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Humanitarian Logistics for Grassroots Disaster Relief

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HUMANITARIAN LOGISTICS FOR GRASSROOTS DISASTER RELIEF

By

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Introduction

In October, 2015, South Carolina experienced severe flooding across the state, which interrupted water supplies and caused large-scale damage to property. In the aftermath, many grassroots relief organizations were formed to help distribute relief supplies and coordinate volunteers. While the relief organizations provided excellent service to survivors in the area, there were also several inefficiencies observed. Donations of relief supplies were not donated to the sites that most needed them, leaving some relief sites with excess supplies while other sites ran low. Volunteers would overflow a project location, as redundant projects were planned by organizations without coordination. Our team met shortly thereafter to discuss these inefficiencies and design a tool to help solve the problem.

Beacon is our solution. Beacon is a mobile application designed to assist grassroots disaster relief organizations in managing relief supplies, requesting donations, and communicating with survivors. The app is divided into three sections: Organizations, Volunteers, and Survivors. The Organization section will allow relief organizations to manage inventories, request donations, and recruit Volunteers. The Volunteer section will allow volunteers to find locations to take donations or projects to work on. Finally, the Survivor section will allow disaster survivors to locate relief sites that have the supplies the survivor needs.

Humanitarian Logistics is a branch of logistics which studies the field in the context of disasters. Research in the field divides the Disaster Relief process into three phases: Preparation, Immediate Recovery, and Reconstruction. Each phase has specific tasks and their sub-phases, which will be discussed in detail in this paper. I will examine grassroots Disaster Relief and Beacon in the context of Humanitarian Logistics by determining how grassroots relief differs from traditional Disaster Relief in each phase. I will also examine how Beacon can assist grassroots relief organizations apply the concepts of Humanitarian Logistics. Finally, I will recommend improvements to Beacon which allow it to better apply the research discussed in this paper.

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Background

The Flood

From October 1st to October 5th, 2015, South Carolina saw record rainfall across the state. Over that period, the Charleston office of the National Weather Service (NWS) reported rainfall totals of 27.15 inches in Mount Pleasant, 17.29 inches for the Charleston Airport, and 16.29 inches for Downtown Charleston (NWS - Charleston 2015). In Columbia, NWS reported rainfall totals as high as 21.49 inches for the Gills Creek area in Richland County, 19.81 inches at Shaw Air Force Base, and an official 2-day rainfall record of 10.28 inches at Columbia Metropolitan Airport (NWS - Columbia 2015).

The historic rainfall was a result of unique meteorological conditions. Beginning on September 30th, a cold front passed through the state and stalled along the coast for a few days due to other weather factors. A low-pressure system developed along the front, while a strong high pressure system developed in eastern Canada. At the same time, Hurricane Joaquin was making its way across the Atlantic. Joaquin was the 10th named storm and the second major hurricane of the 2015 Hurricane season. While Joaquin's path kept it far off the US east coast, it played a significant role in the October 2015 floods. The cold front created a low-level flow off the Atlantic, which tapped into the massive amounts of moisture that Joaquin was drawing from the warm Atlantic waters. The low-level flow carried that moisture over South Carolina, leading to the historic rainfalls discussed above (NWS - Columbia 2015).

These rains led to two types of severe flooding around the state. First, many areas experienced flash flooding caused by the extreme volume of rain that fell over such a short period. Flash flooding is extremely dangerous; in Columbia it killed a woman who was trapped in her SUV after flood waters washed it off the road (LeBlanc 2015). These flood waters quickly washed out roads and bridges, bringing travel to a halt and hindering rescue operations.

The other type of flooding, known as Channel flooding, caused much of the damage associated with the event. Channel flooding occurs when rainwaters or ice melt causes rivers and streams to escape their banks and flood the areas around those flows. This flooding was exacerbated by the collapse of several privately-owned dams which were unable to withstand the stress caused by the extreme volumes of water. In the Columbia area alone, at least six dams collapsed under the weight of the water (Fretwell 2015). Additionally, South Carolina Electric & Gas (SCE&G) opened the floodgates of the Lake Murray Dam for the first time since 1969 to keep the river below the maximum safe level of 360 feet (South Carolina Electric & Gas 2015). This release was largely responsible for the flooding along the Saluda river and forced hundreds of people with homes in the flood plain to evacuate.

Record flood stages were reached in many rivers in the state. According to the US Geological Survey (USGS), seventeen streamgages in South Carolina recorded the highest peak streamflow, the highest river height (stage), or both. Fifteen more gages recorded peaks in the top five for their history. The Black River at Kingstree recorded a peak stage of 22.65 feet, its highest stage in 87 years of records. The Congaree River at Columbia set its eighth highest stage and its highest stage since 1936 with a peak stage of 31.8 feet. Eight of the USGS streamgages were destroyed during the flood, further demonstrating the devastating scale of this flood (Feaster, Shelton and Hines 2015).

