Exploring the Use of Modern Supply Chain Techniques in Managing Natural Disaster Relief in the United States.

By

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An Undergraduate Thesis submitted in partial fulfillment of the requirements for the

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March 2024

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1. ABSTRACT

This research looks at the intersection of two fields: modern supply chain logistics and technologies and natural disaster relief. This research aims to examine the application of blockchain and different technologies used in last-mile logistics in the relief of natural disasters. We conducted a robust literature review to understand modern supply chain technologies and advancements and current humanitarian organization operations, in addition to interviews and data collection to understand the feasibility of incorporation. Our findings recommend that individual humanitarian organizations could benefit from the adoption of blockchain and further uses of last-mile logistics to aid in the relief of natural disasters, but should be examined on a case-by-case basis. Through expert interviews, data collection, and a robust literature review, it was understood that the costs for adopting blockchain and different last mile logistics may outweigh the benefits, but it was found that there are numerous advantages to adopting the techniques. This study contributes to an essential field of research because natural disasters are becoming more frequent in the United States.

Keywords: blockchain, last mile logistics, natural disasters

2. INTRODUCTION

From 2013 to 2023, the United States experienced an average of $18 billion in climate disasters per year, with the five most common being floods, hurricanes/cyclones, droughts, and wildfires (Davies, 2023). Although the United States has an elaborate system for dealing with and aiding in resolving disasters within its country, it is not always the most efficient. For example, it took several weeks to restore power and repair infrastructure in Florida due to Hurricane Michael, and the effects of Hurricane Katrina were seen for years (Mansell, Grant, 2023).

2.1 - Natural Disasters

A natural disaster is any geological or meteorological event that occurs on a large scale and poses a significant threat to human health, safety, and life (SAMHSA, 2023). They can cause immense infrastructure damage and are often unpredictable (Hidalgo, Baez, 2019). Some examples that might spring to mind might include tornadoes, tsunamis, hurricanes, earthquakes, and wildfires.

Since the United States is diverse geographically, many different disasters are common across the country. Most are common in specific climates and regions across the United States. However, every type of disaster has the opportunity to cause millions of dollars in damages to the local community and the surrounding economies. The most common natural disasters in the United States include floods, wildfires, earthquakes, hurricanes, and tornadoes. The exhibit below supplements the following paragraphs through the further categorizing of natural disasters.

Box 1
Classification of natural disasters

Geophysical	Hydrologic	Meteorologic	Climatologic
• Earthquake Ground shaking Tsunami • Volcano Volcano eruption • Mass movement (dry) 1. Rockfall 2. Landslide Mudslide Lahar Debris flow 3. Avalanche Snow avalanche Debris avalanche 4. Subsidence Sudden subsidence Long-lasting subsidence	• Flood 1. General flood 2. Flash flood 3. Storm surge/ coastal flood • Mass movement (wet) 1. Rockfall 2. Landslide Debris flood 3. Avalanche Snow avalanche Debris avalanche 4. Subsidence Sudden subsidence Long-lasting subsidence	• Storm 1. Tropical cyclone 2. Extratropical Cyclone (winter storm) a. Convective storm Thunderstorm/ lightning Snowstorm/ blizzard Sandstorm/dust storm Generic (severe) storm Tornado Orographic storm (strong winds) b. Local storm	• Extreme temperature 1. Heat wave 2. Cold wave Frost 3. Extreme winter conditions Snow pressure Icing Freezing rain Debris avalanche • Drought • Wildfire 1. Forest fire 2. Land fire

Exhibit 1: Natural Disasters and their Classification (Hidalgo, Baez, 2019)

Floods, which are caused by heavy rainfall, storm surges, or the overflow of rivers and lakes, affect many parts of the United States. About 90% of all natural disasters in the United States involve flooding and a third of all natural disasters around the world are classified as floods by numbers and economic losses (Berz, 2001). Many times, floods occur in areas designated as "Floodplains." Floodplains, defined as "any land area susceptible to being inundated by floodwaters from any source," are often found along major rivers and can be significantly damaged due to a natural disaster such as a flood (Greater Houston Flood Mitigation Consortium). Other states frequently affected by flooding may include Louisiana, Mississippi, Florida, Arkansas, and other coastal areas, especially along the Gulf Coast and Eastern Seaboard. These coastal areas are vulnerable to storm surges during hurricanes, which will be further defined in the following paragraphs. The relief needed for a flood can vary dramatically but most often includes relocation of local citizens, providing food and water, and various rescue operations. Floods are relatively frequent and can cause immense damage, leading to varied relief needs.

Wildfires, often sparked by lightning or human activities, predominantly ravage the western states, including California, Oregon, and Washington (Weber, Yadav, 2020). Factors such as dry conditions, strong winds, and abundant vegetation contribute to these regions' frequency and severity of wildfires. The wildfire season typically peaks in the summer and early fall, with catastrophic events like the Camp Fire in California in 2018, which destroyed thousands of structures and claimed dozens of lives, underscoring the destructive potential of wildfires (Herring, Christidis, Hoell, Hoerling, Stott, 2020). Much like floods, the severity of a wildfire can vary, leading to a discrepancy in relief needed. Some common types of relief necessary in the wake of a wildfire may include long-term recovery and restoration, relocation, and distribution of provisions/water (Wildfire Relief, 2024).

Earthquakes, resulting from the movement of tectonic plates, pose risks primarily along fault lines. The West Coast, particularly California, is renowned for its seismic activity, with the San Andreas Fault representing one of the most significant geological features in the region (Weldon, Fumal, Biasi, Scharer, 2005). The Pacific Northwest, including the states of Washington and Oregon, also faces earthquake hazards, as well as Missouri, Arkansas, and Tennessee, despite lower frequency compared to the West Coast (Shedlock, Pakiser, 1999). The damages caused by earthquakes can be devastating both economically and structurally.

Hurricanes, which originate in warm ocean waters, particularly in the Atlantic Ocean and Gulf of Mexico, are characterized by powerful winds and heavy rainfall. These natural disasters pose significant threats to coastal and inland communities, especially along the Southeastern and Gulf Coast states. States such as Florida, Louisiana, Texas, and North Carolina are particularly vulnerable to hurricanes, with historical events like Hurricane Katrina in 2005 and Hurricane Harvey in 2017 demonstrating the devastating impacts these storms can inflict (Collier, Balakrishnan, Zhang, 2019). Hurricanes can wipe out communities and leave individuals stranded for weeks, so it is essential to have relief programs set in place to quickly and effectively respond to natural disasters.

Tornadoes mainly occur in "Tornado Alley," a region encompassing states such as Texas, Oklahoma, Kansas, and Nebraska, where atmospheric conditions are conducive to tornado formation. Tornadoes typically develop when warm, moist air from the Gulf of Mexico collides with cool, dry air from the north (Boruff, Easoz, Jones, Landry, Mitchem, Cutter, 2003). This collision creates instability in the atmosphere. Within these storms, wind shear—variation in wind speed and direction with altitude—plays a crucial role in the development and intensification of tornadoes (Markowskim Richardson, 2013). The tornado season typically peaks in late spring and early summer, with violent tornado outbreaks capable of causing widespread destruction. In the exhibit below, the costs and locations of natural disasters are listed, providing context for common geographical locations of disasters.

