

SUPPLY CHAIN RISK MANAGEMENT STRATEGIES



UNIVERSITY OF WISCONSIN, PLATTEVILLE

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The attached educational project, by FELICIA WHITE, entitled ASSESSING RISK MANAGEMENT STRATEGIES FOR THE GLOBAL SUPPLY CHAIN: MAINTAINING RESILIENCY AROUND NATURAL AND ANTHROPOGENIC DISASTERS, when completed, is to be submitted to the Graduate Faculty of the University of Wisconsin-Platteville in partial fulfillment of the requirements for the (MASTER OF SCIENCE IN INTEGRATED SUPPLY CHAIN MANAGEMENT) degree.

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**Abstract**

Global supply chains are essential for international economies to flourish within their respective markets and continue the streamlined production and distribution of goods and services. Studies have shown that a lack of risk management strategy concerning natural and anthropogenic disasters impedes successful operations, with negative impacts on a universal economic scale. Supply chains that understand these prospective threats can create an evaluation, preparedness, and growth initiative to thrive in times of uncertainty. However, this is not always a priority and ultimately can prove disastrous for an organization's future. By analyzing historical data from previous catastrophes, expectations for anticipated hazards, and diving into current events, this research paper focuses on the potential risks that threaten those processes to establish proper mitigation strategies for creating resiliency and maintaining operational success.

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## Introduction

### Statement of the Problem

Supply chains play an essential role in participating in global trade and maintaining economic growth and stability. Any disruption to that flow of service can cause chaos in unmeasurable ways. "Manufacturers need to guard against disruptions in the flow of materials. With so many things that can -and do- go wrong, contingency planning is no longer a luxury; it is a necessity" (Bartholomew, 2006). It may sound like moving goods and services is a simple task, traveling from one location to another without delay or disturbances to a supplier, manufacturer, or end customer. However, as markets face extreme ambiguity caused by natural disasters and anthropogenic disruptions, supply chains are confronted with constant stress on how to plan, adapt and prevent catastrophic results for their firms. "Supply chains are the mechanisms by which products, and the raw materials from which products are made, move from their source to the consumer. Raw materials, components, and finished products now often move between continents before reaching the consumer" (Chandler, 2015). When an unforeseen event occurs, supply chains can only mitigate the immediate local impact, followed by the global response through their ability to have a contingency plan to keep their firms running. However, the question remains, is that enough?

"A disaster involves extensive damage to people and physical infrastructure that is unforeseen in nature, scale, and extent. It often implies that their risk of occurrence has not been properly assessed and a large share of the damage is the outcome of a lack of preparedness" (Rodrigue, 2017). Disasters are divided into two categories: Natural Disasters and Anthropogenic Disruptions, each having select subsections and often occurring in the same regions (see Appendix A). While the root causes differ, the overall impacts on a supply chain are

similar. They can be detrimental to the success of a supply chain, especially if there is no level of preparedness. Rodrigue (2017) explains that natural disasters can be extreme weather events such as storms, blizzards, floods, hurricanes, tornadoes, and geophysical, such as earthquakes, tsunamis, and volcanic eruptions. Furthermore, there are anthropogenic disruptions in conflicts, terrorism, piracy, economic shocks, and even pandemics. Levi (2015) clarifies that natural and anthropogenic are unknown and uncontrollable supply chain risks (see Appendix B). All have had or can potentially cripple a supply chain firm and the related markets in which they operate.

### **Purpose of the Study**

This research highlights the extreme impact of delays and disruptions to global supply chains on local and international economies while stressing a robust risk management plan. These events are disasters in their own right, given the inability of most supply chains to have a proper plan to protect their survival and fulfill their customer demands. The research conducted in this paper will provide an analysis of successful mechanisms proven to aid in the prevention of organizational failure or recovery efforts should a supply chain fall victim to chaotic events.

In the wake of any disaster, a firm needs to be proactive and responsive to restructuring what losses they have faced. The thought, "What did we learn from this, and how can we prevent it from happening again" will be asked by numerous parties until the supply chain can complete a full rebuild. Jennings (2016) concluded

Approximately 40 percent of manufacturers that do not have robust business continuity plans fail immediately because they are not prepared strategically or financially to cover the costs of extended downtime. An additional 25 percent fail within two years from lost revenues and cash flow problems. These failures, of course, have the potential to raise unemployment levels, reduce tax collections and increase the demand and need for public

services (p.1).

In examining these high figures and the potential impacts they can have on a supply chain and the economies that surround them, there are various steps a firm can take to prevent a disaster from completely shutting down their facilities. Several mitigation strategies are available to guide the reestablishment of a firm's productivity after a disaster and lessons learned to evaluate the risk of having an unprepared supply chain that such events could negatively impact.