Aftermath

When the rain ended and the floodwaters began to recede, the extent of the damage became clear. The flood waters had caused severe damage to water systems across the state, leaving more than 130,000 homes without running water, in some cases for many days (Bacon 2015). Up to 160,000 homes sustained damage from the flood, with many of those homes destroyed by floodwaters (Burris 2015). Hundreds of roads and bridges were closed, as flood waters blocked

roads, covered bridges, or washed them away. Included in these closures was a 74-mile stretch of Interstate 95 between Interstate 20 and Interstate 26, which is one of the busiest interstate highways on the east coast. Drivers who wished to travel this stretch of road were forced to take a 168-mile detour to bypass the closed section of highway (Marusak 2015).

The most immediate needs by survivors were shelter and clean water. As mentioned above, at least 130,000 households were without water for some amount of time. According to the South Carolina Emergency Management Division (SCEMD), more than 20,000 people were displaced from their homes as a result of the flood. These individuals were housed in 32 official shelters across 26 counties, as well as an unknown number of unofficial shelters, often churches, that opened their doors to displaced survivors (SCEMD 2015). Food was another item needed by survivors. SCEMD estimates more than two million meals were served to survivors who were displaced from their homes or unable to prepare food in their homes due to power or water outages (SCEMD 2015). Many of these meals were prepared by volunteers from Southern Baptist Disaster Relief, Harvest Hope Food Bank, and other local food banks. Drivers from the American Red Cross then delivered up to four meals each day to shelters across the state.

There were 14 deaths in South Carolina attributed to the flooding (Bacon 2015), and a total of 25 deaths attributed to the storm system across three states (NOAA 2016). The National Oceanic and Atmospheric Administration (NOAA) estimated the total damage caused by the flood to be approximately two billion dollars (NOAA 2016), while economists from the USC Darla Moore School of Business estimated damages of about twelve billion dollars (Burris 2015).

Relief Efforts

Grassroots Relief Efforts

Most relief efforts were organized and coordinated by government relief organizations such as FEMA, the National Guard, and SCEMD, and large Non-Governmental Organizations (NGOs) such as the American Red Cross and Baptist Disaster Relief. However, there were also many efforts organized by smaller organizations like churches, neighborhoods, and other groups that formed organically in the aftermath of the flood. These groups gathered donations, organized volunteers, and offered shelter to survivors displaced from their homes. Most groups had physical locations, and nearly all of them coordinated supplies and volunteers through social media.

A quick search on Facebook turns up several groups formed for this purpose. These groups vary in size from a few dozen members to a few thousand members and are organized as statewide groups, regional groups, and neighborhood specific groups. The posts in these groups follow the typical patterns of Disaster Recovery (see "Humanitarian Logistics," below), with the earliest posts falling under the "Immediate Response" category and later posts evolving into requests falling under "Reconstruction." Some of these groups were still active at the writing of this paper (having evolved into more general relief groups), while most activity had ended by January 2016.

Problems in Relief Efforts

While grassroots relief efforts helped thousands of people start the recovery process, they were not without their problems. These loosely organized groups lacked the coordination and communication of the traditional disaster relief organizations. As a result, donated supplies and volunteered time were used inefficiently, leading to wasted time; excess supplies in some locations; and unmet need for critical items in other locations.

Most of the problems observed could broadly be attributed to failures in communication. The first failure was in communication between grassroots organizations and survivors. While social media provided a valuable means of communication during recovery efforts, the asynchronous nature of communication on social media created inefficiencies. Posts made by organizations would identify the group's available supplies at the time of posting, but would not update as survivors arrived to collect the supplies. This left survivors unsure about whether the relief site would still have the items they need when they arrived.

The second failure, communication between relief organizations and volunteers, could also be attributed to the asynchronous nature of communication on social media. When a relief organization posted a need for donations or volunteers, they had no way of indicating their progress in collecting the items or volunteers they needed. This would lead to some organizations receiving far too many donations or volunteers, resulting in an inefficient use of resources. Some organizations experienced the reverse, when a request would go unfilled by donors or volunteers who had assumed the request had already been filled.

The third failure was the lack of communication within the grassroots organizations and between those organizations and the traditional relief organizations. While traditional organizations often have working relationships with each other, social media allowed only limited communication between organizations with no clear leadership. This prevented these organizations from efficiently distributing supplies among themselves, as they were unable to easily identify what organizations needed their excess supplies.

I witnessed this last inefficiency firsthand while on the leadership team at the University of South Carolina Baptist Collegiate Ministry (BCM). The BCM has a building on Main Street in downtown Columbia that is owned by the South Carolina Baptist Convention. In the immediate aftermath of the flood, this building served as a convenient location for Baptist churches around the

country to send donated items, particularly cases of bottled water. Despite being connected with the South Carolina Baptist Convention (and thus Baptist Disaster Relief), the BCM had no way of identifying groups that could collect the water to distribute it to survivors. By the time water service had been restored around the state, the BCM still had hundreds of cases and thousands of bottles of water stored in the building. These were not simply excess supplies, but rather supplies that could not be easily distributed due to the lack of communication between organizations.