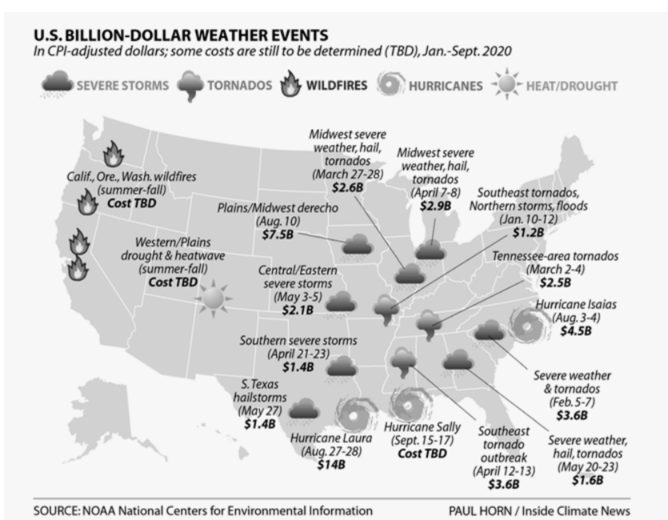

Exhibit 2: Where Climate Disasters Strike Across America (Weisbrod, 2021)

As mentioned above, natural disasters encompass a broad spectrum of catastrophic events, each capable of inflicting varied damages upon both human and natural environments. Natural disasters lead to many different losses and cause many various costs, ranging from the loss of life and injury to homelessness and distress (Alexander, 1993). Primarily, these damages are the physical destruction of infrastructure, including buildings, roads, bridges, and utilities, often resulting in robust disruptions to societal and economic activities (Alexander, 1993). Moreover, natural disasters frequently cause environmental degradation, such as soil erosion, water contamination, and habitat destruction, which can further ecological imbalances and detrimentally affect biodiversity (Kahan, Zaman, Shoukry, Sharkawy, Gani, Sasmoko, Ahmad, Hishan, 2019). Additionally, the psychological toll incurred by such calamities is profound as communities grapple with trauma, grief, and the psychological strain of displacement and loss (Freedy, Shaw, Jarrell, Masters, 1992).

Economic repercussions are also widespread following a natural disaster, with direct costs associated with property damage and reconstruction, as well as indirect costs stemming from paused commerce, minimized productivity, and long-term socioeconomic issues (Kahan, Zaman, Shoukry, Sharkawy, Gani, Sasmoko, Ahmad, Hishan, 2019). Furthermore, natural disasters pose significant threats to public health, precipitating outbreaks of diseases, injuries, and malnutrition amidst compromised healthcare infrastructures (Ligon, 2006). In conclusion, the damages brought about by natural disasters are unique and complex, which is why it is vital to have proper programs in place to mitigate and avoid these risks.

2.2 - Humanitarian Aid

Humanitarian aid plays an essential role in providing assistance and relief to individuals affected by natural disasters. When natural disasters strike, whether in the form of an earthquake or a hurricane, there is often widespread destruction of infrastructure, displacement of the individuals affected, and an interruption of essential services. This is why robust and effective relief programs must be in place in order to minimize the damages and the effects of these natural disasters.

Humanitarian organizations, such as the American Red Cross, the Federal Emergency Management Agency, the Convoy of Hope, the World Bank, and the Salvation Army, are often the first to respond to natural disasters. They provide relief to the affected areas by delivering necessary materials—such as food and water—creating and providing temporary shelters and offering medical and psychological treatment.

The American Red Cross is one of the most well-known and recognized humanitarian organizations. With a vast network of volunteers, staff, and resources, they are able to provide reasonably immediate assistance to affected communities (Disaster Relief and Recovery Services). The American Red Cross has developed a routine for natural disaster relief. It starts with immediately establishing emergency shelters to distribute basic necessities and offer accommodation to those in need. These shelters also serve as makeshift hospitals for medical care and emotional support. At the same time, the Red Cross sends its trained disaster response team to assess the extent of damage and identify teams to determine the extent of damages. The American Red Cross also collaborates closely with local, state, and federal agencies, as well as other humanitarian organizations, to collaborate on response efforts. In addition, the American

Red Cross also offers long term support to communities that have been affected by a natural disaster. The exhibit below, depicts the phases of a disaster, and the steps taken to provide relief.

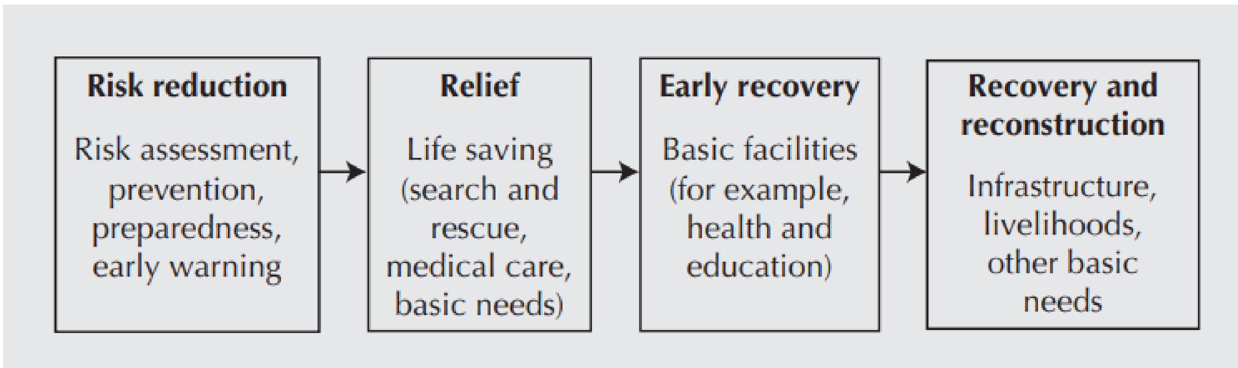

Exhibit 3: Phases of a Disaster (Goyet, 2009)

The American Red Cross uses some more advanced technology to help with the relief it provides in the wake of a natural disaster. For example, the American Red Cross rolled out an app that helped with disaster preparedness and relief. They could use data analytics to access real-time data through the app to help more efficiently (Kirsch, Circh, Bissell, Goldfeder, 2016). This app not only boasted increased data analytics within a natural disaster, but it also allowed for modern "just-in-time" delivery, in this case, delivery of information, that present-day modern supply chain logistics has focused on (Kirsch, Circh, Bissell, Goldfeder, 2016). Additionally, per the American Red Cross website, the firm is looking to build more capabilities within AI, potential future use of Drones, and increased robotic process automation (Innovation at the American Red Cross). Although they have not fully developed these technologies, they are something on the horizon for the American Red Cross.

The Federal Emergency Management Agency, or FEMA, is another organization that provides relief following a natural disaster. Much like the American Red Cross, FEMA has a robust plan for providing relief to an area and community in the aftermath of a natural disaster. The first step is for the local government to request Aid from FEMA, and then a major disaster is declared (Congressional Research Service, 2022). The President of the United States typically does this, and it occurs when they determine that the damage caused is too much for local and state governments to handle without support from the federal government (Congressional Research Service, 2022). The specific request from the local government officials determines what kind of relief FEMA will provide, which can vary from disaster to disaster. From there, FEMA will survey the area, determine what kind of relief is needed, and start acquiring the necessary resources.

FEMA has five main branches within its organization that are responsible for disaster response. Among those include the Distribution Management Division, the Logistics Systems Division, the Logistics Operations Division, the Office of Business, Industry, and Infrastructure Integration, and the Incident Management Support Division (Logistics management). All of these divisions are expected to work together following a natural disaster to provide quick relief, but sometimes communication can be challenging. Unfortunately, there is not much literature on the technical capabilities of FEMA, so little is known about their exact operations from a supply chain perspective. This is something the following interviews will seek to alleviate.