### **Significance of the Study**

This research paper will analyze the differences between natural and fabricated disasters using real-life examples of the impact caused to supply chains and what actions a firm can take to ensure continuous productivity and profitability under a state of uncertainty. This document will also seek to contribute to the global supply chain world and the companies, regions, and people by detailing the most common natural, geophysical, and anthropogenic risks that may negatively impact their day-to-day operations. By gathering secondary research, graphs, timelines, and studies, this report serves as a guideline for those in the supply chain realm to identify potential risks and avoidance strategies, preparedness for impact, and create an action plan for quick mitigation and resiliency efforts. This paper will highlight historical disasters, lessons learned, and eventual outcomes while analyzing current developing disasters and how supply chains modify their risk management approach in real time. Finally, the research conducted for this paper will guide supply chains whose processes may be running smoothly; however, push the importance of a continuously evolving action plan.

### Literature Review and Analysis

"Supply chain disruptions are related to unplanned and unanticipated events that disrupt the normal flow of goods and materials within the supply chain" (Weber, 2021, p. 1). How are supply chains impacted when unforeseen events occur, and how do they survive? The 2011 Tohoku Japan Earthquake highlighted the complexity of supply chain strategy plans for mitigating disasters. The quake rattled structures throughout the area, but the following tsunami and nuclear meltdown flooded the towns and made certain areas completely uninhabitable. Close (2016) reported that "While the quake was felt as far as Europe, it shook supply chains all over the world. Electronics and auto manufacturing facilities were flooded and destroyed in some cases." This disaster affected Japan's country, people, and supply chains and created a downturn in the global market. Jennings (2016) concluded that "While this disaster crippled parts of the Japanese economy, it also impacted companies throughout Asia, Europe, and the U.S. The disaster caused disruptions in the automotive supply chain, resulting in a shortage of small and mid-sized cars and reduced production levels in the U.S." The ensuing aftermath of the earthquake showed weaknesses in global supply chains dependent on products sourced solely from Japanese markets. Close (2016) also commented, "Companies dependent on Japan's 'just-in-time' delivery practices were left without parts. Global production suffered, affecting other nations' countries."

The lack of preparedness proved that no matter the supply chain location, any impact locally can affect globally. According to Prevention Web [P.W.] (2018), this impact with "theoretical models have suggested that an extreme shock to one firm can impact its clients and suppliers as well." Regarding the 2011 Japanese Earthquake, P.W. analyzed that

Companies with at least one supplier affected by the quake underperformed by 2% compared to those with unaffected suppliers. When the researchers compared firms with or without quake-affected customers in a similar manner, they found that the former had a 1.2% decline in growth compared to the unaffected companies (Research Briefs section, para. 6).

Hurricanes pose a considerable threat to U.S.-based manufacturing supply chains and the modes of transportation used to distribute goods globally. Infamous storms such as Katrina, Sandy, Irma, Harvey, and Florence have disrupted the U.S. presence in specific trades. In 2012, Hurricane Sandy caused extreme flooding and damage to the New York and New Jersey metropolitan areas. However, it caused significant issues when air and seaports closed for over a week. Sandy disrupted the flow of goods, created a backlog with transportation, and cost money for firms to rebuild, if at all. Bjacek (2014) argued that Hurricane Sandy "Caused numerous shutdown and supply line disruptions, with some chemical facilities remaining closed afterward." Rodrigue (2017) reported, "The shutdown of all the region's airports, ports, and public transit systems due to flooding and power outages took several days for the system to be brought back to normal operating conditions, which had substantial impacts on commuting." Firms needed to find alternative routes for distributing their products.

By far, the most disastrous storm was 2005's, Hurricane Katrina. Extensive flooding and wind damage caused many deaths and the complete decimation of homes, businesses, and entire towns. Supply chains and their methods of transportation were not immune. Bjacek (2014) researched that "20-30% of U.S. aromatics capacity was affected, total organic chemical shipments dropped 20%, and 5% of U.S. refining capacity was shut down." Close (2016) looked further into the Port of New Orleans, stating,

The port sustained around \$160 million in damage, losing nearly 30 percent of its capacity. The countless troubles began between flooding, wind damage, no people, no power, and a clogged channel. Communication alone took days to reestablish. Locating port staff took over a week due to how scattered employees were after the flood (Food and Raw Materials section, para. 11).

In 2018 Hurricane Florence hit the coast of North Carolina, causing massive flooding and extreme damage to the coastal communities and businesses. Amongst those impacted were specific groups of workers that sustained downtime in their respective trades. Dowell (2018) provided demographics showing how workers in the manufacturing area of Florence hit businesses that counted for over 11% of the local economy. Hurricane Harvey in 2017 hit Houston, affecting 6% of the manufacturing firms within that area. Quickly following Harvey, Hurricane Irma struck the Gulf and Carolinas, crippling almost 12% of manufacturing supply chain workers. Not only did Irma impact over 1 million manufacturing workers, but over 400 countries also felt this overall global control. Supply chains worldwide felt the effects as this area struggled to maintain pre-hurricane levels of productivity (see Appendix C).