Beacon

The creation of Beacon came out of our observation of the problems discussed above. At our first meeting, we determined a mobile application could be designed to solve these problems and help grassroots organizations efficiently manage donations and volunteers. We interviewed several individuals involved with flood relief efforts, including grassroots organizers; leaders in traditional relief organizations; and state emergency managers. These interviews helped guide our design process, which went through many iterations before arriving at the design described in the sections below.

Design Overview

Our ultimate design revolves around a home screen with three buttons taking users to different sections of the application. The first button will take users to section of the app designated for survivors. This section will be focused on an interactive map that would provide survivors with information about where they could find the supplies they need. The second button will be for volunteers who want to donate supplies or time. Volunteers will be able to identify organizations that need their donations or their time and commit to an organization's request. The third button is for organizations. This section of the app will have the most features of the three, as it will allow

groups to sign up for the app, establish a location, and request donations of certain items or a volunteer's time.

Survivors

The Survivors page primarily serves as a source of information for survivors, supplying them the location of relief sites or shelters and the supplies those sites have to offer. This information is provided via an interactive map, which uses a cell phone's location services to determine a survivor's location (green pin) and help them locate the closest relief site. Survivors will be able to filter the map based on the supplies and services they need (small red markers), and the map will show them all the locations within a predefined radius that offer those items (red pins). Once a location is selected, the user will be able to link out of the app to their phone's navigation app and get directions to the site. An early mockup of this portion of the app can be viewed in Figure 1 below.

Figure 1

This section of the app helps bridge the information gap between survivors and relief organizations that we observed during recovery efforts after the flood. By providing a central

source of information, survivors will be able to quickly and easily locate the supplies they need without wasting time driving around looking for what they need.

Volunteers

The Volunteer page will look like the Survivor page, but with additional screens to facilitate donations. Like the Survivor page, the main view of the Volunteer page is an interactive map. Before viewing this map, users who select the volunteer page will be prompted to indicate what items or how much time they have to offer. Once the volunteer enters this information or chooses to skip entering their information, the app will then take them to the map to show the sites that need the items the volunteer has. Like the Survivor page, the map view can be filtered based on a distance radius set by the user. The Volunteer page will have an additional view to the Survivors page, for volunteers who want to volunteer their time. This view will be in the form of a list, which shows all the relief sites or projects that need volunteers during the time the user has specified they are available. Each entry in this list will have information about the project, the location or meeting place for the project/relief site, and the contact information for the organizer of the project/relief site. Figure 2 below shows early mockups of the Volunteer page described in this section.

Figure 2

This section of the app helps solve to communication problems between relief organizations and volunteers. The communication problem led to the misallocation of resources across relief sites, as the organizations had no way of easily updating their needs as they received donations from volunteers. By allowing volunteers to respond to requests by committing time or donations and then tracking those commitments, the app will ensure donations are properly allocated across relief sites. This allows volunteers to be confident their donations will be used in the most efficient way possible.

Relief Organizations

The final section of the app is for relief organizations. This section will be more complex than the first two, as the app requires more input from the organizations than other users. The first step for a relief organization is to sign up for the app. The registration page will allow new users to create a secure account for their organization to maintain the organization's status on the app. The registration page will ask organizers for information about their organization, including the address, operating hours, and other information they wish to provide. Once the account is created, users in this section will be taken to a dashboard where they can manage their organization's presence on the app. The dashboard will allow organizations to request items for donation, set up projects that need volunteers, update the inventory that is shared with survivors, and track the status of the requests and projects.

Under the requests page, the organizations will be able to post the items they need and the quantity of each item. They will also be able to establish work projects that need volunteers to complete them. The project creation section will allow organizations to provide information about the time, location, and skills needed for the project. The inventory management section will populate based on the requests posted by the organizations and can be updated as donations arrive. The organization can also add the items they already have available for survivors prior to signing

up for the app. The last page will allow the organization to track commitments from volunteers to ensure their requests are being met. An early mockup of some of the pages discussed in this section can be seen in Figure 3 below.

Figure 3

This section of the app is the central information source for each of the other sections. Both communication problems which involve individuals (communication between volunteers and relief organizations and communication between survivors and relief organizations) require information to be shared from the relief organizations to both survivors and volunteers. The Relief Organization page allows the organizations to manage the information the app provides to other users to ensure every user has the most accurate information available. This will ensure users are able to make informed decisions about where to take donations or pick up supplies, guaranteeing a more efficient disaster recovery.