The World Bank also provides relief following a natural disaster, but mostly in a financial setting (Disaster Risk Management). They provide insurance and bonds to countries needing financial instruments before or after a disaster and focus on smaller or less developed countries. This is not a direct interest of this paper, but it is worthwhile to note.

Overall, although these humanitarian organizations are massive and have plans in place following a natural disaster, they still operate at a reasonably grassroots level. This can make it challenging to move supplies around and provide relief and support in a timely manner.

2.3 - Blockchain

Blockchain is a decentralized and coordinated technology that allows for the secure sharing and record-keeping of data across a network of computers (Algorand Foundation, 2023). This is slowly being implemented into natural disaster relief, but currently, its uses are primarily for funding the efforts of these humanitarian organizations. I am proposing that this technology will allow these organizations to make better-informed decisions because they have more robust access to data on what relief is available in terms of resources and what relief is required due to the effects of the disaster.

In the 1990s, blockchain technologies were dramatically different than they are today, but at that time, Stuart Haber and Scott Stornetta laid the groundwork for modern-day blockchain (Ashcroft, 2022). The term "blockchain" came from the unique way data in this structure would be packaged into blocks and linked together (Ashcroft, 2022). In 2017, organizations began to use blockchain within their supply chains. Instead of tracking bitcoins like the previous use cases of this technology did, different professionals would track different transaction-related data, inventory, and orders using tokens (Ashcroft, 2022). Today, blockchain is a decentralized, revolutionary technology that allows for the safety and the security of the data in the chain (Dutta, Choi, Somani, Butala, 2020).

Blockchain works by creating a shared network that authorized individuals can access. Records are added to this network, but they cannot be edited without changing the preexisting file/value, making it very safe for managing supply chain operations as majority consent is needed to change the records (Dutta, Choi, Somani, Butala, 2020). All transactions within the blockchain are time-stamped and cannot be changed once they are added. Due to its record-tracking nature, blockchain is incredibly safe and can work with significant amounts of data, making it attractive. The exhibit below, highlights numerous benefits of adopting blockchain.

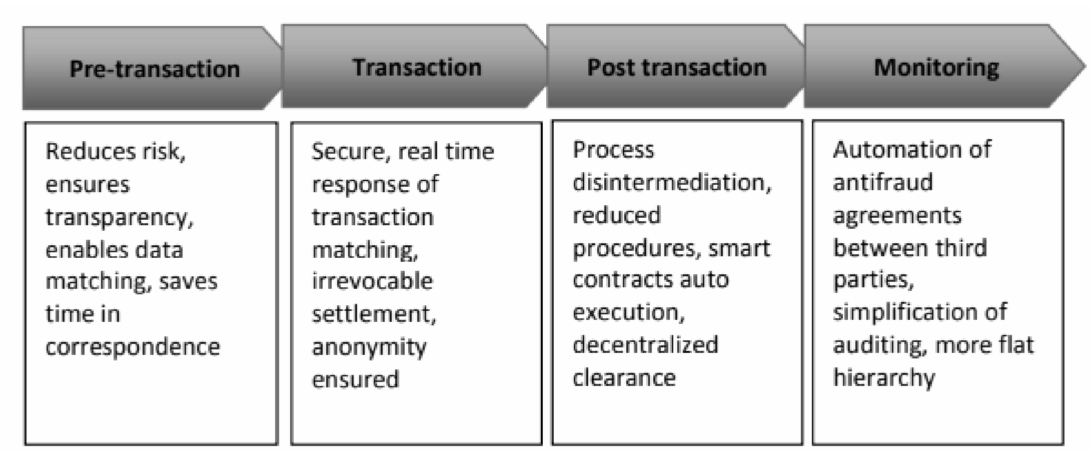

Exhibit 4: The blockchain-supported transaction journey (Dutta, Choi, Somani, Butala, 2020)

Additionally, blockchain is an attractive answer to solving numerous supply chain issues. For example, blockchain has contract automation, which means that a computerized part of the program writes and holds different parties accountable for different contracts (Manupate, Schoenherr, Ramkumar, Wagner, Pabba, Inder, 2019). This allows for an added layer of security and timely responses by those using the network in various supply chain-related scenarios.

To understand the benefits of adopting blockchain technologies, first, there needs to be an understanding of what those benefits look like. Blockchain is adopted by firms in order to improve operational efficiency, which is understood to be the positive practice of a firm that increases value through higher utilization of a company's goods and resources during business operations (Kwon, Lee, 2019). This idea of operational efficiency can be further broken down into two categories: time-based efficiencies and cost-based efficiencies. Blockchain was designed to reduce both by decreasing the need for a "middleman," which increases security. The introduction of blockchain has been found to decrease transaction costs, including both time- and cost-based efficiencies (Hasan, Shiming, Islam, Hossain, 2020). Some of the transaction costs that can be minimized through the adoption of blockchain include the costs of technology infrastructures, search costs, and different costs that are associated with negotiations (Hasan, Shiming, Islam, Hossain, 2020). In addition to these benefits, the adoption of blockchain technologies is thought to limit the effects of the "bullwhip effects". The bullwhip effect refers to how limited information on the demand from consumers can have dramatic impacts upstream on the suppliers (Lee, Padmanabhan, Whang, 2004). With blockchain technologies, these effects are limited as information sharing and access to data increase (Sarfaraz, Chakrabortty, Essam, 2023). In addition to decreasing the bullwhip effect, it is assumed that adopting blockchain can lower lead times by creating higher visibility within the supply chain and a better understanding of inventory (Gaur, Gaiha, 2020).

However, there are some drawbacks to adopting blockchain into the firm's supply chain operations. Some of these drawbacks may include financial considerations, the irreversible nature of the transactions, and the legal requirements of the technology. Economic considerations are also important to consider when understanding the effects of the adoption of blockchain in supply chains. Blockchain can be an expensive tool to adopt, and corporate spending on blockchain adoption is expected to reach $2.1 billion by the end of 2018 (Nash, 2018), which means this technology might be too costly for a humanitarian organization, which mainly relies on donations for funding. Although it is expensive, it is the belief of many that the benefits outweigh the costs. In addition to the financial costs, though, there are few regulations around blockchain, which can lead to confusion among consumers and users. This is another drawback of the technology, but it is likely to become more apparent with further tool use. Finally, the transactions that take place within the blockchain are irreversible. This is not a significant issue within disaster relief, though, as the use case will be more towards contracting delivery of certain materials that are needed, not necessarily the movement of different currencies.

In conclusion, blockchain is a valuable technology for managing supply chains because it allows for transparent information and data sharing on a decentralized platform. Its ability to track and verify transactions can help streamline processes while decreasing costs due to fraud and errors. Finally, blockchain allows for real-time visibility into a firm's operations, thus reducing lead times and increasing transparency into a firm's supply chain.

2.4 - Last Mile Logistics

Last mile logistics refers to the final step in delivering a good, not necessarily the actual physical mile before it gets to the end consumer, in this case, those affected by natural disasters. The last mile of delivery is costly and time-consuming, and many other logistical issues can arise when dealing with significant amounts of data and moving pieces. Some technologies that have emerged over the past few years include the use of route optimization software, real-time tracking systems, and delivery drones/automated vehicles. All of these technologies fall under the umbrella of "Last Mile Logistics," and I believe it would be helpful in providing relief following a natural disaster.

Route optimization software refers to technology developed since the late 20th century that allows sophisticated algorithms to solve complex optimization problems (The History and State of Vehicle Routing, 2024). Prior to the development of this technology, all route mapping was done by hand—and is still done in some cases—but now, route optimization software has become integral to the last-mile delivery process.

