service level agreements (SLAs) (Chithur, 2015)
- Audit policy is clearly set up and strictly enforced with meaningful performance metrics (Ellison et al, 2010)
- Policies for security employed and strictly enforced for transportation providers (Ellison et al, 2010)

Maximize security of products

- Use warehouses and transportation within trusted governments and businesses (Network, 2011)
- Have sufficient scenario plans in place (Network, 2011)
- Go through careful background checks of your service providers, especially if in foreign countries (FBI, 2016)
- If products or materials are sensitive, ensure that transportation and storage providers have positive record of dealing with that type of product (Burnson, 2015)

Inventory and Production

Reduce forecasting errors through inventory systems appropriate for your product portfolio

- Decide between make-to-stock, make-to-order, and configure-to-order models depending on products and demand variability (Deveau, 2012)
- Use financial hedging against materials you are sourcing or holding in inventory, in order to decrease volatility in cash flows (Chu et al., 2009)
- Use available software to balance daily operational costs and risk mitigation (Kaminsky et al., 2011)
- Use stochastic-supply inventory models (Sazvar et al., n.d.)

Minimize quality-related issues

- Steps have been taken to minimize rework of products (Sparta Systems, n.d.)
- Quality tests are sufficient enough to minimize potential recalls of products (Sparta Systems, n.d.)
- Identify quality issues amongst suppliers and more of the upstream parts of the process (Sparta Systems, n.d.)
- Perform scheduled maintenance on machines involved in production processes (Carbonara et al., 2014)

Increase frequency of review/audit of inventory

- Best practice is to continuously monitor and audit inventory (Pasula et al., 2013)
- Address policies and procedures within the company's overall objectives, strategies, standards, ethics, goals, process aspirations and capabilities (Protiviti, 2004)
- High frequency of review for changed process (Protiviti, 2004)
- Have benchmarked results and report those at all levels (Intertek, 2013)

Maximize flexibility in production plans to meet forecasts

- Do not regularly schedule 100% utilization in production (Lapide, 2014)
- Delay material movement until demand levels are very certain, while remaining on schedule with the customer (Lapide, 2014)
- Shift production quantities across internal resources (Tang et al., 2008)
- Shift production quantities across different products (Tang et al., 2008)

Information Systems

Maximize security of all computer systems to avoid malicious software attacks

- Careful background check of any person or organization being granted access or authorization to systems (Swanson et al., 2010)
- Maintain a log of security related events or breaches (Swanson et al., 2010)
- If using best practice of computerized SCRM system, ensure adequate resources are allocated to information security to ensure proper implementation of guidance and controls (Boyens et al., 2013)
- If using best practice of computerized SCRM system, establish a set of roles and responsibilities that ensures that the broad set of appropriate stakeholders are involved in decision making, including who has the required authority to take action, who has accountability for an action or result, and who should be consulted and/or informed (Boyens et al., 2013)

Maximize data analyses on suppliers, properties, and global hazards

- Combine internal data and third-party data to increase visibility of suppliers (Kelly et al., 2010)
- Identify types of supplier risks that will most affect your suppliers and use live data to trigger warnings (Kelly et al., 2010)
- Use ICT systems that integrate supply chain data and governmental agencies (Urciuoli, 2015)
- Leverage social media to capture real-time critical data or events before they impact your organization (Inbound Logistics, 2012)