Overview of Humanitarian Logistics

Humanitarian Logistics as a field encompasses the logistics operations associated with Humanitarian Relief. Apte defines the field as "the special branch of logistics which manages response supply chain of critical supplies and services with challenges such as demand surges, uncertain supplies, critical time windows in face of infrastructure vulnerabilities and vast scope and size of the operations" (Apte 2010). The United Nations World Food Program and Doctors Without Borders both use a definition by Thomas and Mizushima, which says Humanitarian Logistics is "the process of planning, implementing, and controlling the efficient, cost-effective flow, and storage of goods and materials, as well as related information, from the point of origin to the point of consumption for the purpose of meeting the end beneficiaries' requirements" (Thomas and Mizushima 2005). Humanitarian Logistics is distinguished from traditional logistics in its focus on positive outcomes for its beneficiaries, rather than reducing costs and creating value for an organization. While typical key performance indicators in traditional logistics are cost, quality, and delivery performance, success in humanitarian logistics can be measured in survival rates and recovery time.

The literature of Humanitarian Logistics has an almost universal understanding of the primary streams of the field. Kovács and Spens distinguish two main streams of humanitarian logistics: Continuous Aid Work and Disaster Relief (Kovács and Spens 2007). Continuous Aid Work generally refers to relief efforts for large scale and long-term problems, such as famine, drought, or disease. The work in Africa to end the HIV/AIDS epidemic is probably the highest profile example of such relief work. Disaster Relief refers to the response to man-made or natural disasters such as earthquakes, floods, or terrorist attacks. The relief efforts discussed in sections above fall into this category, as do the responses to events such as Hurricane Katrina or the Haiti earthquake.

While the open-ended nature of continuous relief prevents it from having clear phases, Disaster Relief has three distinct phases that occur before, during, and after a disaster. Kovács and Spens call these phases "Preparation, Immediate Response, and Reconstruction" (Kovács and Spens 2007), while Çelik, *et. al.* use the four phases of Mitigation, Preparedness, Response, and Recovery (Çelik, et al. 2012). The sections below will discuss each of Kovács' and Spens' categories in detail, with a discussion Çelik *et. al.*'s mitigation phase included in the Preparation section.

Preparation

Preparation is the first phase of Disaster Relief. It can be further divided into two parts, General Disaster Preparedness and Pre-disaster Preparation. General Disaster Preparedness encompasses actions taken by emergency managers and relief organizations when there is no specific threat of disaster. These actions include developing logistics networks, negotiating contracts with suppliers, and building inventories of non-perishable goods. Pre-disaster Preparation includes staging supplies, preparing roadways, and ensuring suppliers have the capacity to meet demand in the aftermath of a disaster. Disaster Mitigation is also an important part of the Preparation phase of Disaster Relief, as the most efficient way of responding to a disaster is preventing them from ever happening.

While most of the literature on Humanitarian Logistics includes Disaster Mitigation as a part of the Preparation phase of Disaster Relief, Çelik *et. al.* discuss it as a separate, fourth phase of the process. In either case, Disaster Mitigation refers to efforts taken to prevent disasters or reduce their severity. In the case of man-made disasters such as terrorist attacks or nuclear accidents, Mitigation takes the form of intelligence gathering, heightened security, and safety procedures and protocols. The mitigation of natural disasters takes the form of infrastructure improvements, the prescribed burning of forests, or the controlled release of avalanches. Altay and Green also include

zoning laws, building codes, and insurance coverage as important mitigation activities (Altay and Green III 2005).

Despite being viewed as a subsection of disaster preparation in most of the literature, mitigation is the most studied of any phase of Disaster Relief. In a review of Operations Research articles discussing Disaster Relief, Altay and Green found that 44% of the articles they reviewed address the Mitigation phase (Altay and Green III 2005). Çelik *et. al.* found that almost half of those articles address risk analysis of disaster scenarios (Çelik, et al. 2012). The other half of the papers include logistics topics in four different areas: "network design and routing of hazardous material transportation, location of early warning systems, location of unreliable facilities, and implementation of protection systems for vulnerable facilities" (Çelik, et al. 2012).

General Disaster Preparation is the broadest category of any phase, covering any of the actions taken by emergency managers or relief organizations to prepare for future disasters. According to Kovács and Spens, this is the time for groups to develop response plans, collaborate on last-mile delivery strategies, and train staff on response scenarios (Kovács and Spens 2007). Kovács and Spens also emphasize the importance of developing relationships with suppliers during this phase (Kovács and Spens 2007). Negotiating long-term purchase agreements during this time can ensure the relief organization has access to the supplies they need when responding to a disaster.

In addition to much of the above, Çelik *et. al.* discuss the importance of standard supply chain planning actions when preparing for future disasters. Among these are decisions such as facility location, resource allocation, and transportation planning (Çelik, et al. 2012). Many of these decisions can be made using the tools used in traditional supply chains, however several models have been developed to optimize for measures which are more useful in relief operations. Such measures include response time, fairness in resource distribution, and number of casualties (Çelik, et al. 2012).