Route optimization software uses mathematical algorithms to find the most efficient route that visits a set of locations and then reports back to the starting point. Some roads may be blocked or destroyed in a natural disaster, so finding the optimal route with these hazards is significant. Geographic Information Systems (GIS) have also become incredibly helpful in route mapping by allowing the operator to understand potential routes. GIS allows the operator to uncover insights about potential routes through spatial data (Ramzan, 2023). The information collected from Geographic Information Systems includes traffic data, geographical constraints, and possible paths, allowing the engineers or the route optimization software to discern the most direct/optimized route (Ramzan, 2023). Not only does route optimization software help lower the time to delivery, but it can also save time, money, and resources while cutting down on carbon emissions—this can be incredibly beneficial in response to wildfires because of the elevated levels of carbon already present in the atmosphere (Patel, 2024). Additionally, another added benefit that plays into the lowered cost is that with route optimization, fuel costs can be reduced by 20% (Jovicic, Boskovic, Vujic, Jovicic, 2011).

In addition to the route optimization software, real-time tracking systems are essential to last-mile logistics. This technology allows for the transparency and validity of data as goods move through the supply chain. The development of real-time tracking systems was furthered through the development of Global Positioning Systems (GPS) technology and advances in data processing (Chadil, Russameesawang, Keeratiwintakorn, 2008). There are 24 satellites in the United States that make up the GPS system (Chadil, Russameesawang, Keeratiwintakorn, 2008). This system can send signals to receivers on the surface of the earth to track the materials in the supply chain in real time.

Additionally, Radio-Frequency Identification (RFID) has become popular and helpful in determining real-time tracking of materials in the supply chain. This technology, which uses RFID tags or sensors attached to boxes within a shipment—or individual items—helps provide additional identification and tracking capabilities (Sabbaghi, Vaidyanathan, 2008). Together, both of these technologies can be incredibly useful in the wake of a natural disaster because they provide accurate and robust information on when supplies and relief can be provided to those affected.

Finally, this paper will focus on delivery drones and automated vehicles, the last piece of technology within last-mile logistics. These technologies are reshaping last-mile logistics through the introduction of automated delivery solutions. Recently, the development of these technologies has been accelerated through the continued advancement in robotics, artificial intelligence (AI), and data analytics (Li, Kunze, 2023).

There are many moving pieces with automated vehicle delivery and also delivery drones, such as onboard computers, sensors, cameras, and advanced algorithms to perceive their surroundings (Chen, Xie, Chen, Chu, Lin, 2022). However, although their technologies can differ, the drones and vehicles are integrated into logistics networks through centralized control systems or autonomous operation platforms, potential paths for these automated vehicles can be seen in the exhibit below (Nurgaliev, Eskander, 2023). These systems manage the fleets' dispatch, routing, and monitoring and work to optimize the routes taken by the two machines

(Nurgaliev, Eskander, 2023). These two pieces of technology offer incredible advantages in terms of speed, cost-effectiveness, safety measures, and flexibility when compared to human alternatives. They can be instrumental in natural disaster relief (Yoo, Chankov, 2018).

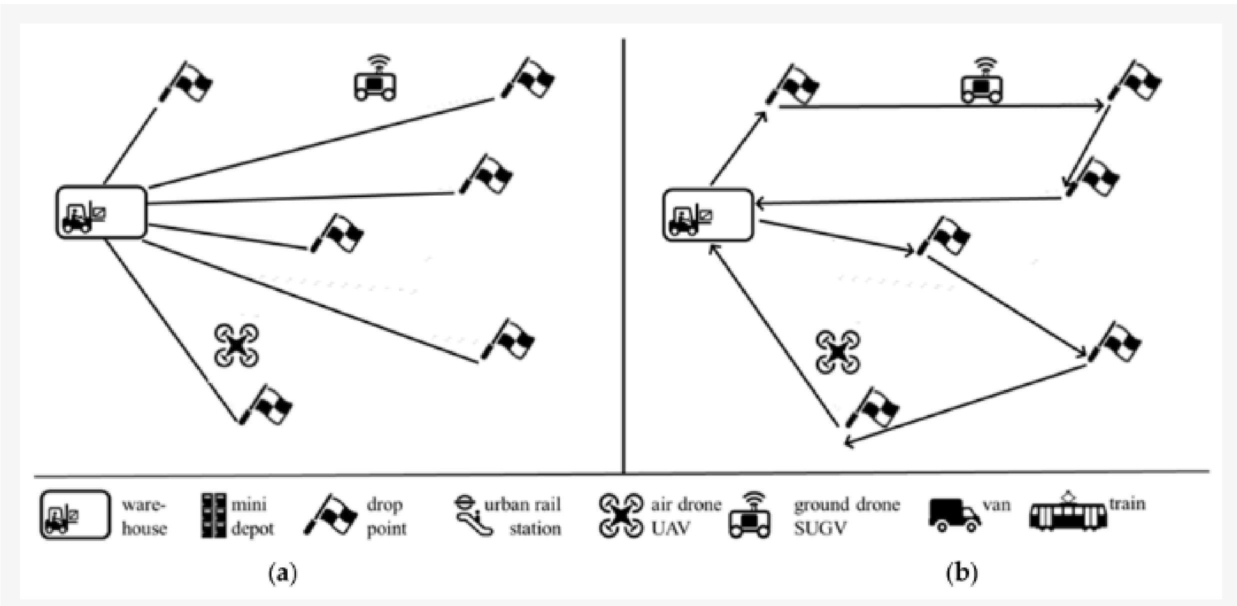

Exhibit 5: Delivery concept of direct drone delivery: (a) single stop, (b) multi-stop. (Li, Kunze, 2023)

Overall, there are many technologies under the umbrella of last-mile logistics. However, this paper will focus on the following because of their applicability to natural disaster relief: route optimization software, real-time tracking systems, and delivery by drones/automated vehicles.

2.5 - Guiding Question / Contribution Statement

The guiding question for this paper is how the adoption of blockchain and different last-mile logistics can aid in the aftermath of a natural disaster. By assisting in natural disaster relief, I mean making the operations more efficient by cutting down resource distribution time, ensuring those affected have proper aid, and providing a quicker recovery. Optimizing natural disaster relief could mean utilizing fewer resources and saving countless lives.

This paper seeks to frame the question referenced above through an understanding of blockchain and last-mile logistics, an understanding of the logistical challenges due to natural disasters, and first-hand accounts given by industry professionals. Each natural disaster is different and provides a plethora of new logistical challenges and issues, meaning that there is no way to ever be fully prepared. However, technology can be adopted to minimize uncertainty after natural disasters and mitigate controllable risks, which is something this paper is working to address.

Although many humanitarian organizations have begun adopting different supply chain logistics and data analytic methods to help with natural disaster relief, the field needs more information and studies on how the adoption of blockchain can aid in the process of relief. This paper aims to fill that gap and provide an analysis of the adoption of blockchain technologies and last-mile logistics by creating a robust understanding of the technologies and pairing that information with specialist interviews. These two concepts/tools are complementary to each other, and there is little literature on the pairing of these two resources to combat the disasters caused by these natural events. Additionally, the thesis will focus on relief in the United States as the country is exposed to a wide variety of natural disasters and has numerous organizations focused on humanitarian aid following a disaster. This will allow the humanitarian organizations to access more information and data when making decisions about the level of relief, the timing of different operations, and the number of individuals that can be helped.

