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How Disruptions Affect Global Supply Chains

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## ABSTRACT

In recent years, supply chains have become more global. The more widespread a supply chain becomes, the more susceptible it is to disruptions. This research will examine how different types of disruptions affect supply chains. It defines what a disruption is and provides real world examples of how a company is impacted when the supply chain is interrupted. Then, potential strategies to mitigate the effects of disruptions are discussed. While there are no clear-cut solutions to preventing disruptions, companies can act proactively and prepare for the disruption so the supply chain can still operate. The research also discusses how the COVID-19 pandemic is reshaping how supply chains are being managed. Since there is no disruption that can compare to a global pandemic, companies are forced to make quick decisions to keep the supply chain running. A risk analysis tool is then introduced to assist in explaining how damaging a disruption can be to a supply chain. The results of the research show that one of the best ways to build a resilient supply chain is to connect all the links within the chain from the suppliers all the way to the distributors. Connectivity leads to fast communication which is key when dealing with a disruption. This research concludes with three recommendations that can be use in any industry to make the supply chain more resilient.

**TABLE OF CONTENTS**

LIST OF FIGURES .....	iii
ACKNOWLEDGEMENTS .....	iv
Chapter 1 : Introduction .....	1
Chapter 2 : Background .....	5
History.....	5
Internal Disruptions.....	7
External Disruptions.....	9
Comparison .....	10
Chapter 3 : Strategies for A More Resilient Supply Chain.....	14
Chapter 4 : Characterization of Disruptions .....	23
Chapter 5: Conclusion.....	35
BIBLIOGRAPHY .....	37

**LIST OF FIGURES**

Figure 1: Empty Matrix .....	3
Figure 2: Linear Supply Chain.....	6
Figure 3: Circular Supply Chain .....	7
Figure 4: Disruption Comparison .....	11
Figure 5: Walmart Katrina Relief .....	13
Figure 6: Breakdown of Linear Supply Chain .....	21
Figure 7: Digital Supply Network.....	22
Figure 8: Machine Breakdown.....	24
Figure 9: Product Defect .....	25
Figure 10: Outdated Technology .....	27
Figure 11: Natural Disasters .....	29
Figure 12: Man-Made Disasters.....	30
Figure 13: COVID 19 .....	32
Figure 14: Completed Matrix.....	34

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## **Chapter 1 : Introduction**

Disruptions happen constantly throughout a supply chain. Certain types of disruptions can be avoided. An example of an avoidable disruption is stocking out of an essential product or component. Other events cannot be controlled, such as extreme weather and natural disasters. Companies cannot prevent disruptions such as natural disasters from happening, but they can make their supply chains resilient so that production can still occur after the event is over. For example, a company could have multiple factories in the United States that produce the same items. If one of the factories is located in Florida and a hurricane strikes the area, that factory would have to shut down, but the company would still be able to produce at the other plants. The overall goal of building resilient supply chains is being able to adapt to numerous scenarios that could impact the flow of the supply chain.

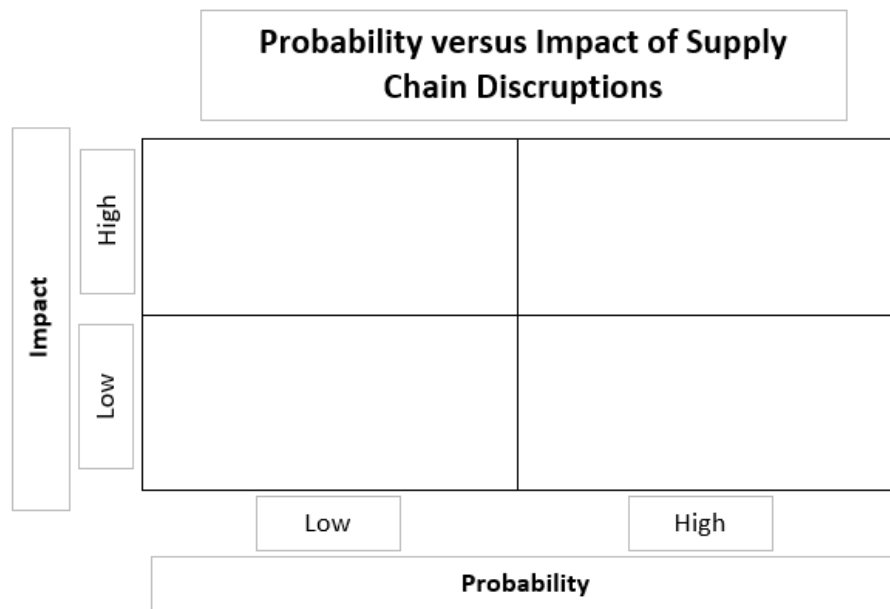
This research will analyze different types of disruptions and explore how companies can make their supply chains resilient. Natural disaster and man-made disasters will be discussed. The world is also experiencing a black swan event that has tested the limits of supply chains around the world. While some of these events cannot be avoided, companies can take preventative actions to mitigate the effects. The purpose of this research is to examine how companies have been affected by each disruption, and recommend possible solutions to make supply chains more resilient.

Most of the data used in this research will be acquired from public sources. News articles and similar sources will be utilized to define the different types of disruptions and how they affect businesses. Some insights will be taken from a Smeal College of Business roundtable

involving executives from different businesses that sponsor the school. The roundtable was conducted in early March of 2019 when COVID-19 was starting to spread across the United States. The goal was to share practices to mitigate the effects of quarantine, travel restrictions, and other policies being implemented across the world. There were executives present from various industries, but the best practices applied to companies in any industry. Some highlights of this roundtable will be explained in the research.

Throughout the research, a matrix will be used to classify the likelihood of a disruption happening compared to the impact on the supply chain. I will be placing the different disruptions on the matrix based on the material collected from the online sources. The matrix will be the basis for which companies should decide how to prepare for each disruption. If an event has a very low chance of occurring, companies should not devote many resources to prepare for it. COVID-19 is an outlier because there is a slim chance for an event of its magnitude to occur, but it can be devastating to a supply chain. The matrix compares the probability of a disruption occurring to the impact of the disruption on a supply chain. The matrix is shown below in Figure 1.

Figure 1: Empty Matrix



The rest of the thesis will be structured as follows. The next section will be about the background of the research. In this section, I will define the different types of disruptions and give a few examples. After the background section comes the analysis. In this section, multiple examples will be given of how companies have been affected by different disruption. Strategies to lessen the negatives effects will then be examined. Some of these strategies have been used by companies, and others are merely suggestions that have yet to be used. After the analysis section will be the characterization of the disruptions. As previously mentioned, the Probability versus Impact matrix will be used to examine which disruptions companies should prioritize when trying to mitigate issues. First, the different disruptions will be placed on the matrix. Then, common warning signs and other aspects such as geographical impact will be discussed to help companies identify which disruptions could affect their supply chain. The last part of the research will be the key takeaways and conclusions. In this section, I will give my



recommendations on which strategies will be the most effective in planning for disruptions. The most important element to remember throughout this process is that disruptions within a supply chain are almost inevitable, but it is possible to prepare and react in a way that lessens or even eliminates the effects.