One such model is a Facility Location Model developed by Balcik and Beamon. The model is an adaptation of the maximal covering location model which considers the likelihood of a disaster in each region, the budget allocated to pre-positioning supplies, and the criticality of each item type to survival, in addition to the traditional cost and capacity metrics used in location calculations (Balcik and Beamon 2008). By considering additional information pertinent to Disaster Relief, this model provides results which improve coverage and response time in a disaster.

The second phase in the preparation phase is Pre-disaster Preparation. This phase takes place between when a disaster is forecasted and when it occurs. Pre-disaster Preparation does not occur in all disasters, as not all disasters can be forecasted. Earthquakes, tsunamis, and man-made disasters (such as terrorist attacks or nuclear plant malfunctions) cannot be predicted or specifically prepared for. Hurricanes, some flooding, and blizzards are all predictable to some extent, and thus allow for specific preparations to occur before they hit.

The Pre-disaster Preparation phase covers the actions taken to prepare for an expected disaster. The literature almost universally emphasizes the importance of pre-positioning relief resources during this phase. Making the correct decisions about the positioning of resources before a disaster will result in more effective distribution of supplies and rescue operations to survivors. Salmerón and Apte have developed a two-stage stochastic optimization model for the prepositioning of resources before a disaster. The model minimizes expected casualties and unmet demand to determine the locations to position resources and the quantities of resources to place at those locations (Salmerón and Apte 2010). In the second stage, it uses the same minimizations to determine how to distribute newly received resources or redistribute unused resources while also considering the effectiveness of the first stage decisions (Salmerón and Apte 2010). Such a model ensures resources are distributed efficiently to meet the greatest demand and help the most people.

Çelik *et. al.* discuss a more general two-stage stochastic decision model that combines the decisions of General Preparation and Pre-disaster Preparation into a single framework and has been applied by several researchers. The first stage, which they call "here and now" decisions (Çelik, et al. 2012), are decisions that are made in the General Preparation phase. In the model, these decisions, such as warehouse locations and initial resource allocation, are made with a high level of uncertainty as to the nature of the disaster (Çelik, et al. 2012). Once a disaster scenario is known, the second-stage decisions, which are called "wait and see" decisions (Çelik, et al. 2012), can be made. The primary second-stage decision is the prepositioning of supplies. This decision (and others like it), is made as a function of the first-stage decisions and the nature of the impending disaster (Çelik, et al. 2012). The models which follow this framework aim to help relief providers make decisions in the face of uncertainty by considering the probability of a given disaster scenario and minimizing a selected measure such as unmet demand or the number of casualties among initial survivors (Çelik, et al. 2012).

Immediate Recovery

Immediate Recovery, sometimes called Response, begins with the start of the disaster and continues until the situation has stabilized and survivors can begin the Reconstruction phase. Altay and Green define this phase as "the employment of resources and emergency procedures as guided by plans to preserve life, property, the environment, and the social, economic, and political structure of the community" (Altay and Green III 2005). Much of the work done during this phase involves rescuing stranded survivors and distributing critical supplies to survivors that need them. All of the literature I reviewed divides this phase into two major topics: Distribution and Inventory Management.

Distribution involves the planning and execution of strategies to ensure critical supplies are delivered to survivors in need. Distribution in the aftermath of a disaster is filled with uncertainty,

as it is often impossible to determine the road conditions of a route when creating a distribution plan. Additionally, fuel shortages in disaster areas can cause significant problems in distributing supplies. Kovács and Spens present several distribution-related problems that occur in the response phase, including facility location, the last mile problem, and a lack of coordination between relief organizations (Kovács and Spens 2007). They also assign the coordination problem to inventory management, as do a few other authors.

While facility location is completed during the Preparation phase, poor facility location can have a large negative impact on distribution. In traditional distribution models, central distribution centers are often considered the most efficient choice. However, Long argues that such a model is detrimental in Disaster Relief, as victims are often unable to travel to the distribution centers and damage to infrastructure may prevent relief organizations from delivering supplies from the distribution center to survivors (Long 1997). Instead, Long claims decentralized distribution is "of utmost humanitarian importance" (Long 1997), as this allows resources distribution sites to be located closer to survivors in need.

"Last mile distribution is the final stage of the relief chain; it refers to delivery of relief supplies from [distribution centers] to the people in the affected areas" (Balcik, Beamon and Smilowitz 2008). The last mile is where many of the challenges of distribution are met. As last mile distribution occurs in the disaster-affected area, portions of transportation infrastructure is often rendered unusable, forcing deliveries to be routed along costly detours. Additionally, demand for supplies is often erratic and unknown, making the efficient loading of last-mile delivery vehicles challenging.