This paper will follow the structure of a gap analysis. Previously, a robust understanding of the current operations of natural disaster relief was laid out, in addition to defining last-mile logistics and blockchain. The following sections of this paper will work to combine these ideas and outline the benefits of using the technologies mentioned above through data collection, interviews, and a final analysis of the benefits and drawbacks of these technologies. .

3. DATA COLLECTION

3.1 - Natural Disasters

In order to understand the complexity and the magnitude of these disasters, it is important to observe and analyze data that pertains to them. I pulled data from EM-DAT, or the Emergency Events Database, to describe natural disasters and their relief in further detail. EM-DAT is a database that stores information on natural and technological disasters that have occurred across the world since 1900, it is maintained by the Centre for research on the Epidemiology of Disasters (CRED).

EM-DAT provides information on all major natural disasters across the globe, but in this paper, all data used is specific to the United States. The exhibits below are a breakdown of every natural disaster that has occurred in the United States since 2000, separated by disaster type. Storms are the most common natural disaster, and this classification included tropical cyclones, blizzards, tornados, and severe weather. Of the disaster types that were highlighted earlier in this paper, though, floods were the most common, much like the literature in the literature review section of this paper mentioned.

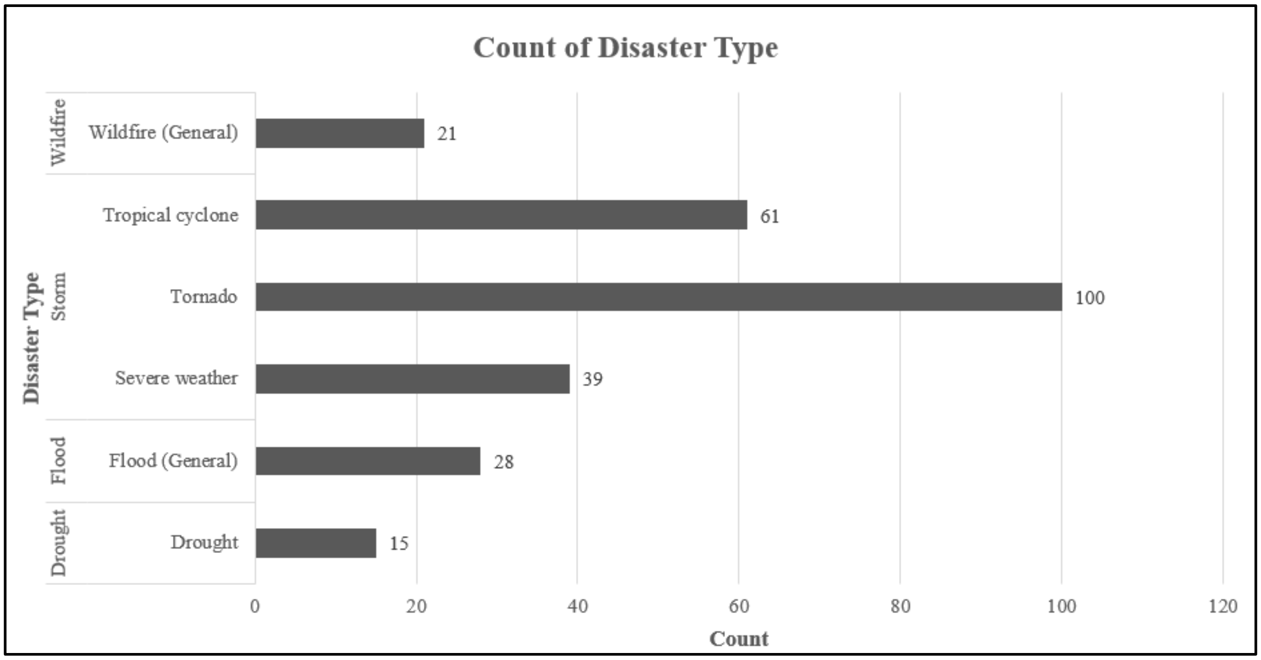

Exhibit 6: Em-Dat Data on US Based Natural Disasters 2000-2023

Now that the frequency of the disasters has been understood, the length of time an event was classified as a disaster is also important. This refers to the amount of time it takes to return to normal conditions, when official declarations are revoked. The following two charts describe the total number of months where an event is classified as a natural disaster and the average number of months classified as a disaster by disaster type. Although storms occur more frequently than droughts do according to EM-DAT, droughts on average are classified as a disaster for much longer. This is probably due to the nature of droughts and how they can often be prolonged meteorological events, relative to storms, which typically do not last as long. This is important to consider, because while an event is still considered a disaster, aid in some capacity is being shared/delivered in order to help those in need as they rebuild, although this is not the main focus of this thesis. The duration of assistance from a humanitarian organization can vary greatly due to the severity of the disaster and the relief needed, but as the number of months a disaster is classified as such, one can expect the relief organizations to be providing humanitarian aid.