## Chapter 2 : Background

### History

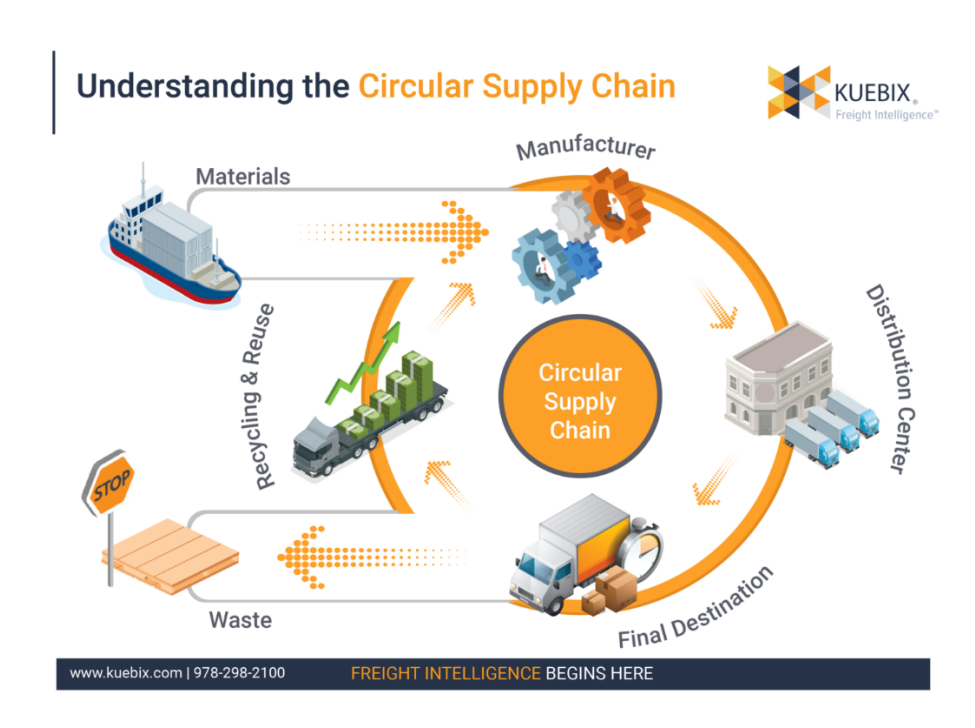
Supply chains used to be more linear in that goods flowed through a distribution network starting at the suppliers and ending with the consumers. The process was straight forward and had clear and defined steps that could easily be followed and tracked. A modern supply chain can be more circular because companies want to reuse material and create less waste. A visual comparison of a linear and circular supply chain can be found in Figure 2 and Figure 3 below. Supply chains are also becoming more complex because companies are outsourcing parts of their production process to different countries in order to save money. Modern supply chains are harder to track and understand because of the globalization of business and wanting to incorporate reusable materials into products. A modern supply chain can be compared to cogs in a machine. The cogs work together simultaneously for the machine to operate properly. Once one of the cogs stops, the entire machine begins to malfunction. While modernizing a supply chain can be beneficial for a company, it can also lead to more disruptions. In the dictionary, a disruption is defined as “a disturbance or problems that interrupt an event, activity, or process” (riskmethods,2020). A supply chain disruption can be defined as “a breakdown in flow of goods and their delivery to consumers” (riskmethods, 2020). Supply chain disruptions can be internal or external. An internal supply chain disruption is something that occurs within a company’s operations. The disruption is caused by something within the company’s control, meaning that the company has the means to fix the disruption before it gets out of hand. An internal disruption can be something simple such as a machine breakdown, or more complex like a product defect. An external disruption is something that occurs outside of

the company's control. Extreme weather and natural disasters are examples of external disruptions. Disruptions can also be localized or global depending on the intensity. A machine breakdown and extreme weather are both examples of a localized disruption because they are only impacting a small area of the supply chain. A major product defect is an example of a global disruption because all production across the supply chain must be stopped until the issue is solved. The COVID-19 pandemic the world is currently experiencing is an example of an external disruption in the most extreme sense. The impact of COVID-19 will be further discussed later. Now, a few examples of disruptions will be shared to explain how they affect a company.

**Figure 2: Linear Supply Chain**



Figure 3: Circular Supply Chain



### Internal Disruptions

Large factories, such as the Wabtec manufacturing plant in Grove City Pennsylvania, experience internal disruptions on a daily basis. Each production line has a number of machines, and if one of them goes down, the whole line has to shut down until it is repaired. Management then has to compare the actual number of units produced to the goal for the shift and plan accordingly to try and meet the goal for the day. As of summer 2019, different strategies were still being discussed to reduce the number or severity of breakdowns or allow production to continue while repairs are taking place. Machine breakdowns are disruptions that are almost never seen by the public, but cause problems almost on a daily basis within many businesses. This machine breakdown example is an internal example because Wabtec has the

ability to analyze the machine and fix the problem. This is also an example of a localized disruption because the only area being impacted is the one production line within the facility. If the machine breakdown caused a shortage in the overall supply of products, the problem could evolve into a global disruption. Identifying what is causing internal disruptions and finding a way to minimize them can bring a business great success. Failure to properly handle disruptions can hurt a company's public image and lead to further problems.

In 2016, Samsung had to recall over 2.5 million phones because of multiple occurrences of phones burning consumers and sometimes catching fire. This disruption forced the company to stop production of the Galaxy Note 7 until the issue was resolved. At first, Samsung had no plan of action for resolving the issue. Consumers wanted answers and the company had no response. The Galaxy Note 7 was even banned on U.S. aircraft because of the uncertainty around the batteries catching fire. One of the biggest problems for Samsung is that their headquarters is in South Korea, so their communication with American consumers was almost nonexistent. Thomas Cooke, professor at Georgetown University's McDonough School of Business, described Samsung's initial response as a case study about "what not to do" (Tsukayama, 2018). Samsung eventually gathered the U.S. executives together to form an action team and find out more information about the situation. After weeks of running tests and analyzing phones, engineers were able to discover that some factories were cramming batteries into cases that were too small, causing the phone to overheat or catch fire. Samsung's executives were able to come up with a plan of action that helped them retain most of their customer base. E-mails were sent directly to AT&T and Verizon customers with a trade-in offer so that consumers had the chance to get a different Samsung product. The company took extensive measures to make the Galaxy Note 7 almost unusable so that a consumer would exchange the

phone for something different, thereby eliminating the threat of more phones overheating. The executives also implemented quality teams across the supply chain to test for defects within the phone to prevent a similar event from happening in the future. Samsung's aggressive response, combined with the size of the company, helped them push through this disruption without a major loss. Other companies may not be as lucky in the future. Samsung spent over five billion dollars recalling smartphones and not many companies have that ability. Having a strategy for handling disruptions can be the difference maker for companies, no matter the size. The Samsung Galaxy Note 7 is an example of an internal disruption because the source of the problem came from within the company. Samsung had the ability to fix the problem because they control the factories producing the phones.

### **External Disruptions**

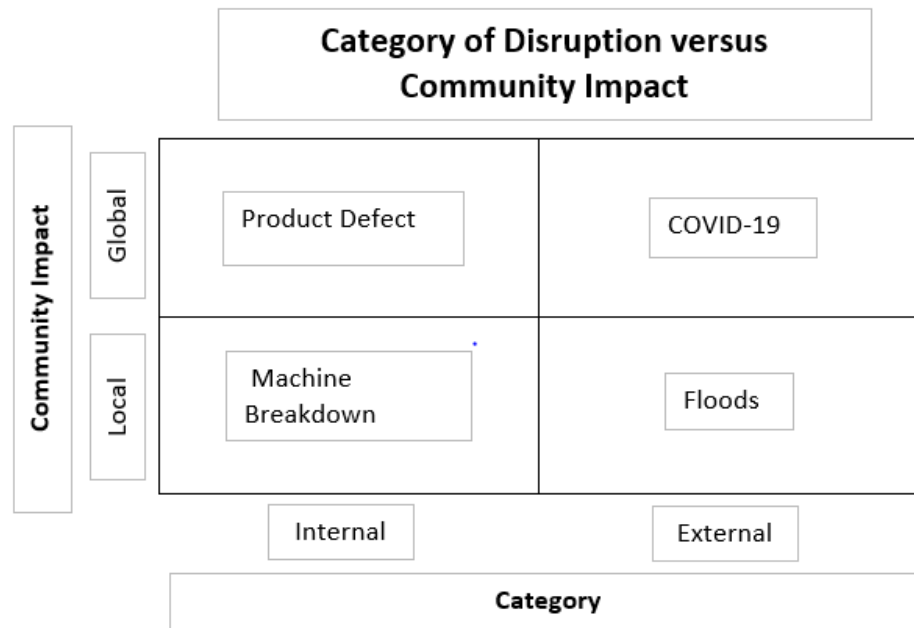
Next, an example of an external disruption will be discussed to show the impact and consequences of not being prepared. In 2011, Thailand experienced its worst flood in almost five decades. The floods impacted a number of businesses across different industries. One of the hardest hit companies was Toyota. Toyota was forced to shut down three of their factories in early October 2011 because of the disaster. Just a week later, Toyota announced that the company had to postpone production in the North American factories until the situation in Thailand improved. The company also had to reduce production in South Africa, Malaysia, Indonesia, the Philippines, Vietnam and Pakistan until supply could return to normal. This example shows how a modern supply chain can be compared to cogs in a machine. Since nothing could be produced in Thailand, all production further down the supply chain had to stop. In the