Balcik, Beamon, and Smilowitz have developed a model to optimize last-mile distribution routing in a disaster scenario. Their model determines optimal routes by minimizing routing costs and unmet demand, subject to the available supplies, the capacity of delivery vehicles, and the time

available for transportation (Balcik, Beamon and Smilowitz 2008). The model is only effective, however, when information about road and traffic conditions is correct. To this end, the model must be combined with information from Intelligent Transportation Systems (ITS) to function efficiently. Balcik, Beamon, and Smilowitz emphasize the importance using real-time GIS data to assess transportation network infrastructure (Balcik, Beamon and Smilowitz 2008). According to the authors, "such data would be valuable in last mile distribution if it could be transmitted to vehicles using available communication devices. In this way, drivers could be apprised of road conditions and changes to delivery schedules" (Balcik, Beamon and Smilowitz 2008). While the intent of the model is to create schedules, which do not need to change, the uncertain nature of Disaster Relief distribution means road conditions may deteriorate or survivors may be required to move, necessitating a change in schedule that must be pushed to drivers.

The second topic in the Immediate Recovery phase is Inventory Management. This topic covers the decisions about what resources to use and where to send them, the handling of in-kind donations from volunteers, and keeping resources organized for easy retrieval. Like Distribution, Kovács and Spens identify problems which affect Inventory Management. In particular, they identify unusable donations, the lack of standard labelling for supplies, and poor communication between relief organizations as the most important issues to consider (Kovács and Spens 2007).

Unusable donations are often a major problem for large relief organizations, as the donations take valuable time to sort and fill limited storage space. The donations can even be dangerous in some cases, such as expired drugs or food. According to Murray, "Inappropriate donations are so common that relief missions now routinely bring incinerators with them to the scene of a disaster to destroy items that may be dangerous or are clogging up the system" (Murray 2005). Relief organizations often recommend volunteers wishing to donate give money rather than in-kind donations, which allows the relief organization to purchase the supplies most needed by survivors.

The lack of standard labeling of supplies is another problem which affects relief organizations (Kovács and Spens 2007). Organizations often receive deliveries of similar items from multiple sources, which use different systems for identifying the same items. Poor labeling makes locating items more difficult for relief workers, resulting in workers spending more time looking for items and less time delivering those items to survivors. According to Murray, some organizations have taken to color-coding items on receipt, such as using red for food items or blue for clothes (Murray 2005). Such a system makes locating items a simple task and can be easily taught to volunteers, resulting in the more efficient delivery of supplies to survivors.

Beamon and Kotleba have developed a model for inventory management in humanitarian relief operations. While the model they developed is intended for long-term Humanitarian Relief scenarios, it can be used for short-term disaster response which is expected to last beyond the initial inventory of relief supplies (i.e. supplies will be reordered). This model gives relief organizations a method for calculating two sets of inventory policies, Standard and Emergency (Beamon and Kotleba 2006). A reorder with the Standard reorder size is placed when inventory levels reach the Standard reorder level and are delivered according to the Standard lead time (Beamon and Kotleba 2006). However, as demand for relief supplies is often highly erratic, a second inventory policy is necessary to reduce the chance of a stock-out. Should inventory levels reach the Emergency reorder point, the organization will place an order using the Emergency reorder size, which will be delivered using the faster Emergency lead time (Beamon and Kotleba 2006). The model calculates each of these values by considering the costs associated with each inventory policy, the expected demand rate, and the probability of a stock-out (Beamon and Kotleba 2006). When a relief organization receives most of their relief supplies from one or more suppliers, this model ensures they maintain efficient inventory levels and avoid a stock-out, which is potentially deadly during relief operations.

The lack of coordination between relief organizations causes problems both in Distribution and in Inventory Management. There are frequently many organizations that respond to a disaster, all with the goal of providing relief to survivors. However, these organizations do not usually coordinate their efforts, leading to duplicated efforts in distribution (Kovács and Spens 2007). Redundant distribution plans result in wasted time and supplies, as some survivors will be served multiple times, while others may be missed altogether. From an inventory management perspective, the lack of coordination creates confusion about the availability of resources in the area (Kovács and Spens 2007), leading to over purchasing supplies when another organization may have the needed supplies available just down the road.

The United Nations has taken steps to improve on the coordination problem through the development of the Logistics Support System (LSS). The system was developed in coordination with the World Health Organization (WHO), UNICEF, the World Food Programme (WFP), and other National and International Organizations. The LSS serves to "consolidate and share information on a limited number of key commodities between all actors to facilitate inter-institutional coordination" (Martinez 2015). LSS allows participating organizations to have a more complete understanding of the available resources in a relief zone and coordinate the delivery supplies they do not have with other organizations. However, not all relief organizations are able to participate in the LSS, so it is only able to give an incomplete view of the available supplies in the relief zone. A system which includes all relief organizations, including grassroots organizations, would provide complete information about the available resources and allow effective coordination among organizations.