Another uncontrollable and extremely unpredictable natural disaster is a volcanic eruption, and the most infamous to have hurt supply chains was the 2010 eruption of Iceland's Eyjafjallajökull volcano. The blast sent massive amounts of ash into the atmosphere creating a no-fly zone between the United States, Europe, and any connecting firms worldwide utilizing that trade route. Rodrigue (2017) reported, "Volcanic ash is composed of tiny, jagged particles of rock, which are highly abrasive. If an airplane flies through such an ash cloud, the result can be engine failure." The "largest natural disruption of air travel in history" followed next, causing airports in London, Paris, Brussels, Frankfurt, and Amsterdam to close. All of which are central

hubs to connect for flights to further destinations. Supply chains in various countries sustained heavy financial losses by reducing production, sending labor home, or choosing more expensive alternative transportation methods for their goods. Banker (2010) revealed why air freight was so crucial to a few firms and how detrimental it was to their business

BMW and Nissan said they plan to suspend some production this week because of disruption to supplies. Audi said it might have to cancel shifts because of missing parts. Although all three mainly use suppliers near their factories and use road and sea for most deliveries, they depend on air freight for a small number of high-value electronic components (Pressure on Supply Chain section, para. 2).

What happens when disruptions occur not by nature but by man? The result can be as complex and expose a supply chain's weakness in levels of preparedness. Anthropogenic disruptions are known as "artificial," meaning they can be intentional or unintentional disturbances within the supply chain. Whether the trouble is natural or manufactured, the impact can be the same to an unprepared supply chain; loss of profit, productivity weakened, and adverse effects on inventory levels on goods and services.

"It is estimated that piracy's total annual monetary cost to the international community is somewhere between \$4.9 and \$8.3 billion" (Helmick, 2015). With technological advances made to vessels, such as advanced tracking systems, global positioning systems, and the ships' enormous size, it is impressive that smaller vessels can still take the entire operation. Pirates are present in specific areas along trade routes that are difficult to navigate yet necessary to reach specific destinations. These include the Gulf of Aden, the Red Sea, the Suez Canal, and the Arabian Sea. The most notorious locations were the Gulf of Aden and the Maersk Alabama piracy attack in 2009. Even after this incident occurred, piracy attacks continued to rise. Helmick

(2015) reported that in 2013 there were a total of 264 pirate attacks on the high seas. This number was an 11% decline from 2011. Piracy and supply chains have many factors, including delayed cargo delivery and potential total cargo loss (theft, destruction from the attack, or decay with perishable items). "Cargo that is delivered late may lose value if it can be delivered. Cargoes in the high-value, time-sensitive sector incur additional in-transit inventory carrying costs for their owners" Helmick (2015). Supply chains may not realize these potential risks associated with ocean shipping and may fail to secure their goods for each order properly. Helmick (2015) found that even if 2% of cargo transiting through the Suez Canal fell victim to piracy attacks, it still accounted for \$7.4 billion worth of total load. Rodrigue (2017) stated that "The outcome of piracy on global supply chains has been small but not negligible as ships have changed their routing and that insurance surcharge are being levied for cargo transiting through areas prone to piracy." (see Appendix D).

Quality and price must also be discussed as supply chains grow internationally within their domestic regions. However, additional costs to specific goods can cost firms unnecessary funds and determine if relationships based on the location of their supplier or end customer are worth sourcing. This is a direct result of applicable tariffs on goods. Ahya (2018) concluded that "The impact to global growth from current trade measures is manageable. However, if the situation escalates further, it could impart significant downside risks to our growth forecasts." Essentially supply chains could struggle to continue ongoing growth trends due to downsizing in internationally sourcing materials.

Tariffs, in turn, could impact the entire global trade market as firms would be forced to stay within local areas that may not supply the specific material needed or at the quality or price point that international firms could provide. Suppose countries pose higher tariffs on regions they

usually trade with globally. In that case, it could have the potential for further political strife in the ways of conflicts, trade tensions, or embargoes (see Appendix E). Ahnya (2018) analyzed the potential effect tariffs would have on international growth and found three key factors:

- Demand decline for exports subject to tariffs, should the cost be passed through
- Domestic supply chains suffering weaker demand
- Negative effect on international suppliers sourcing other global supply chains

The entire purpose behind a globally sourced supply chain may change if tariff rates rise. Firms may find themselves limited to what they can provide other companies or even their end consumer, thus impacting overall productivity and profitability within their respective markets.