month of October, Toyota lost over 150,000 vehicles because of the flood (BBC, 2011). The recovery process from a natural disaster could be extensive depending on the severity. Yuuki Sakurai, chief executive of Fukoku Capital Management in Tokyo told BBC that it may be months or in some cases a year before companies can fully recover from a flood. In total, Toyota lost around \$1.03 billion because of the supply shortage caused by the floods. The company had to withdraw its profit and sales forecasts because of the event. The floods in Thailand are an example of an external disruption because Toyota had no control over the event. While Toyota is not able to prevent an external disruption, the company could have taken preemptive actions to lessen the impact of the disruption. Preventative actions will be discussed in the next section, but to provide an example, Toyota could have kept up with the predictive technology, the weather channel and other services available to see the likelihood of a flood occurring and have a few backup facilities in different areas that could produce cars while the factories in Thailand are closed.

### **Comparison**

Figure 4 below depicts a matrix that displays the difference between the examples discussed above. The examples are compared based on the type of disruption and the area impacted. For example, a machine breakdown is shown in the bottom left quadrant because it is a disruption that is localized and internal.

Figure 4: Disruption Comparison



The biggest similarity between the Samsung and Toyota example is that both companies waited to act until after the disruption occurred. Being proactive can lead to companies being able to operate effectively even when a major supply chain disruption occurs. The first step a company can take to be proactive is to collect data. Having data on hand is helpful because it gives a company a good idea of what “normal” operations look like. A company can use this data to see exactly how different disruptions affect operations. An important aspect to keep in mind is that a company should be analyzing the whole supply chain. Keeping track of the entire supply chain is essential because a company can track how a disruption impacts each step of the supply chain. Once enough data is collected on the supply chain, companies should then find a way to connect the supply chain electronically. Once a disruption occurs, each step of the supply chain will be notified so that action can be taken before it gets out of hand. With the data collected, companies should also identify their key suppliers



and make alternate plans if the supplier cannot deliver. Finally, companies should anticipate disruptions happening during each point of production. Some aspects to keep in mind are location, quality, and number of suppliers. Being naïve could cost a company million or even billions of dollars as seen from the previous examples. Not only will being proactive save companies money, but also it gives them a chance to assist their community when external disruptions like natural disasters occur. Giving back to local communities is beneficial for a company not only because it provides a good image to the public, but giving back also builds employee morale and shows interested employees that this company is a great place to work.

An example of a company providing support after an external disruption is how Walmart provided assistance to the New Orleans area after hurricane Katrina. Walmart promised each associate affected by the hurricane a job once the area recovered. The company also delivered over 2,400 truckloads of supplies to affected areas. Walmart has set in place multiple strategies for providing relief to areas in need. The company created the Walmart Foundation which emphasizes the importance of disaster relief and resiliency throughout the company. Over the last ten years, the Walmart foundation has donated over \$50 million in global relief and resiliency efforts and has responded to disasters across the United States as well as in Mexico, the Philippines, Haiti, the United Kingdom, Canada and Chile. Walmart is by no means the only company with programs like the Walmart Foundation, but it is a great example of how being prepared for disruption can help a company and surrounding areas. Below, in Figure 5, is a fleet of Walmart trucks waiting to enter New Orleans after hurricane Katrina struck.

**Figure 5: Walmart Katrina Relief**



### **Chapter 3 : Strategies for A More Resilient Supply Chain**

One of the best ways to mitigate the effects of a disruption is to be prepared for different situations. There are no defined “solutions” because most situations are different and many disruptions happen without warning. Examples like a machine breakdown or product defect are disruptions that have no warning. COVID-19 is an extreme example of a disruption that has no warning because a global pandemic has an extremely low probability of occurring. Some actions companies can take to be prepared to respond to disruptions that have no warning are to conduct an audit of the entire supply chain, implement standards for products, build up inventory, and create an emergency plan. These are some simple steps that can save a company time and money once a disruption occurs.

Conducting an audit of the supply chain could be the first course of action for a company when trying to determine which areas are vulnerable. An audit would provide a company with everything it needs to know about their supply chain. Key suppliers would be identified which can be vital when assessing the risk of a disruption. An audit can also help identify areas that may have potential issues because of external factors such as environmental, social, or political conditions. A company will use the information gathered to decide the best course of action to improve the resiliency of the supply chain. Auditing can help with disruptions that have a warning and those that have no warning because, as previously mentioned, the audit will point out potential areas that are prone to certain types of disruptions. For example, maybe the audit will reveal that a certain supplier has trouble meeting their demand. This example would be a disruption that has a warning because the supplier has a reputation for late delivery.

Implementing standards for products is an effective strategy because standards help lower the possibility of product defects like those that occurred with the Samsung Galaxy

Note 7. For example, Wabtec has product standards in place for the components of the locomotive engines the company builds in Grove City, PA. If multiple engines around the world started to fail because of a product defect, the company would be faced with a huge challenge because the railroad operating crew members and possibly also maintenance personnel of the locomotives would be put into harm's way. To avoid a product defect, each part is inspected and either approved or rejected. If the part is rejected, it is clearly marked and sent to remanufacturing in an attempt to meet the standards and be used in an engine. If Samsung had similar standards in place, they would have been able to catch the defect in the phone's battery before any product was delivered and avoided the problem entirely. Standards are also important because they allow a company to create quality products on a consistent basis. Quality is a trait that every customer looks for no matter the product.

Another step companies can take to improve the resiliency of their supply chains is to build up inventory. With supply chains becoming more global, keeping extra inventory on-hand could help companies continue production through disruptions. Asymchem was able to produce during the beginning of the COVID-19 pandemic because of their extra on-hand inventory. Asymchem is a company that is based in Morrisville, North Carolina and produces ingredients for medicines sold by other companies. Asymchem has eight factories in China that are key in the production process. When the COVID-19 breakout began in China, the Asymchem factories were forced to close. Even after the factories resumed operation in late February, some of their suppliers were still experiencing closures. Even with COVID-19 forcing production to be delayed in China, Asymchem was still able to meet demand in the United States because the company keeps a month's worth of extra inventory on hand. SMEAL College of Business hosted a town hall meeting with executives from various companies to discuss how COVID-19 is

impacting their businesses and inventory was one of the main topics. One executive explained how their company identified their key products and then stocked each distribution center across the U.S. with those products. This strategy allowed the company to stock essential products, even with the pandemic worsening. An expert from the trucking industry also commented that delivery of items would not be delayed because of the decrease in traffic on highways. The practice of keeping excess inventory on hand in case of disruptions may start to become a staple across all industries because of the pandemic.

Another strategy that can help a company produce through a disruption is creating an emergency plan. The plan would be for a scenario such as COVID-19 or other global disruptions that could impact a significant part of a supply chain. Part of the emergency plan would include finding local suppliers to support the business during the disruption. While diversifying the supply base and globalizing is important, it can also hurt a company if there are no backup plans in place. The example of Asymchem was given earlier and without their excess inventory, the company would have experienced a major shortage of products. Sourcing from local suppliers is expensive, but companies only have to use these suppliers as a last resort when a disruption occurs. The supply chain audit would be a viable resource when creating an emergency plan because the plan would most likely be centered around the weakest links in the supply chain.