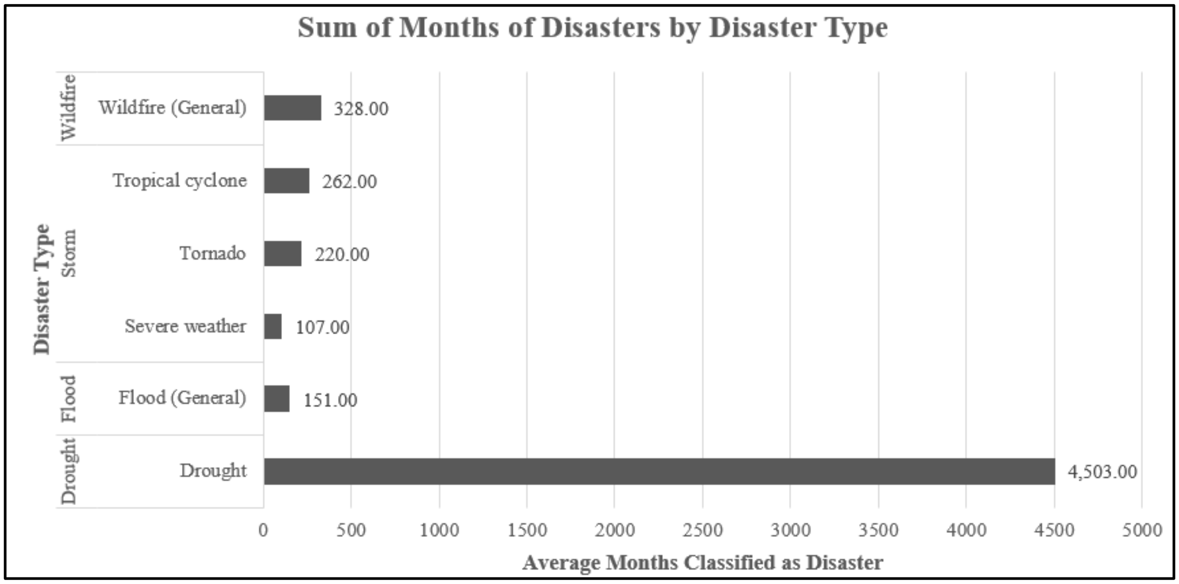

Exhibit 7: EM-DAT Sum of Months of Disasters by Disaster Type 2000-2023

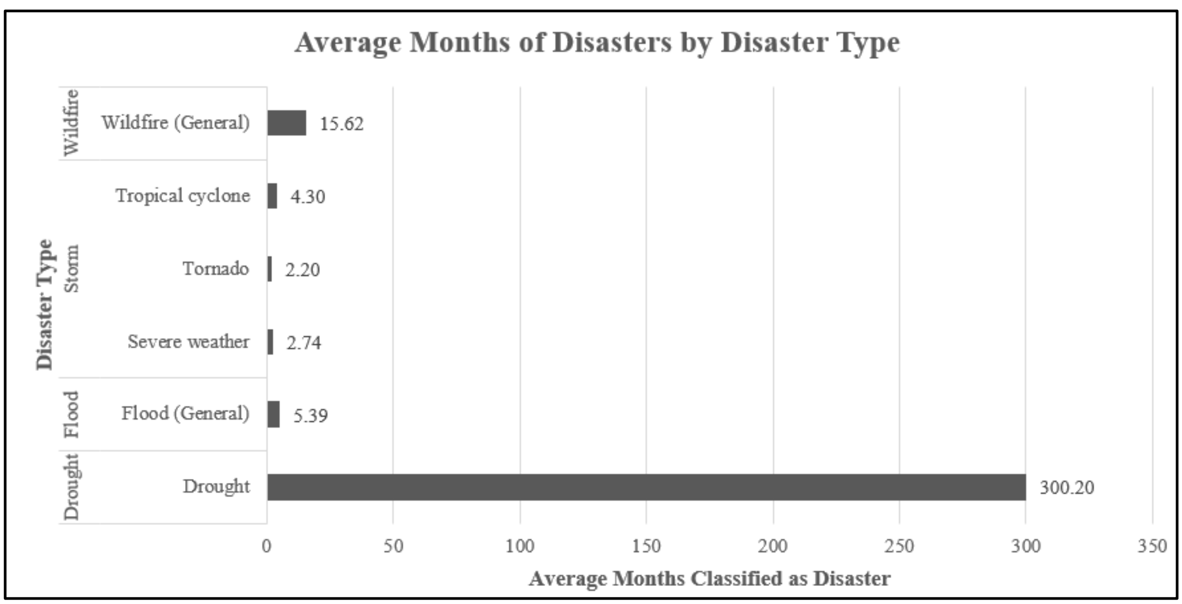

Exhibit 8: EM-DAT Average Months of Disaster by Disaster Type 2000-2023

Exhibits 9 and 10 follow the same format as the previous two, in which the sum and the average are shown per disaster, but in this case the total damages are examined rather than the number of months a disaster is considered to be a disaster. Yet again, although storms have the largest sum of total damages, droughts tend to be the most expensive in terms of average damages.

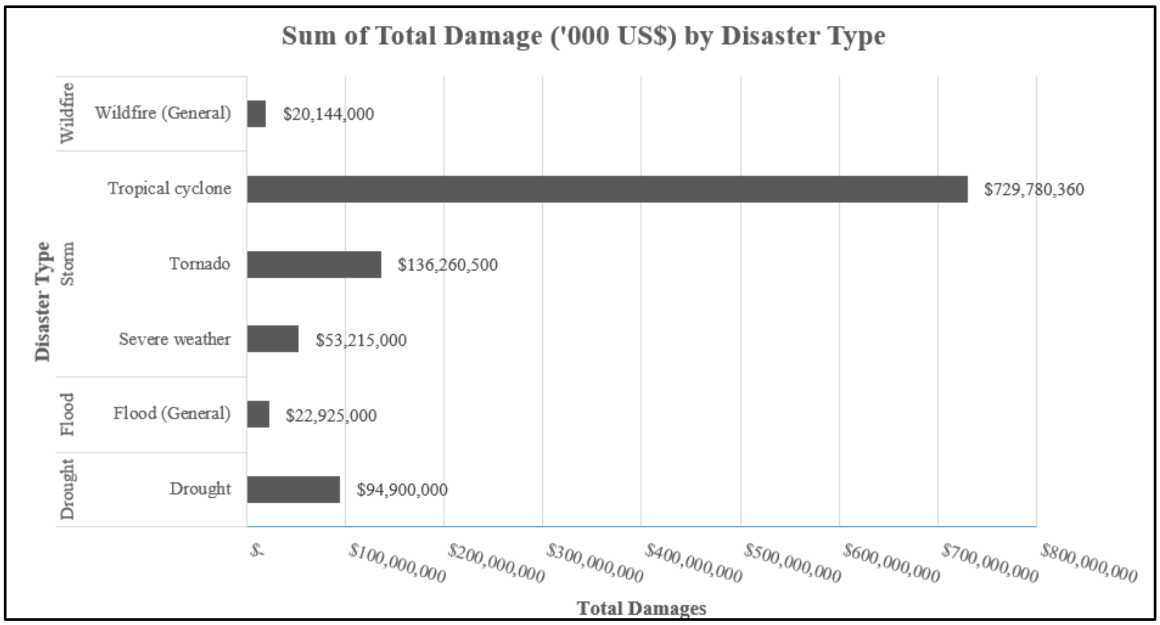

Exhibit 9: EM-DAT Sum of Total Damages by Disaster 2000-2023

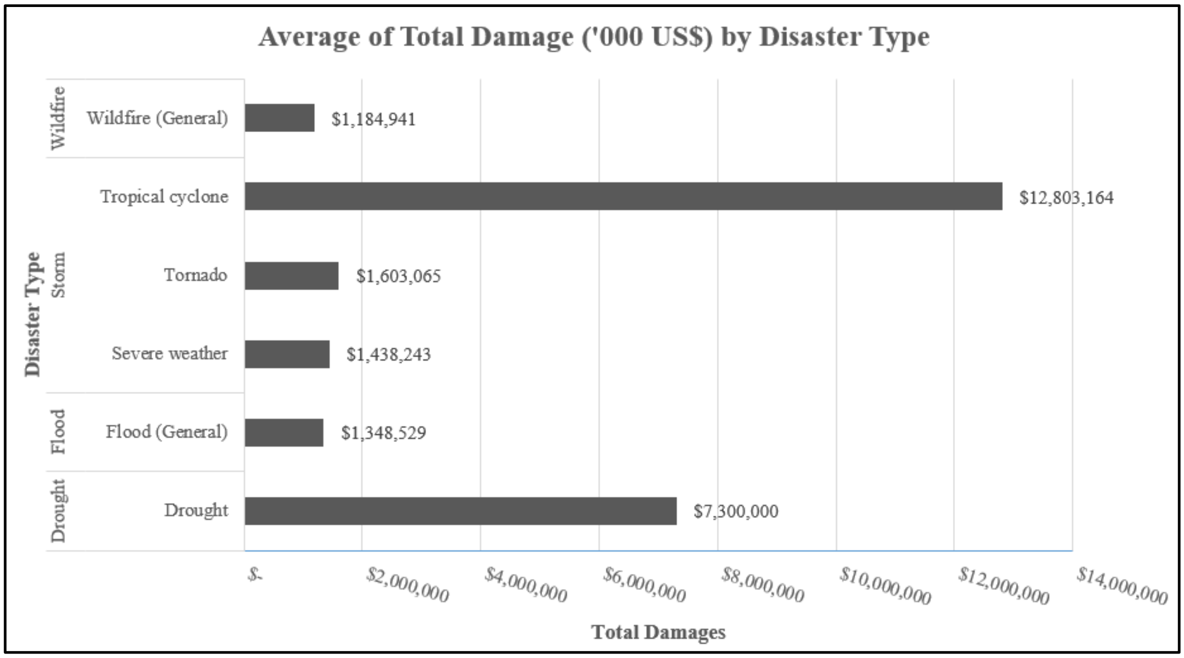

Exhibit 10: EM-DAT Average of Total Damages by Disaster 2000-2023

Based on the data, it is evident that the United States government has spent quite a lot of money on natural disaster relief between now and 2000. This data was selected to provide context into how often natural disasters happen, how long they can be an issue for a certain part of the United States, and how costly they can be to a government. Due to this, it is important to have proper plans in place to deal with natural disasters because of the incredible costs, frequency, and variety of disaster types.