When trade markets boom and supply chains need parts or goods, they depend on the reliability of the transportation methods and carriers. However, supply chains' significant loss could follow when those reliant choices face delays. As ocean ports strike, they can disrupt supply chains and the local and global economies. The prevention of goods coming in and out of a port could be detrimental to consumers who need specific interests. Retail stores depend on the upcoming arrival of an item where manufacturing facilities need particular parts to finish a final good. Hamelink (2015) reported that port strikes impact numerous firms in a multitude of ways:

- Retail chains cannot sell holiday items that were planned months in advance
- Agriculture firms lose perishable produce on both the import and export side of the port
- Production facilities cannot receive their parts meaning unfinished products sit obsolete

- Transportation companies have to reroute vessels to alternative ports, costing shippers and consignees additional money to pick up their shipments and coordinate with their truckers.

Port strikes often warn of political strife amongst the workers; however, sometimes, it can be spontaneous with no chance of finding substitute options for importers and exporters, leaving them scrambling to save their product and money.

There is no disaster more disruptive than the other. Each affects supply chains that diminish timely delivery to their end consumers; however, in 2020, no global supply chain could prepare for a pandemic. The entire world abruptly stopped when COVID-19 prompted a mandatory shelter-in-place order. Industries worldwide were forced to stop production, send home workers, and wait out the following steps from their respective governments. Planes weren't flying, ships anchored, and cities were emptied (see Appendix F). "Beyond geography, COVID-19 has nearly unprecedented scope...What is unique about COVID-19 is impacting both goods and services" (Moritz, 2020, p. 6). Within the first three months of the pandemic, global supply chains suffered due to a lack of preparedness for this event. "75% of companies are already reporting disruptions due to transportation restrictions...more than 80% believe their organization will experience some impact because of COVID-19 disruptions" (Evaluation Engineering, 2020, p. 8).

Weber (2021) explains that COVID-19 was different from other natural and anthropogenic events as it impacted both demand and supply concurrently "Supply disruptions originated from delays in delivering certain raw materials and imports, whilst demand was disrupted because of the sudden changes in consumer lifestyles, which wholly altered consumers' way of living, working, and shopping" (p. 2). Additionally, labor shortages increased with

employees contracting the virus and staff required to stay home to quarantine due to possible exposure. These issues were just the start of supply chain failures to keep up with increasing global demand. Goods that were already en route to their final destinations faced delays due to shipping bottlenecks, "hundreds of ships have been stuck outside ports, unable to load goods due to a lack of lorry drivers and warehouse congestion" (AIQ, 2022, p. 3). Furthermore, prices and transit times increased due to changes in demand coupled with a lack of supply. Trans-Pacific shipping times jumped from 42 days to 80 days from the end of 2019 to 2021. During that same time frame, the costs of ocean containers skyrocketed from \$2,000 to \$20,000 each (see Appendix G). After reviewing the various disasters that can negatively affect supply chains and the global economy, there is a definitive need for these organizations to build resiliency in their operations.

### **Methodology**

The primary methodology for collecting information to support this paper comprises secondary research and data analysis relevant to natural and geophysical disasters, anthropogenic events, and the current COVID-19 pandemic. Data is sourced from scholarly journals, expert-led blogs, online and print articles, case studies, and textbooks to highlight the significance of these topics. Additionally, material by international researchers and local government regulatory agencies is incorporated to emphasize the need for risk mitigation strategies in global supply chains. All resources will be analyzed and detailed in a literature review and comprehensive discussion to capture the importance of risk mitigation strategies while visually and academically stressing the consequences of under-preparedness.

### Discussion

While there are many varying models on what is considered the most effective way to prepare or prevent total devastation from an event, there also is a common trend amongst researchers in that firms just need a plan. Conversations need to occur at any firm on an executive level that can be adopted and practiced throughout the chain. Rodrigue (2017) has a 5-step approach titled "Disaster Risk Management," the most organized methodology for a supply chain to plan disasters effectively. Each method has its own set of guidelines that alternative researchers universally stress.

The first method is the initial risk assessment when a firm should first and foremost assess any potential risk factors before an event occurs. Planning ahead of time will ensure that a supply chain can stay organized throughout a disastrous occurrence. Topics of question should focus on the location of firms' facilities concerning natural events such as rain, flooding, tornadoes, hurricanes, etc. Also, the firm should be located in a relatively neutral economic and political zone if a country enters a conflict or trade disagreement. Close (2016) suggests that monitoring regions for threats can increase awareness of a firm and its suppliers when choosing locations to settle in (see Appendix H). Not only should the firms' location be strategized, but their suppliers and main transportation hubs should also be in more desirable locations. Also, proper channels of communication regarding assessments of their firms and how they may impact each other would prove successful. Jennings (2016) believes that "By improving visibility across supply chains, increasing collaboration among firms and enhancing control mechanisms, manufacturers seek solutions to supply chain problems." Close (2016) concluded that asking suppliers for their disaster plans can help integrate recovery procedures that directly and indirectly affect a supplier and their customer.