Nike is an example of a company that utilized multiple strategies mentioned above to gain visibility of their supply chain during the COVID-19 pandemic. In June of 2019, Nike began tracking most of its non-licensed products through the use of RFID tags on the items. The RFID tags have allowed Nike to see how fast their products move through the supply chain and reach the consumer. With demand being suppressed since the start of the pandemic, Nike is

using the RFID tags to identify which products are still selling in specific areas. Nike's former CEO Mike Parker emphasized that in the current environment, "the importance of inventory positioning will go up as restrictions on labor and movement hamper full-tilt warehouse operations" (Cosgrove, 2020). Multiple digital retailers are sharing information with Nike in an attempt to help the company further refine their global inventory level. The company is prepared to shift a large majority of their business online with the help of their data collection and tracking methods. While orders may be delayed for a short time, Nike is confident that they will have perfected order size and product placement by the time that business begins to pick up again.

Nike and Asymchem are just two examples of why companies should invest in preventative actions for disruptions. The pharmaceutical industry may have suffered major losses if not for Asymchem taking the extra precaution of building up inventory. Nike could have experienced major economic losses during the pandemic if not for their strategic positioning and visibility of their supply chain. Not only was Nike's supply chain audit able to provide them with valuable information, but also it gave them the ability to transform their business for the future. Nike is now able to identify popular items and reconfigure their inventory as needed while focusing on their online retailing. Just to reiterate, there are no defined solutions that will guarantee a company will not be affected by a disruption, but there are ways to mitigate the effects or even avoid the disruption all together. There are some disruptions that do have warnings and they have slightly different mitigation strategies associated with them.

Disruptions such as natural disasters and late deliveries do have some form of warning before they start affecting a company. Even though companies will have a warning, it is important for them to have a plan in place because the warning may be given only a few hours before the disruption occurs. One of the main differences between events such as natural

disasters and a warehouse fire is that natural disasters can be predicted and tracked as they move across the United States. Certain natural disasters are also prone to areas of the country. For example, hurricanes most frequently occur in the southeastern United States between June and November. Companies can use information like this to be prepared for similar disruptions.

One of the first areas companies should look when thinking about predictable disruptions is the supply base. A proper supply base should be diverse with uncorrelated sources of supply. Sources of supply should not be correlated to limit how a disruption within a supplier affects a business. Suppliers should also be diverse in the sense of geography. Having suppliers in different areas ensures that some amount of product will be delivered even if there is a disruption with another supplier. Companies should also consider building relationships with backup suppliers in case they are needed. The backup suppliers should also be located in different geographical locations in order to avoid localized disruptions affecting primary and secondary suppliers. An example of a company not diversifying their supply chain is Asymchem and their facilities in China. Asymchem has eight production factories in China and, as mentioned earlier, all of them had to shut down because of the COVID-19 outbreak. Even when some of the facilities were able to resume production, the suppliers in China remained closed. Luckily, Asymchem had enough backup materials to fill orders, but the decision to have suppliers and factories in the same region could have cost the company in the long term. The pandemic has definitely impacted almost every country around the globe, but the virus impacted countries at different times. Having some suppliers in different areas across Asia would have allowed Asymchem to continue production throughout the pandemic.

Another action for companies to take when dealing with disruptions that have warnings is to partner with a logistics expert to analyze how disruptions will affect different parts

of the supply chain. A logistics expert can also give insight on how to mitigate the effects of disruptions. Once processes and strategies are in place, each company can change them as needed to effectively operate through disruptions. Companies can also choose to outsource certain processes to logistics firms with their own distribution networks in order to cut down on the potential number of disruptions. Other companies have dedicated departments that focus on risks within the supply chain.

XPO Logistics is an example of a company that partners with other companies to improve the efficiency of their supply chain. XPO is ranked as a top ten logistics provider and has partnered with large companies such as Mercedes-Benz. XPO Logistics is divided into two segments, logistics and transportation. The logistics segment is focused on e-commerce fulfillment, reverse logistics, distribution, and managed transportation. Companies could utilize this segment of XPO to identify areas of concern within the supply chain. The transportation segment of XPO focuses on truckload, last-mile delivery, expediting, and global deliveries. Companies can utilize this segment to find backup suppliers for the parts of their supply chains that are in higher risk areas. To better explain how a logistics firm can help protect against certain disruptions, the partnership between Mercedes-Benz and XPO Logistics will be further explored.

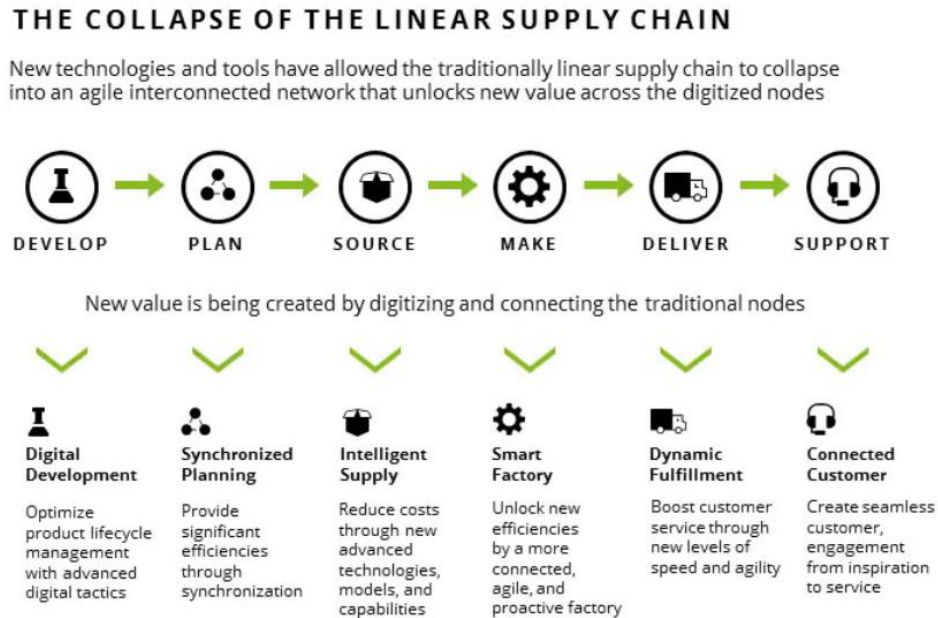
In March 2020, Mercedes-Benz and XPO Logistics agreed to a long-term partnership in the United Kingdom. XPO agreed to deliver parts to commercial and passenger vehicle dealerships using their pre-established distribution system. The partnership entails XPO completing over forty deliveries each day to delivery depots in preparation for the upcoming demand. Juan Manuel Santiago Mendez, CEO of Mercedes-Benz Parts Logistics – UK, said in a statement that operations in the UK are vital for keeping the business as a whole moving (XPO



Logistics, 2020). Mercedes-Benz warehouses and factories in the UK are responsible for more than 750,000 part numbers. The company believes that XPO Logistics possesses everything necessary to meet the high standards of Mercedes-Benz and deliver the product with minimal disruptions. The biggest benefit for Mercedes-Benz is that XPO already has a distribution plan in place. However, as a result of their decision to outsource to XPO Logistics, Mercedes-Benz now has less control over their supply chain in the UK. If XPO were to encounter a setback, Mercedes-Benz would not have many options to meet the demand. The decision to outsource should come after considering a company's current assets and procedures compared to the third party's systems.

Companies can also implement new technologies and predictive analytics to prepare their supply chains for disruptions. AI-enabled mapping, environmental analysis solutions, and aggregate apps that provide geopolitical overviews are available for predicting disruptions similar to natural disasters. Social media analysis is also being used to collect data on how customers and other outlets are responding to disruptions. Deloitte is using predictive technology to try and transform how supply chains are managed. The company introduced the concept of digital supply networks to attain supply chain visibility (Deloitte, 2021). Deloitte is taking the traditional linear supply chain and incorporating analysis tools to connect each aspect of the supply chain. Below, in Figure 6, is a picture explaining how different aspects are being transformed with digital supply networks.