3.2 - Interviews

In order to accurately complete the gap analysis of this paper, interviews were used in order to provide industry expertise to the problem of using modern-day supply chain logistics to aid in natural disaster relief. Two types of interviews were conducted: interviews with humanitarian organizations and interviews with skilled operations organizations.

The interviews conducted with the humanitarian organizations provided context to the logistics and planning put together by the firm and their propensity to adopt new technology. These interviews were conducted with members of the American Red Cross and the Federal Emergency Management Agency. Every interview followed the same process in which the scope of my project was explained then a series of questions would be asked about the aforementioned fields. Among the questions asked are the following:

1. How many disasters have you worked on throughout your time at X organization?
2. What do you see as a strength with regards to your organization's ability to provide relief following a natural disaster?
    a. Can you provide specific examples regarding a recent natural disaster of this strength?
3. What do you see as a weakness with regards to your organization's ability to provide relief following a natural disaster?
    a. Can you provide specific examples regarding a recent natural disaster of this weakness?
4. What would help your organization to be better prepared to help provide relief to those affected by natural disasters?

In addition to these interviews, conversations were also held with individuals who worked for or were associated with organizations that are skilled in supply chain management/logistics operations. Among those organizations include Tesla, Amazon, and Intermix. The focus of these interviews consisted of understanding what operations are currency in place at each of these organizations and how they can be implemented in disaster relief. The questions that were asked to these individuals include the ones below:

1. What capabilities regarding blockchain and last mile logistics does your organization currently have?
    a. Do you utilize blockchain in your operations?
    b. How does your company focus on last mile logistics?
2. What has the development process been for these technologies?
3. Are there any other technical capabilities that you think have aided you the most in logistics operations?
4. Have you adopted any AI capabilities within your operations?
5. What results have you seen quantitatively due to the adoption of these technologies?
6. What were the drawbacks/struggles that you saw when introducing these technologies?
7. Do you have any experience with natural disaster relief?
8. Do you believe the adoption of blockchain and a better understanding of last mile logistics will help with natural disaster relief, and why?

These interviews proved to be very helpful in terms of understanding the intricacies of supply chain logistics, in addition to the current operations of the humanitarian organizations. The results from these interviews are described in detail in the analysis section of this paper.

4. ANALYSIS

4.1 - Interviews

After reaching out to nearly fifty individuals for an interview request, I was able to sit down and speak with seven different people at humanitarian and skilled logistics organizations, who provided context into supply chain logistics, humanitarian aid, and also the guiding question of this paper. Exhibit 11 is a breakdown of the companies I connected with and who from the organization I was able to interview.

Company/ Organization	**Amazon**	**Tesla**	**Inditex**	**MIT**	**FEMA**
Title	**1**. Senior Manager of Finance for Supply Chain and Transportation **2**. VP, NA/EU Transportation & Global Mile	**3.** Group Manager, Global Supply Chain **4.** Finance and Business Operations Specialist	**5**. Omni-channel Manager/ E-commerce logistics in North America	**6.** Research Associate, MIT Humanitarian Supply Chain Lab	**7.** Supervisory Emergency Management Specialist

Exhibit 11: Organization and Job Title of Interviewees

4.1.1 - Finding #1: Blockchain is not widely used within the interviewed companies

One finding from the interviews was that blockchain is currently not widely used by the companies that were interviewed. This theme of not being widely used also surfaced in the literature review, but the companies that did report the use of the technology did see positive results. The technology is still being fully developed and has specific use cases that will be further discovered, but as of now, none of the skilled supply chain companies use blockchain technologies in their logistics systems. The Vice President of Global Transportation Services at Amazon, mentioned in his interview that Amazon had "looked at blockchain in a variety of places ranging from contract management in other countries to imports, but did not find a good use at their scale". Since humanitarian organizations work with lots of information and data, but a fraction of the scale of a company like Amazon.com, issues should not arise pertaining to scale. Baker also highlighted in this interview that Amazon Web Services does use blockchain technologies, but often specifically for Crypto Currency exchange.

Many of the above firms saw the benefits of adopting Blockchain into their company's operations, but due to scale, use case concerns, or existing practices, their company had not adopted the technology. Although the literature pointed towards Blockchain's continued development and expansion into supply chain operations, this finding did address the main question of this thesis, by demonstrating that the use of blockchain in supply chain operations is potentially feasible, although not currently widely used.

4.1.2 - Finding #2: Companies use a diverse set of technologies and techniques within their supply chain

Another key theme that arose in these interviews were the technical capabilities that these firms were using in order to manage and organize their logistics, which were often different from those that are the focus of this paper. Below is a table that identifies the technologies that the experts form these organizations focused on during their interviews.

Company/ Organization	**Amazon**	**Tesla**	**Intadex**	**MIT**	**FEMA**
Technology Identified during the Interview	Diverse Operations Research Methods (Multi Objective Linear Programming - MOLP, Simulations, and Integer Programming), Machine Learning	Inventory Management Systems (WARP), Global Information Systems (GIS), & SQL	RFID, Warehouse Management Systems (Monoboxing, Robotics, & Inventory Management systems)	N/A - This Department is a Research Lab, not an Operations Company.	Windshield Assessments, Geographic Information Systems (GIS), & Warehouse Management Systems

Exhibit 12: Main capabilities and technologies referenced by the interviewees during the interviews

The main discoveries from these discussions include how different the capabilities are at each of the firms that were interviewed. Amazon is incredibly complex, using Machine learning, to "detect patterns in poor delivery experience to isolate customers with bad on-time performance, group them by zip code, and surface to the carrier managers to find solutions,". This seems like an advanced technology that is able to provide accurate results and eliminate risks, while providing high quality results. Additionally, Amazon utilizes Operations Research, like many other firms, but this allows the company to run multiple simulations of their networks/facilities.

This is different from a firm like FEMA, where the assessments of damages are still being conducted through windshield assessments, meaning that a person has to drive into the affected area and manually take account of the damages, according to a supervisor at FEMA. Once the data is collected, though, the operation becomes more advanced for FEMA, where they begin to use barcode/other warehouse management technologies and Global Information Systems (GIS) to build maps and manage the movement of data within the firm.

Tesla is also very different, using more of a bootstrapping approach to their logistics. They have their own inventory mapping system called WARP, but beyond that their logistics system was described as a "glorified excel sheet" according to a specialist at Tesla. WARP allows for real time inventory management, which would be beneficial in natural disaster relief; it was compared to a "mini-blockchain" by a Group Manager at Tesla, due to its ability to track inventory, deals, and be self-reliant. However, even with this technology, other parts of their logistics were less organized. He highlighted how at the end of the quarter, he would have to physically drive cars from the factory to the dealerships in order to make quarterly estimates for sales and production. This is a less technical approach to supply chain management, but it furthers the idea that these companies have incredibly different operations within their businesses and are constantly evolving within their operations.

Finally, the last skilled operations company that I will highlight is Inditex, the largest fast fashion group in the world. An Omnichannel Manager at Inditex spoke about the logistical brilliance of the company. Inditex relies heavily on RFID technology within their supply chain and their Warehouse Management System, which allows the company to always have an up to date inventory account in real time. This allows them to understand what delivery options they can offer, as well as fulfillment opportunities. Additionally, Inditex owns all of the steps within their supply chain, which is different from Amazon, but similar to Tesla. This shows that even though there are some similarities and differences within these companies, there are still many technological options for creating a well rounded and robust supply chain.