A supply chain should also use a variety of suppliers that can maintain their inventory levels during non-stressful times and provide the flexibility of sourcing from alternative suppliers in the event of a disaster and the potential for shortages. "Supply chain risks have traditionally been managed by evaluating the magnitude and likelihood and business impacts of risks and locations, and configuration of technological assets...it is important to know where the suppliers of all tiers are located" (Isopoussu et al., 2021). This first step in risk assessment could potentially save a supply chain from encountering any risks. Careful consideration of location and the probability of adverse impacts within that area should be at the forefront of a supply chain evaluation. "Forward-thinking companies are building business continuity practices into their supply chains to recover faster and avoid temporary or permanent plant shutdowns" Jennings (2016).

Following the risk assessment, the supply chain should focus on preparedness and evaluate how it would respond to a disaster before it occurs. Close (2016) suggested that firms create best, average, and worst-case scenarios and play off those to create their personalized disaster plan. Rodrigue (2017) agrees that a firm should keep its processes and procedures up to date with the latest techniques. Plans should detail safety procedures and monitor demand fluctuations that can follow a disruption to the firm. Does the supply chain have the capacity to handle an increase in demand following an emergency, and if no growth is determined, how can the firm prevent unused inventory from becoming obsolete? Creating a disaster team responsible for managing the firms' plans for recovery and working cross-functionally with other stages within the supply chain to see how certain disasters would impact each component is also critical (see Appendix I). VMA Staff (2015) agreed that

Companies address these challenges by building safeguards into their supply chains and planning that includes contingencies. They enhance those risk management efforts by purchasing contingent business interruption insurance, covering lost profits if an event shuts critical suppliers or major customers (Lessons section, para. 2).

The disaster management team should work with their legal team to review what insurance policies they have in place, what they cover, and how much monetary probability is still considered a risk. Reviews should also include participating stakeholders such as suppliers, vendors, or end consumers' vulnerabilities. Close (2016) suggested that supply chains should not only have a plan for themselves but also

Have a plan for response established beforehand that specifics which will lead relief efforts and how these relief efforts will be carried out, with contingency plans for different types of disasters and in different regions where the company does business (Food and Raw Materials section, para. 15).

By taking care of the shareholders involved in a supply chain business, being prepared ahead of a disaster will ensure that all parties have protection within the best abilities of the functioning supply chain.

After a natural disaster or anthropogenic disruption, preparedness plans are tested through mitigation. The main goal is to control and attenuate the disorders caused by the disaster. Rodrigue (2017) also stresses that one of the core aspects of proper disaster mitigation is achieving resistance within the supply chain, which is accomplished through redundancy and flexibility. Redundancy can be duplicating assets by connecting locations and receiving additional inventory from alternative suppliers. Supply chains can maintain flexibility by finding new transportation routes to receive products or finding new suppliers not located within an

impacted zone. A supply chain does not necessarily need to bear the burden of building strength throughout its firm. Jennings (2016) concluded that

Governments play a fundamental role in building supply chain resilience. Plans include increasing the speed and effectiveness of disaster recovery, providing timely financial support to help firms quickly restore operations, and facilitating business rehabilitation and maintenance. Collaborations are exploring new mechanisms in insurance information sharing and physical asset development that will reduce the risk of supply chain disruptions and minimize the economic impact of disasters (Emergency section, para. 5).

Once mitigation has been conducted, the next target is to bring the supply chain back to its maintained operating consistencies with a solid response plan. Rodrigue (2016) implies that "If a mode is impaired, the usage of alternative modes and infrastructure has to be considered." This includes analyzing the need for specific products after disaster strikes, how their demand may increase or decrease, and how that will impact the supply in the affected areas. Close (2016) also stressed that prompt transparency with suppliers, partners, and internal staff could go a long way toward recovery. Jennings (2016) shared the same thought: "Public managers are taking steps to understand supply chains that affect companies in their communities. Supply chain mapping can provide greater insight into potential emergencies before they happen and point to potential collaborations which can avert or shorten problems." Maersk Lines, the world's largest ocean shipping company, has implemented their "Cluster Response Preparedness Mapping." The map measures the six most disaster-prone countries and helps find the nearest port to find alternative routings to ensure supply chains can still receive their products (Close, 2016). By having quick response methods to a disaster, a firm can gain global support from shareholders

that depend on their services for success, decreasing the amount of downtime a firm may face (see Appendix J).

Recovery is successful if the plans mentioned above are controlled, monitored, and consistently have the supply chain's resiliency in mind. Rodrigue (2016) research concluded that recovery

Concerns all the steps necessary to recover the capacity lost during the disaster. It involves repairs, restarting discontinued services, and investments in new and improved infrastructures. The goal is to bring back the capacity and level of service to pre-disaster conditions. With the lessons learned from the disaster, more resilient infrastructure and networks are likely to result (Transportation Disaster Planning section, para. 5).