**Figure 6: Breakdown of Linear Supply Chain**

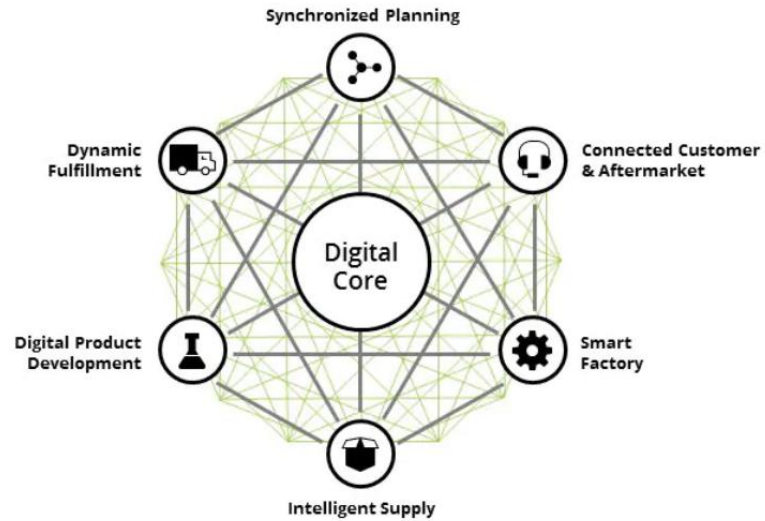


Once each area of the supply chain is connected, the digital supply network can start collecting data. The digital supply network can make a business more efficient and prepared for disruptions by transferring information through the “digital thread” (Deloitte, 2021). First, information is captured from sensors and other physical elements and then creates a digital record. The records are then exchanged between supply entities in order to uncover meaningful insights that the company can share across all of its entities. Finally, the insights and information are turned into actions and procedures to make the supply chain more resilient. Below, in Figure 7, is a visual representation from the Deloitte website of a digital supply network. An important note to remember is that this method will work at a different pace based on the company implementing it.

**Figure 7: Digital Supply Network**

**THE BIRTH OF THE DIGITAL SUPPLY NETWORK (DSN)**

Innovative and disruptive technologies can enable supply chains to transform into Digital Supply Networks, which can serve as a powerful competitive weapon



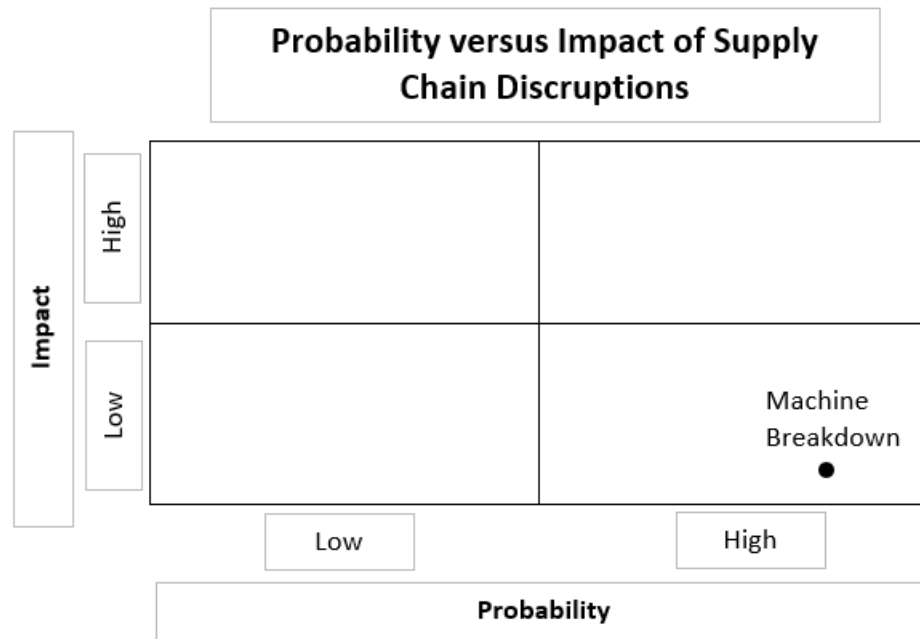
With all of these preventative strategies in mind, each business must decide which is best suited for them. Next, the different disruptions mentioned will be characterized based on the risk matrix. Once completed, the matrix will serve as a tool to help determine how much of a threat each disruption is to a business.

## Chapter 4 : Characterization of Disruptions

With potential strategies in hand, companies must now perform a risk analysis on various disruptions to determine the likelihood of the supply chain being affected. Each disruption will be individually placed on the Probability versus Impact matrix, As seen in Figure 8, for ease of explanation and then the completed matrix will be discussed at the end of the section. First, the internal disruptions will be evaluated. Internal disruptions should be the number one concern for companies since they have the ability to correct the disruption. External disruptions should be addressed after the supply chain has become resilient against internal disruptions.

The first internal disruption to be discussed is a machine breakdown. First, the machine break down will be placed on the matrix. As a reminder, probability is on the y-axis, and impact is on the x-axis. So, the farther right on the axis, the higher the likelihood of the disruption occurring. If a disruption is placed towards the top of the matrix, it will have a great impact on the supply chain. The figure below displays where a machine breakdown ranks on the Probability versus Impact matrix.

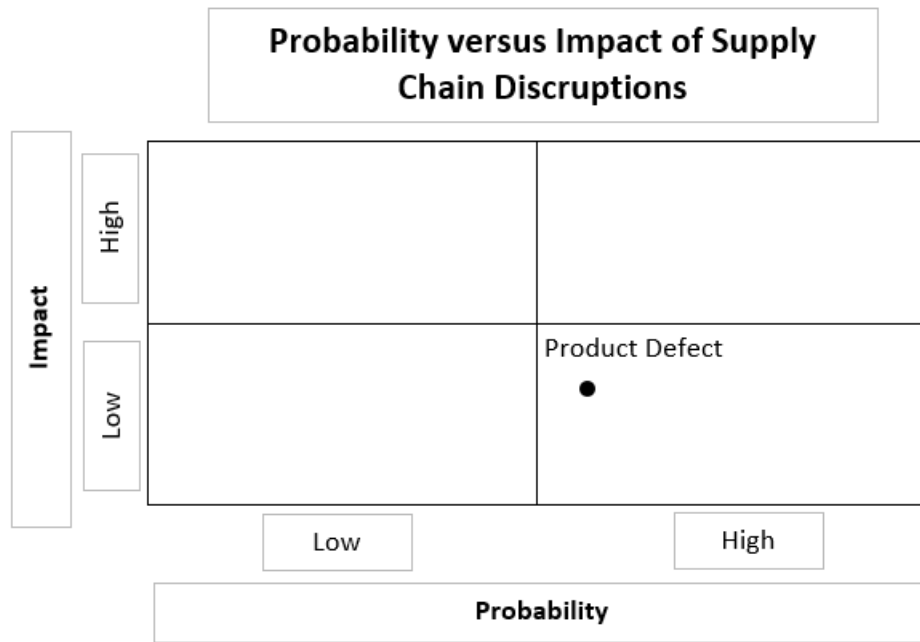
Figure 8: Machine Breakdown



A machine breakdown has a very high probability of occurring, but has a minimal impact on the supply chain. This type of disruption has a high probability of occurring because machines break down quite frequently. Some production facilities may even have breakdowns of different machines on a daily basis. However, simple breakdowns have almost no effect on the supply chain because they can be fixed by maintenance quickly. Breakdowns can become an issue if they last an extended period of time, but for this instance it is assumed that a breakdown can be fixed in a reasonable time frame. Some simple strategies that can be implemented to mitigate the effects of a machine breakdown is having extra inventory on hand or having multiple machines for the same process. Having even a small amount of inventory can eliminate any risk of a simple machine breakdown because the inventory can cover the units that were lost during the downtime and allow production to continue. The Asymchem example fits perfectly in this scenario because their extra on-hand inventory allowed production to continue while multiple factories, as opposed to just machines, were unable to produce.