Reconstruction

The final phase of Disaster Relief is Reconstruction, which Çelik *et. al.* also call Recovery (Çelik, et al. 2012). Reconstruction takes place from when the disaster area has stabilized and

critical services are restored (power and water) to when the area has fully recovered from the disaster. As disasters span a large scale of severity, Reconstruction can last from a few months to many years. In the most severe scenarios, areas may be abandoned rather than rebuilt, such as in the case of the nuclear incident in Chernobyl, Ukraine. Following an explosion in a nuclear reactor at the Chernobyl nuclear power plant in 1986, tens of thousands of people were forced to evacuate their homes to escape deadly radioactive fallout. As radioactive materials remain dangerous for decades, entire towns were abandoned and many evacuees were forced to permanently resettle. According to the Chernobyl Report, nearly 500,000 people in Ukraine, Russia, and Belarus were forced to resettle due to the incident (Gray 2002).

Actions that occur during Reconstruction include restoring infrastructure, cleaning and rebuilding homes and businesses, and demolishing destroyed structures. World Vision, an international relief organization, has created a three-phase response plan which covers both the Immediate Response phase and Reconstruction: 7-days, 30-days, and 90-days (Kovács and Spens 2007). The seven-day phase falls under Immediate Response and World Vision provides the services that would be required during that phase (see above). The 30-day phase spans both phases in sever disasters, but usually marks the beginning of the Reconstruction phase if it has not yet started. During this phase, World Vision provides survivors with "survival kits" which can sustain a family for 30 days (Kovács and Spens 2007), and should also contain cleaning supplies when relevant to disaster recovery (such as following a flood). Finally, the 90-day phase focuses on long-term rehabilitation for survivors, which includes providing assistance for fixing damage to homes and businesses and building new homes for displaced families (Kovács and Spens 2007).

The literature on Reconstruction is much more limited when compared to the other phases. This is likely due to the lack of funding for long-term reconstruction; as the grant-based funding relief organizations rely on is biased toward short-term response (Gustavsson 2003). The literature that does exist and my own observations identify two important issues in Reconstruction: Post-

disaster debris and waste management (Çelik, et al. 2012) and the management of excess relief supplies.

Disasters often leave enormous amounts of debris in their wake, which must be cleaned up and disposed of in a responsible manner. According to Çelik *et. al.*, "postdisaster debris and waste management can be a very costly and complicated process" (Çelik, et al. 2012). Some estimates of the size of debris generated by a disaster can be as high as fifteen times the annual waste generated by the affected area (Brown, Milke and Sevilla 2011). The makeup of this debris can be highly variable, spanning from natural debris, structure debris, and general waste. Effectively managing this waste is important to keeping survivors safe, but there are still gaps in the management of disaster waste.

Brown, Milke, and Sevilla identify several problems and offer some guidance on closing the gaps. A lack of funding is a significant challenge to waste management, as limited funding poses a challenge to collecting waste, which in turn threatens public health (Brown, Milke and Sevilla 2011). Environmentally, the relaxation of regulations during disaster recovery can cause long-term damage to the environment. Specifically, reduced recycling levels, increased use of open burning, and relaxed disposal regulations are all used to expedite clean-up work (Brown, Milke and Sevilla 2011). In general, an improved understanding of the institutional aspects of disaster waste management is crucial to improving the efficiency and effectiveness of managing waste in the aftermath of a disaster.

I was unable to identify any literature regarding reverse logistics in the context of Disaster Relief. This is perhaps the most overlooked topic in humanitarian logistics, but has the potential to incur large costs for organizations that have not planned for them. After recovery from a disaster is complete, many organizations have supplies staged at distribution centers near the disaster area. Organizations should relocate these supplies at this point, but often lack the resources or capacity

to do so. This is particularly a problem for disaster-specific organizations that form in the aftermath of a disaster, as those organizations do not have a larger organization which can recover the unused supplies and redistribute them to other locations that need them. My own observations of this scenario can be found in the Relief Efforts section.

The lack of research on this topic can likely be attributed to a lack of consideration of reverse logistics as a part of the Disaster Relief process. During the Reconstruction phase, the emphasis of Disaster Relief rightly moves from relief organizations to individuals, businesses, and governments rebuilding buildings and infrastructure. There is little interest in how a relief organization ends operations in a disaster area. Potential areas of research for this topic could include the current state of reverse logistics in Disaster Relief, the application of traditional reverse logistics models to Disaster Relief, and the development of new models specifically for Disaster Relief.

Grassroots Relief and Beacon in the Context of Humanitarian Logistics

As discussed above, Beacon is a tool designed to help grassroots relief organizations coordinate relief supplies, donations, and volunteers in the aftermath of a disaster. While the body of research in humanitarian logistics focuses on the traditional relief organizations, there are lessons in each phase of the Disaster Relief process that can be applied to grassroots relief organizations. Beacon has been designed to solve some of these problems, but there are still areas where Beacon can be improved. In this section, I will examine Beacon in the context of each phase of the Disaster Relief process, identifying the problems it solves and the areas where it can still be improved.