While this is the goal for all affected parties within a supply chain, it is not always as available depending on the firm's risk assessment and preparedness levels and firm locations near the disaster. "Recovery is contingent upon the availability of capital, equipment, and managerial expertise. Therefore, in advanced economies, recovery is much faster than in developing countries" (Rodrigue, 2016). While recovery efforts help establish operations back to how they were before disaster struck, changes may still be inevitable. For a firm to continue success after an adverse event, adjusting to these new structure changes, lessons learned guidelines, scheduling conflicts, and switching of suppliers needs to be recognized and welcomed. By accepting potential changes, a supply chain and its respective partners can continue to be productive and profitable.

### **Conclusion**

Focusing on the five steps towards disaster risk management is the critical stage of implementing a supply chain business continuity model (see Appendix K) and the "ability to

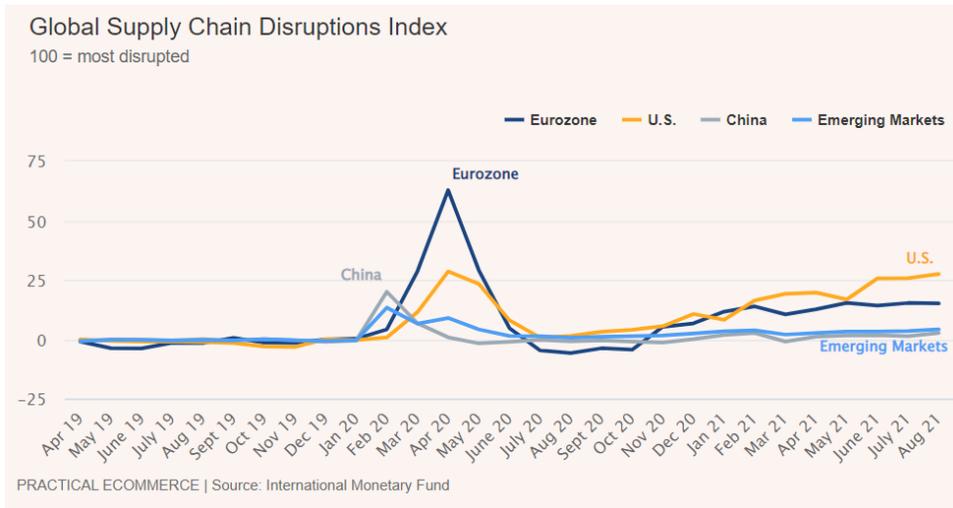
recover from a disruption and move either back to the original or a totally new state" (Isopoussu et al., 2021). In analyzing past disasters' impact on supply chains and their economies and evaluating mitigation strategies for prevention and recovery, future disruptions remain a lingering threat. Storms will get stronger; people will jeopardize operations, and economies will fluctuate in strength; however, a supply chain's ability to overcome depends on adapting, understanding, and growing from these issues. These companies will continue to develop throughout the global marketplace, spanning into areas at a higher risk. "Between 2005 and 2014, the world averaged 335 annual natural disasters. This totaled \$1.5 trillion in damages worldwide, causing more than 1.1 million deaths and affecting the lives of over two billion people" (Close, 2016)(see Appendix L).

Climate change will impact the world, but the surge of storms could move more people and more supply chains and force permanent changes to how products are distributed globally. Anthropogenic disruptions will continue to intensify with the possibility of more tariff regulations, country embargo rulings, and cyber terrorism as supply chains grow more and more dependent on technology. COVID-19 has shown that all global supply chains have vulnerabilities and continually need assessment to thrive. These issues are ones that supply chains need to increase visibility within their organization to flourish with each passing year. Every new disaster can be catastrophic if preparedness fails; however, resiliency is achievable with the successful implementation of risk management plans.

Appendixes

Appendix A

Index of Global Supply Chain Disruptions from April 2019-August 2021



Note. Eurozone had highest disruptions spike at the start of the COVID-19 pandemic.

Appendix B

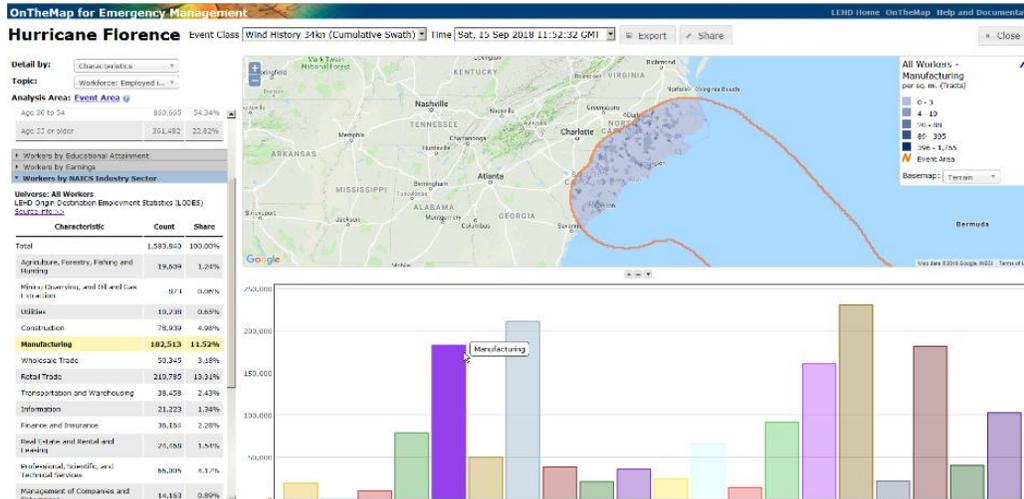
Natural and anthropogenic disasters: Unknown/Uncontrollable versus Known/Controllable