Next, product defects will be discussed. The likelihood of a product defect varies based on the company. A product defect for a company like Samsung is completely different than a defect for Netflix. A defect similar to the battery on the Samsung Galaxy Note 7 may be easier to identify than a glitch in the software of the Netflix service. Since product defects can vary to such a degree, they can have different impacts on companies. For the sake of argument, the product defect in the Figure 9 below is similar to the battery defect on the Samsung smart phones.

Figure 9: Product Defect



This type of defect was put into the top part of the high probability/low impact quadrant because some defects will be caught and fixed within the production process. Product defects are bound to occur when a product such as a smart phone is mass-produced on an assembly line. When the defect is not identified right away, it can have a high impact on the company and supply chain. As was seen in the Samsung example, factories all across the supply chain were forced to stop production because of the battery defect. One of the most efficient

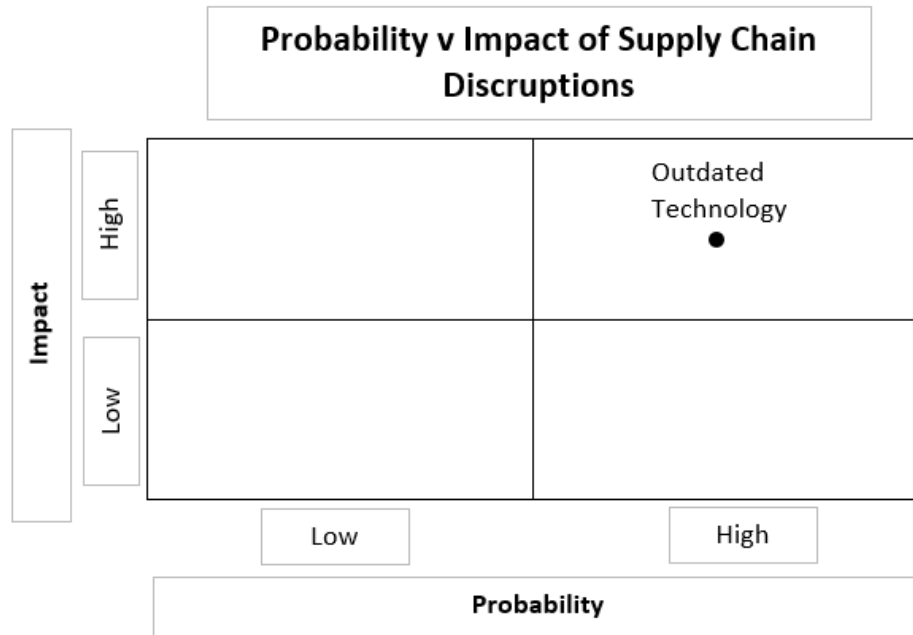
strategies to limit products with defects entering the marketplace is to implement standards and quality control teams within production facilities. For example, adding a worker or workers at the end of the production line who inspects each completed product and disposes of the ones with defects would help minimize defects that would reach the customer. It is almost impossible to catch every product that has a defect before it reaches a consumer. However, as long as there are a minimal number of defective products, there will be a minimal effect on the business.

Another strategy that can help software-based products is to introduce open-source software. 3-D printing companies such as MakerBot have used the open-source strategy in the past and it helped the business identify problems within their code. Open-sourced software allows everyday people to interact with the code and make suggestions on how to improve it or fix problems. Not only can this strategy help with preventing defects, but also it can have a positive impact on the company overall by showing customers that their suggestions and feedback are being considered.

Another disruption that can affect a company in any industry is having outdated or slow software. This is considered a disruption because slow software can cause an increase in lead times between supply chain links and result in inconsistent production numbers throughout the entire chain. New inventory strategies such as just-in-time delivery cannot succeed with dated forecasting systems. Forecasts used to be formulated mostly in excel or a similar program. This method of forecasting can become a problem if the file is continuously updated. Each time the file is updated, it must be sent up and down the supply chain so that production can match the forecast. At some point within the supply chain, there is a chance that the wrong data is being used, which could impact other processes downstream. Now companies are exploiting new strategies and are using programs that are easily shareable across supply chain links. Before

possible solutions are discussed, the disruption will be placed on the matrix, as seen in Figure 10, to further explain how impactful outdated technology can be.

**Figure 10: Outdated Technology**



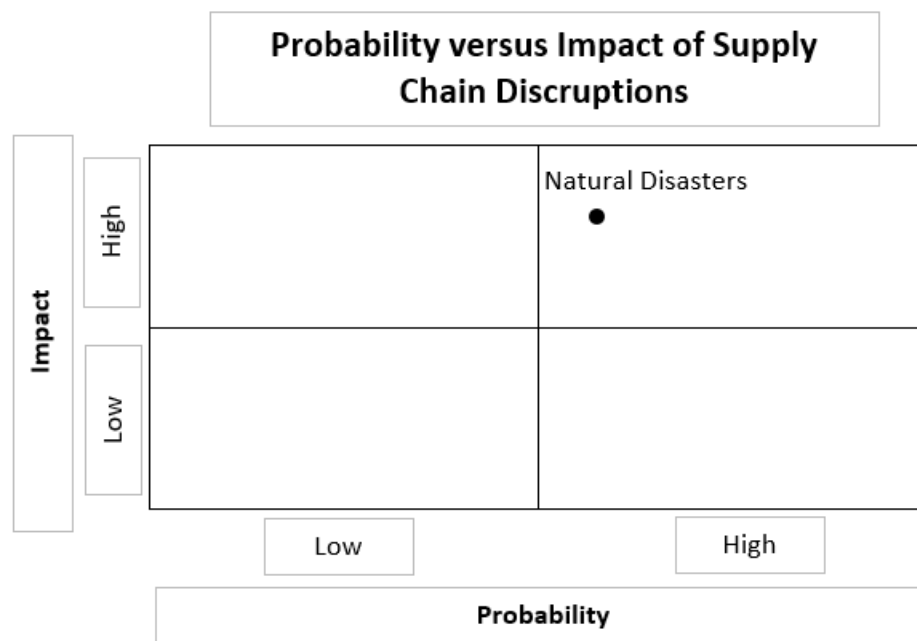
A disruption due to outdated technology has a high probability of occurring because technology is always changing and evolving. Companies don't always keep up with this change and can be at a disadvantage with their competitors. A disruption caused by outdated technology has a high impact on a supply chain because it can cause extended delays throughout the production process. As mentioned before, Deloitte recently introduced the idea of a digital supply network that links each step of the production process together to create visibility and identify weak points (Deloitte, 2021). Implementing the digital supply network can help pinpoint which technologies could be updated in order to improve efficiency. Updating technology can allow companies to incorporate new strategies into the supply chain in order to keep the whole process connected and the business competitive.



Next, the external disruptions will be put onto the matrix. Since these types of disruptions cannot be controlled by a company, they can have a greater impact on the supply chain. Strategies and processes that make a supply chain more resilient are more effective when an external disruption occurs. These disruptions can come with no warning and can be extremely destructive. Having strategies in place can help companies maintain normal production levels through even the worst disruptions.

The first external disruption to be discussed is natural disasters. Natural disasters are localized events that can affect a supply chain on a global level. With the continued increase of outsourcing production to other countries, companies must take into consideration the likelihood of a natural disaster impacting some of their production facilities. The example of Toyota in Thailand was used earlier to explain how destructive natural disasters can be to a business. As a reminder, Toyota lost over 150,000 vehicles, and had to shut down or lessen production in multiple factories because of the floods in 2011 (BBC, 2011). Figure 11 below, shows where natural disasters fall on the Probability versus Impact matrix.