These firms utilize a vastly diverse set of tools and technologies within their logistics departments, proving the technologically diverse nature of supply chain management. Most of these firms are confident in their ability to move products through their supply chains, but others were less assured. Due to this, it is understood that each firm is different and has different expectations and abilities to run certain technologies, so one technological solution might not be the most practical. This is a key finding from this paper.

4.1.3 - Finding #3: Last Mile Logistics techniques offer immediate benefits while the costs of adopting blockchain may outweigh the benefits

Another theme that arose, though, is that the leaders within these skilled logistics organizations do see the benefit to the adoption of blockchain and last mile logistics within natural disaster relief, but understand that there are some drawbacks. The Vice President of Transportation at Amazon says that blockchain and last mile logistics could "help by speeding up the procurement process for the supplier or the recipient," which would be incredibly important in natural disaster relief where time is of the essence. However, a specialist at Tesla, believes that companies that operate in hardware have a harder time implementing blockchain because you have to move from online into "real life". This was an interesting perspective, as the literature that was supplemental to this project highlighted how the use of blockchain could make transactions and contracts more efficient due to the increase in transparency. This is something that will be explored further in the conclusion part of the paper.

A researcher at the MIT Humanitarian Supply Chain Lab mentioned that although the lab has not focused on blockchain as it pertains to natural disaster relief, that she does see benefit in the adoption of the technology. Aid can be provided quicker through faster validation of damage, which is why she supports the use of GIS and GPS technologies following a natural disaster and believes that these technologies can be supplemental to blockchain. On the other hand, a manager at Inditex is not convinced that a natural disaster relief process needs the level of encryption that blockchain provides, although it might be useful in contract tracking.

For last-mile logistics, the Senior Manager for the financing of supply chains at Amazon believes that the middle and last miles of the supply chain are the most important. He argues that having robust transportation systems is the reason that Amazon is so skilled in this, using drones, vans, and even airplanes to access these points in the delivery process. The Supervisor at FEMA also mentioned the importance of managing the last mile, citing their use of satellite phones to share information from the ground level to those organizing the distribution of aid. Overall, each of the individuals interviewed could easily see the importance of building a robust last mile logistics system, and mentioned the importance of GIS and GPS technologies in order to make this happen.

In conclusion, these individuals within the skilled operations organizations, and even FEMA, believed that there are numerous benefits that can be seen when implementing Blockchain and different last mile logistic technologies, but there are also some key drawbacks that need to be considered. These are further explained in the conclusion of this paper, but it is important to the result of this paper, that there is not one simple solution to logistics within natural disaster relief.

4.3 - Conclusion

It is important to note the lack of numerical evidence or data that supports these qualitative findings. This is a drawback or flaw within this field of research, which opens up the door for further research on the quantitative aspects of adopting these technologies. There are few papers that talk about the Key Performance Indicators for humanitarian organizations, but one paper that is helpful in providing additional context into this problem is *Performance management practices in humanitarian organizations* (Abidi, Leeuw, Dullaert, 2020). This paper focuses on the use of supply chain performance metrics in Humanitarian Organization efforts and found that many traditional performance measures are relevant to humanitarian organizations, but it also confirms that little research has been conducted in this field so best practices are still unknown.

Another study that addresses this flaw within this field of research uses KPIs from the military and applies them to humanitarian organizations, in order to close this gap in quantitative metrics (Davidson, 2006). This paper develops four key performance indicators for the humanitarian organizations: donation-to-delivery time, financial efficiency, appeal coverage, and assessment accuracy (Davidson, 2006). These metrics cover the percent of items delivered, the timeliness of delivery, and the accuracy, which are all important to determining the effectiveness of the humanitarian organizations. After creating these metrics, the authors created a score card, which allowed for easy evaluation of the operations of these humanitarian organizations, this is referenced in Exhibit 13. Although this is not a widely used practice, we believe that this should continue to be implemented within humanitarian organizations and the metrics should be published in order to understand the impact that these humanitarian organizations have on the affected communities. KPI's could be useful in determining which modern technologies may have the largest potential for improving the effectiveness of humanitarian aid. We recommend further research into this field and general reporting metrics for the field of humanitarian aid.

South Asia Earthquake Appeal Date: October 9, 2005				
Status Update: Final *Date: March 18, 2006*	Operation Total (Weighted)	Priority 1 Housing	Priority 2 Kits & Sets	*Total Op Target*
Percent of Appeal Coverage (in quantity of items)				
After 1 week	63%	61%	77%	
After 2 weeks	47%	45%	18%	
After 1 month	74%	73%	51%	
After 2 months	91%	92%	71%	
After 3 months	93%	99%	100%	
Percent of Items Delivered (in quantity of items)				
After 1 week	6%	1%	4%	
After 2 weeks	9%	5%	2%	
After 1 month	33%	27%	8%	
After 2 months	48%	46%	19%	
After 3 months	67%	72%	47%	
Donation-to-Delivery Time				
Mean (# days)	33	35	29	
Median (# days)	28	31	24	
Financial Efficiency				
(Donor Cost - Budget Cost) / Budget Cost	-5%	-11%	30%	
Actual CHF Spent - Budget CHF	(3,510,849)	(5,209,538)	1,810,531	
Transportation Cost / Total Product Cost	10%	N/A	N/A	
Assessment Accuracy: Revised Budget / Original Budget				
After 2 weeks	131%	118%	365%	
After 1 month	139%	123%	377%	
After 2 months	148%	127%	493%	
After 3 months	158%	127%	493%	

Exhibit 13: South Asia Earthquake Final Scorecard (Davidson, 2006)

Although there are numerous benefits to adopting different technologies within supply chain logistics, such as blockchain and technologies within last mile logistics, there are also challenges. For example, these technologies can be very costly. It can be prohibitively expensive for a company to adopt blockchain, so the use of it within natural disaster relief might make the most sense for an organization that already has the technology due to their ability to accept crypto currency donations. Additionally, natural disasters provide a unique set of challenges that another organization may not have to deal with. Due to this, some technologies that work well for a major organization that has perfect data, might not work well for a humanitarian organization that does not have access to robust data sets, is majorly pressed for time, and might not have access to the affected area.

We recommend that further research focuses on the practicality of adopting Machine Learning into natural disaster relief, as it was not a tool that was examined in this paper, but based on the interviews could prove to be an interesting alternative to the technologies examined here. This technology could help to better predict when and where a natural disaster is likely to occur, speed up damage assessment and resource allocation, and optimize delivery routes to the affected area. However, Amazon's Head of International Logistics mentioned that "You can't just blindly follow the results of the ML models or simulations…you have to have people that understood both the last mile as well as the software". This could ultimately be a challenge for humanitarian relief organizations, which may not be able to hire/source experts on both. I believe additional research into this field would be interesting and could further the field of using supply chain logistics to aid in the relief of a natural disaster.

Based on the information above, though, we recommend that humanitarian organizations look into the possibility of adopting blockchain technologies and different last mile logistics into their operations as they pertain to natural disaster relief, and the potential of partnering with firms that have relevant expertise as to minimize the challenges highlighted earlier. These technologies allow for quicker access to data, more transparency within the supply chain, and more accurate decision making, which could be the difference between life and death for someone who has been affected by a natural disaster. As mentioned above, there are some considerations for adopting these technologies, but we believe since every company is different there is no one-size fits all response to logistics. We see benefits within adopting these technologies and recommend the exploration of the tools by these humanitarian organizations to understand whether or not they work for them.

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