Note. Each disaster can be equally problematic and is not listed in order of most to least disruptive

## Appendix C

### Worker Disruption from Hurricane Florence



Note. Supply chain manufacturing was 3<sup>rd</sup> hardest hit for worker displacement during 2018's Atlantic hurricane season.

## Appendix D

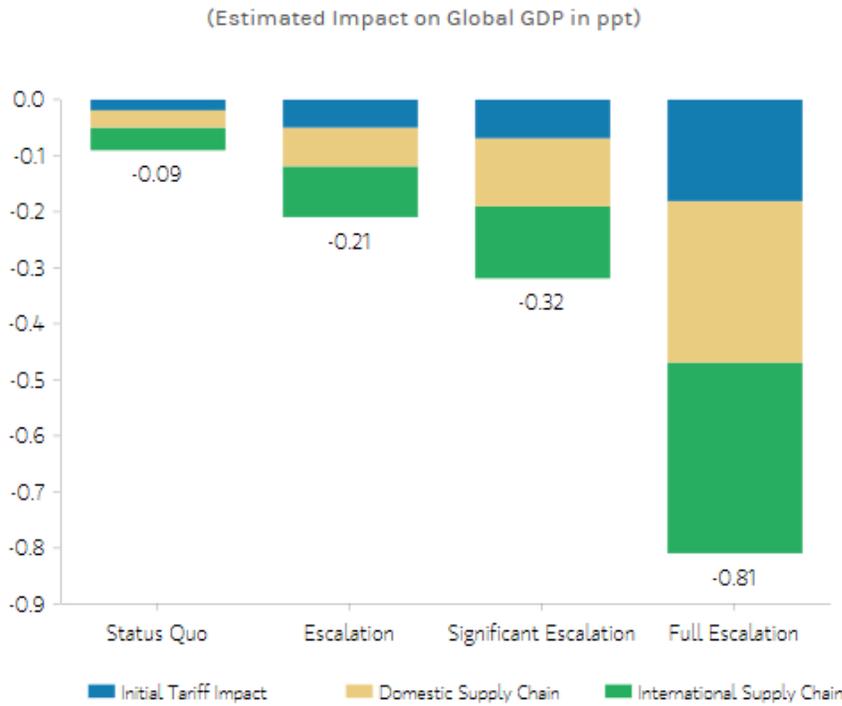
### Main Maritime Shipping Routes to Avoid Piracy Against Cargo Ships



Note. The Suez Canal links European and African routes yet is the highest for piracy attacks in the world.

**Appendix E**

*Imposed Tariffs and Their Impact on Global Supply Chain GDP*



*Note.* As global trade grows, so do the possibilities of increased tariffs on highest valued items.

**Appendix F**

*Dimensions of Supply Chain Disruptions of COVID-19*

Dimension	Typical Disruptions	COVID-19
<b>Geography</b>	Most disruptions are local or regional	COVID-19 is widespread & global, impacting all regions
<b>Scope</b>	Limited scope: Fewer industries affected (i.e., a hurricane disrupts the petrochemical industry)	Widespread scope impacting both goods (like toilet paper) and services (haircuts, restaurant meals). Knock on closure of sporting events, cruise ships, schools/universities, etc.
<b>Demand vs. Supply</b>	Disruptions most often impact supply, sometimes demand	Impacts demand, and possibly supply
<b>Prior Planning &amp; Experience</b>	Disaster planning has been done, and prior experience is available	Limited disaster planning for global pandemic, with limited prior experience (1918 Spanish Flu?)
<b>Financial System</b>	Low to moderate correlation with global financial system	High correlation with global financial system
<b>Term</b>	Short-term needs for emergency services (i.e., flood rescues)	Longer-term emergency service needs (i.e., hospital beds, ventilators)
<b>Human Impact &amp; Behavior</b>	Localized human impact, with limited duration. Public fear is short-term, and most risks are visible (i.e., experiencing a tornado or earthquake).	Widespread human impact, with unknown duration and unknown impact. Public fear is longer-term and risks are invisible / unknown.