Figure 11: Natural Disasters

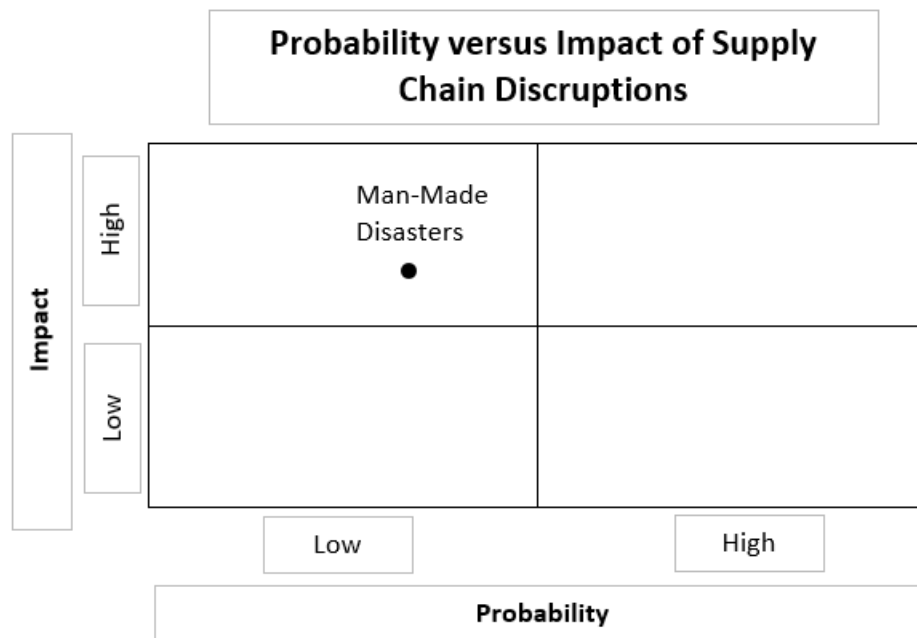


Although they can occur anywhere at any given time, natural disasters have a high probability of occurring in some areas during certain times of the year. For example, hurricane season in the United States starts in June and ends in November (Erdman, 2021). So, if a company has a facility in one of these problem areas, there is a high probability of a disaster occurring. Natural disasters also have a high impact on the supply chain because of their power. Natural disasters such as hurricanes and earthquakes have the ability to destroy buildings, and the company then has to take time to rebuild a facility destroyed this way. While some natural disasters do vary in power, facilities still experience closings when the disruption strikes for the safety of the workers. No matter the intensity of the disruption, a company will experience some form of a delay until the event has ended. Companies could choose to not have production facilities in areas that are prone to natural disasters, but often times the benefits outweigh the risks. One strategy that can help mitigate the risks of natural disasters is having uncorrelated sources of supply. Uncorrelated supply sources ensure that a company will receive at least some

materials while a supplier is experiencing the disruption. Another strategy to consider is keeping important inventory on hand at other factories so production can continue in the short run while the disruption is taking place.

The next external disruption to be discussed is a man-made disaster. Some examples of man-made disasters include: fires, chemical spills, and explosions. Like natural disasters, man-made disasters are local disruptions that can have global effects. However, these disasters can happen anywhere as opposed to natural disasters that occur in specific geographical areas. There is a lesser chance of a man-made disaster occurring because more precautions can be taken to prevent them from happening. Figure 12 below, illustrates where man-made disasters fall on the Probability versus Impact matrix.

Figure 12: Man-Made Disasters

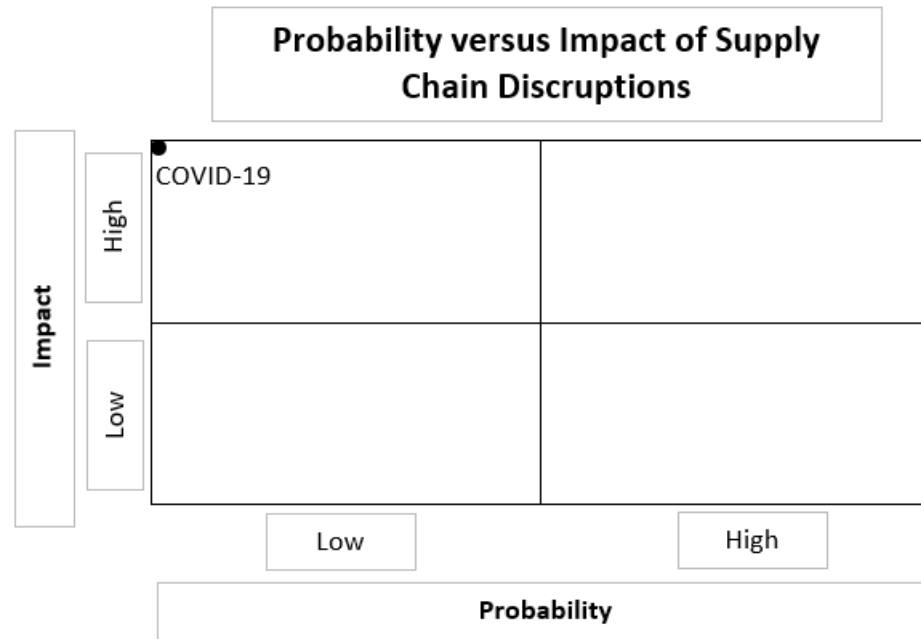


As previously stated, man-made disasters have a lower probability of occurring than natural disasters because more precautions can be taken to avoid them. For example,

Wabtec has procedures in place to protect against fires throughout their production facilities. Each production line has protective cabinets where all flammable materials must be kept for safety reasons. Safety checks are performed on a regular basis by management to ensure that all flammable materials are stored appropriately. Even though man-made disasters have a lower chance of occurring, they can still have a great impact on a supply chain. Phillips experienced a small fire in their Albuquerque, New Mexico production plant in 2000 (Economist, 2006). The fire only lasted ten minutes and the company believed they would catch up to demand in one week. However, when asked to ramp up production to meet demand, other Phillip's factories did not have the capacity. The disruption cost the company over \$430 million because of the part shortage. Some strategies companies can consider to mitigate these types of disruptions are keeping extra inventory on hand and implementing strategies like Wabtec. Even keeping a minimal amount of inventory could have prevented the disruption Phillips experienced in 2000.

The final disruption to be placed on the matrix is COVID-19. COVID-19 is a difficult disruption to run risk analysis on because it is considered as a black swan event. A black swan event is considered as "an unpredictable event that is beyond what is normally expected of a situation and has potentially severe consequences." (Scott, 2020) In other words, black swan events are a once in a lifetime occurrence that cannot be predicted. Companies had no need to prepare for a worldwide pandemic because there was an extremely low chance that a pandemic like COVID-19 would break out. What makes black swan events so devastating is that they can destroy markets and economies. More and more small companies are closing as the pandemic continues, and large companies are having to change their strategies to stay afloat during this disruption. Before further discussing the effects of COVID-19, it will be placed on the matrix, Shown in Figure 13 below, to aid in analyzing the risks associated with the disruption.

Figure 13: COVID 19

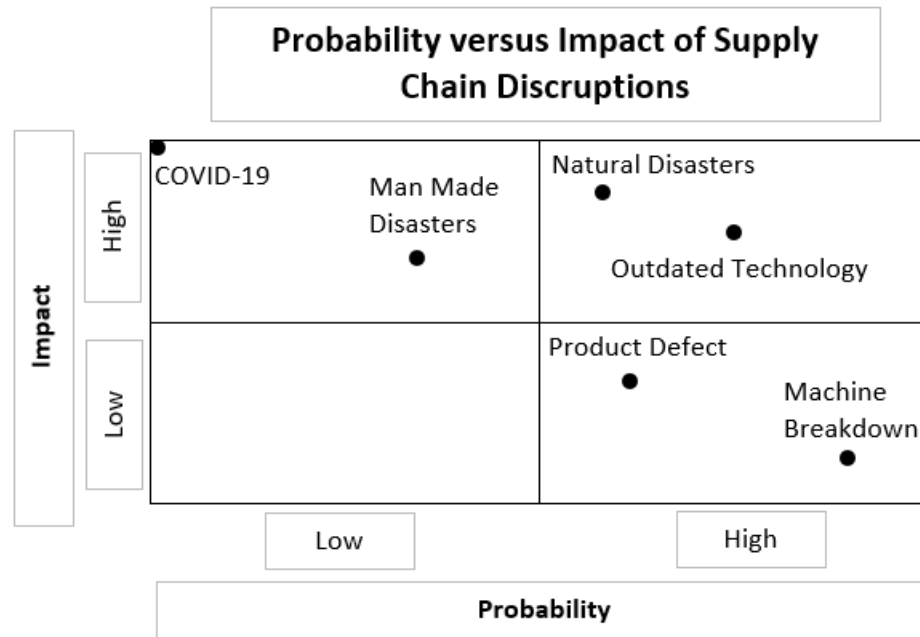


COVID-19 has an extremely low probability of happening because, as mentioned before, it is a black swan event that happens once in a lifetime. However, COVID-19 has a devastating impact on the supply chain, especially with the growing popularity of global supply chain tactics. With global supply chains becoming normal for most businesses, a world-wide disruption like COVID-19 means that entire supply chains could be halted for extended periods of time. Throughout the pandemic, nations all across the world have been shut down. With all the nation-wide shutdowns happening, many industries took a hit and were struggling to find solutions in the short-term. In-fact, the pandemic has basically forced many companies to completely change how their supply chains operate. The example of Nike was mentioned earlier in which they used RFID tags to identify the popular products by geographical area to ensure the most bought products are always in stock. Another example was used earlier from the SMEAL College of Business roundtable where executives expressed the importance of storing vital inventory in all important distribution centers. Executives from the roundtable also suggested

that each company should have a response team that immediately gets together when an impactful disruption takes place. The main takeaway from both of these examples is that companies need to have responsive supply chain strategies in place in order to effectively deal with unpredictable disruptions. As the pandemic continues, it should be interesting to see how different companies reshape their strategies in order to mitigate the effects of such a disruption.

With each disruption now placed on the Probability versus Impact matrix, companies can use it to assess risks within their supply chain. However, it is important to note that there are more possible disruptions than the six described in this section. Each company will have to look at internal and external forces to see if the supply chain is in danger of any other disruptions. The matrix will also need to be adjusted based on the company. For example, a company may find that none of their suppliers or facilities are located in areas that are prone to natural disasters. This disruption can then be shifted on the matrix to reflect the risk of a natural disaster occurring. Below, in Figure 14, is the completed matrix for comparison.

Figure 14: Completed Matrix



The purpose of the matrix is for companies to customize it and use it as a powerful tool to identify potential threats to the supply chain. Once threats can be identified, companies can then start taking action to make the supply chain more resilient to the most common disruptions. As more strategies are implemented, the impact of disruptions will start to decrease in intensity. The strategies suggested in the analysis section, combined with the risk analysis matrix, can be great stepping stones to creating a more efficient and resilient supply chain.

## **Chapter 5: Conclusion**

The overarching goal of this research is to identify different types of disruptions, explain how the disruptions affect the supply chain as a whole, and suggest strategies to make the supply chain more resilient to disruptions. Understanding the causes or warning signs of disruptions is important because disruptions will happen on a frequent basis. If there are no preventative strategies in place, even the small disruptions will begin to cause problems for a company. The two categories of disruptions that can affect a company are internal and external. An internal disruption is caused by a process or machine that is inside the supply chain and controllable by the company. Companies should work diligently to identify the internal disruptions they face because the information to mitigate the effects or even prevent the disruption can be attained through data collection and analysis. External disruptions are harder to prepare for because some of them come without warning and can be destructive. Companies also have no control over external disruptions, they can only mitigate the effects with resilient strategies and procedures.

Common examples were then given to illustrate the difference between internal and external disruptions. All of these disruptions have occurred in the past and therefore can be analyzed to decrease the impact next time they occur. However, the business world is currently experiencing a once in a lifetime disruption in COVID-19. While this type of disruption is likely to not happen again, it has started to reshape how supply chains are managed and operated. The example of Nike was given to explain how companies have responded to the COVID-19 disruptions. Nike completely changed its inventory systems to reflect what items were still being



bought in the pandemic. The changes made by companies during the pandemic may remain permanent and reshape industry norms.

The key takeaways from the strategies presented throughout the research is that each link within the supply chain should be connected. One of the best ways to mitigate the effects of a disruption is to make it known that a problem is occurring within the supply chain. With each link connected, other production plants and facilities can use the mitigation strategies to continue production while the disruption is occurring. The executives who participated in the SMEAL College of Business COVID-19 roundtable came to the consensus on three recommendations when dealing with disruption in general. The first one is to map the supplier network all the way up to the raw material suppliers. This recommendation helps companies gain visibility into their supply chain to identify problem areas. The second recommendation is to make sure all sources of supply are uncorrelated. Having uncorrelated sources of supply helps mitigate the effects when one supplier encounters a disruption and is unable to deliver products. With uncorrelated suppliers, the company can just ask a different supplier to fill the orders left by the supplier having issues. The third recommendation is to have buffers and flexibility within the supply base. Having buffers can help when an unexpected disruption hits and forces a company to act quickly before analyzing the whole situation. Buffers and flexibility give a company time in the short-term to make a plan to deal with a long-term disruption.

In conclusion, companies should utilize risk analysis tools similar to the Probability versus Impact matrix to identify potential threats to the supply chain and then find the strategies that would work best in their system. Not every strategy will work for every company and therefore requires individual companies to collaborate and find what works best for them.

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# ACADEMIC VITA

**Zachary R. Buckel**

## EDUCATION

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**The Pennsylvania State University** State College, PA  
*Smeal College of Business* May 2021  
Bachelor of Science in Supply Chain and Information Systems  
Minor in Management Information Systems

## RELEVANT EXPERIENCE

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**GE Transportation, a Wabtec company** Grove City, PA  
*Operations Intern* May 2019 – Aug 2019

- Completed project workshops on Lean/Six Sigma methodologies
- Strengthened knowledge in manufacturing operations and quality assurance
- Designed complex spreadsheets to sort and analyze data to find relevant information
- Increased production by creating visual aids for continuous improvements

**GE Transportation, a Wabtec company** Erie, PA  
*Logistics Intern – Cancelled due to COVID-19* May 2020 – Aug 2020

## CAMPUS INVOLVEMENT

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**Schreyer's Honors College – Member** Aug 2019 – Present  
**Culture of Disney Classes – Leadership Strategies, Techniques of Teamwork, Culture of Excellence** April 2019  
**Penn State Behrend Honors College – Member** Aug 2017 – May 2019  
**Delta Sigma Pi Professional Business Fraternity – Member** Aug 2018 – Present  
**Lambda Sigma Honors Society – Member** Jan 2018 – May 2018  
**Curling Club at Penn State – League Member** August 2019 – Present  
**Penn State Behrend Curling Club – Treasurer** Jan 2018 – May 2018

## ACADEMIC EXPERIENCE

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**Demand Fulfillment** University Park

- Compared forecasting models to determine optimal inventory levels through in-class examples
- Acquired knowledge about how trade-offs and uncertainty affect a business and how to make decisions
- Enhanced Excel skills through numerous class activities and homework assignments

**Business Analytics** University Park

- Gained knowledge of the challenges of big data and its relationship to competitive strategy
- Analyzed the complexities of social network data and gained experience by utilizing Gephi software
- Learned how to effectively use Excel functions, pivot tables, and VBA to analyze data

**Strategic Procurement** University Park

- Discussed sources of supply and the strategy of developing a supply base
- Learned ways to evaluate, select, and manage suppliers through classroom assignments
- Listened, learned, and networked with industry leaders through guest lectures

## VOLUNTEERISM

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**Relay for Life | Grove City, PA** July 2019  
**Our Lady of Mount Carmel Parish | Erie, PA** Feb 2014 – Aug 2018

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