*Note.* COVID-19 has more unknown variables with the least amount of preparedness across global supply chains versus natural and anthropogenic disasters.

**Appendix G**

*40 Foot Ocean Container Rates from Q4 2019 to Q4 2021*



*Note.* Asia to U.S. west coast hardest hit with a 300% increase within one year.

**Appendix H**

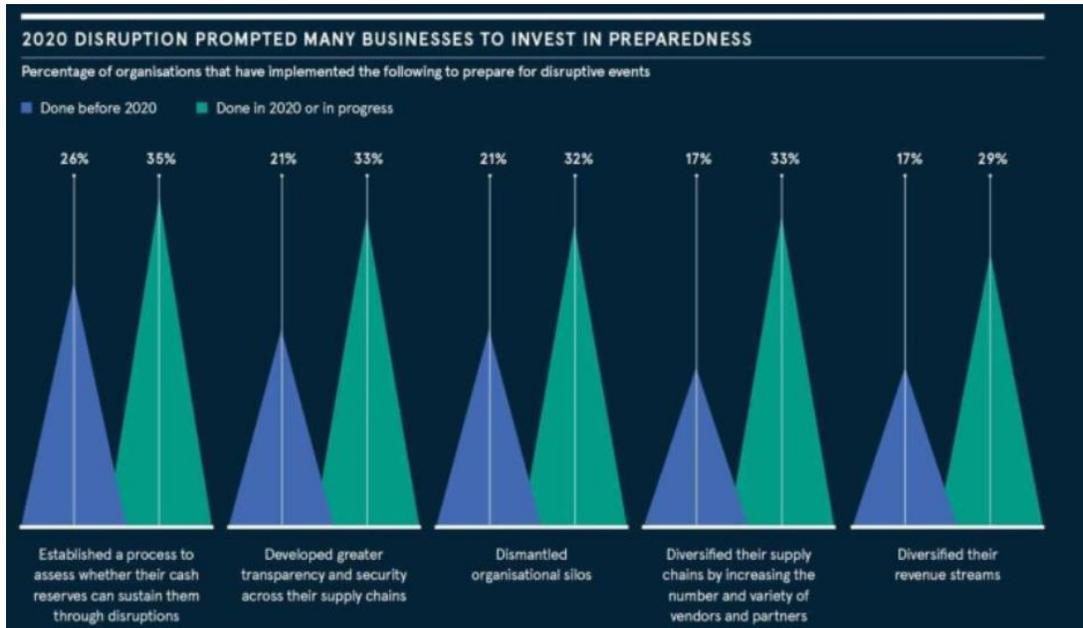
*Supply and demand based on optimal supplier location*



*Note.* Most suppliers tend to be near a coast for easy access for all methods of shipping.

**Appendix I**

*Companies investing in disaster preparedness before and after 2020*



*Note.* After 2020's COVID-19 global shut down, there was a 10%-20% increase in business investment towards disaster preparedness.

**Appendix J**

*Business operational levels and length of time towards recovery*



*Note.* Resiliency starts during, not after, the impact and builds towards recovery and back to high operational levels.

**Appendix K**

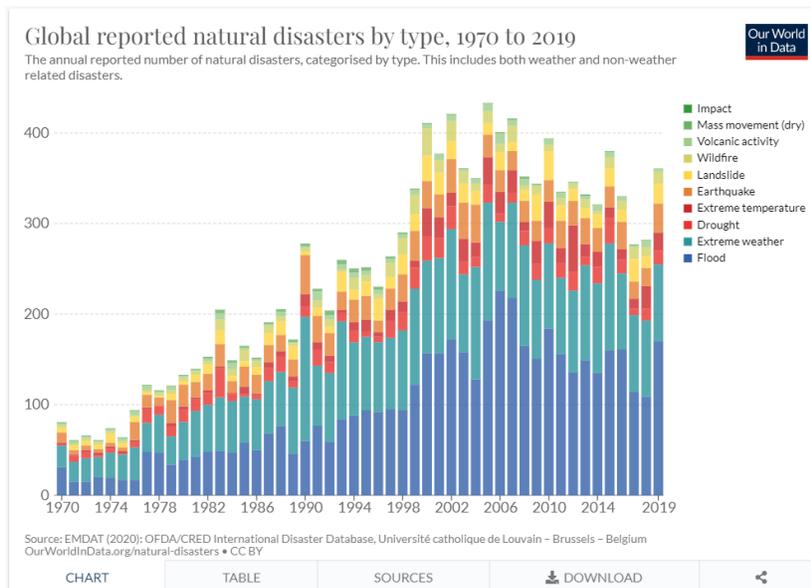
*Withstanding disruptions depends on capabilities of business continuity management*



*Note.* Only 4% of supply chains showed strength amongst all seven levels.

**Appendix L**

*List of Global Natural Disasters from 1970 to 2019*



*Note.* Flooding and extreme weather continue to rise as the years progress.

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