Preparation

The Preparation phase is the most difficult phase for a grassroots relief organization. Many grassroots relief organizations only form after a disaster has already occurred, forcing them to skip preparation and move straight to immediate recovery. However, some organizations are able complete one or both types of preparation, and Beacon can help them with this.

Few grassroots organizations get the benefit of General Disaster Preparation. Most organizations form after a disaster, and those that form before a disaster typically do so to prepare for a specific disaster. A few non-traditional relief organizations, such as churches, may get the chance to complete some amount general disaster preparation, which they should spend building relationships with other organizations, both traditional and grassroots. These relationships benefit all parties as well as the community at large.

Grassroots organizations that have relationships with other grassroots organizations can provide better support to their community in a disaster. They can work with other organizations to coordinate the delivery of critical supplies that have been donated, especially unique needs that may not be available at every relief site. Traditional relief organizations benefit from relationships with grassroots organizations due to the grassroots organizations' proximity to the community that may one day be hit by a disaster. Having a relationship with a grassroots organization, especially one with a permanent location, gives the traditional relief organizations access to relief workers familiar with the community and a location to stage and distribute relief supplies. In exchange, the grassroots organization gets access to the traditional organization's resources and can ensure the traditional organization is meeting the needs of their community.

Beacon's role during General Disaster Preparation is limited. Beacon is primarily meant for managing donations during a disaster, which cannot happen until a disaster has been predicted or has occurred. However, the team managing Beacon still has important work to do during this phase.

Like most crowdsourced apps, Beacon benefits from network effects. As more organizations, survivors, and volunteers use the app, it provides better information to every user and ensures more people get the help they need. To achieve these network effects, the public must be aware of Beacon. During General Disaster Preparation, the team managing Beacon should be working to promote the app. This could include working with local, state, and federal emergency management offices to include Beacon on their lists of items to include in a disaster preparedness kit. It should also include participating in disaster preparedness events that are hosted by government and non-governmental organizations to promote the app.

More grassroots organizations can participate in the Pre-disaster Preparation portion of the Preparation phase. In addition to the standing grassroots relief organizations which participate in general disaster preparation, some disaster specific organizations are formed prior to the disaster and get the benefits of pre-disaster preparation.

The grassroots organization's pre-disaster preparation will look much like the preparations done by traditional relief organizations, albeit on a smaller scale. The organization will begin collecting relief supplies, identifying locations to use as distribution sites, and recruiting volunteers. The majority grassroots organizations will not have purchase agreements with suppliers, so any relief supplies they collect prior to the disaster will either be donated or purchased from local stores.

Additionally, grassroots relief workers will often live an area expected to be impacted by the disaster and must prepare to be impacted themselves. The organization may also be affected by a disaster, so the preparation phase should include preparing to react to damaged infrastructure. When the disaster is expected to cause large-scale power outages, the organization should have or be able to access a generator to power any critical items. They should also be prepared for the loss of potable water for an extended period, as this often occurs following severe flooding. Finally,

relief workers should be prepared to stay at the relief site for multiple days, as damage to infrastructure may make returning home dangerous or impossible.

Beacon's role during pre-disaster preparations is to help grassroots organizations begin organizing their relief efforts. During this phase, organizations will register with the app, establish relief sites, register inventory of the supplies they have, and begin requesting donations. While Inventory Management is not a topic typically discussed during the preparation phase, it is an important topic for organizations using Beacon. During the Immediate Response phase, an accurate inventory count is crucial to ensure survivors are aware of where they can easily access supplies and ensure volunteers' donations are used as efficiently as possible. So, determining the correct quantities of various supplies and ensuring an accurate count is registered in the app is critical to Beacon being successful from the beginning of the Immediate Response phase.

There are many ways Beacon could be improved in the Preparation phase. During General Disaster Preparation, it could offer ways for grassroots organizations to communicate with other organizations. Organizations in the same general area could build a network with one another which they can leverage during a disaster, while more distant organizations could share ideas; successes; and failures to help the community of grassroots Disaster Relief. Beacon could also partner with traditional relief organizations to connect those organizations with the grassroots organizations. This would help facilitate the connections between the two groups which I recommend above.

Beacon could also be improved to utilize the facility location model discussed above. A grassroots organization may have multiple options for locating a relief site, without the manpower to utilize each location. The app could ask the user a few questions about the area and then determine which location will be most effective at providing relief. Implementing the model could be difficult, but would greatly improve the effectiveness of the app.

Immediate Recovery

The Immediate Recovery phase is where most grassroots organizations thrive. These organizations are often formed during this phase, with the sole goal of assisting in the managing and distribution of relief supplies. Beacon is also most useful here, as it was designed to assist in the management of donations and the distribution of relief supplies.

As discussed above, Distribution and Inventory Management are the most important actions that occur during Immediate Recovery. For grassroots relief organizations, Inventory Management is by far the more important of these, as survivors usually come to the relief site for supplies, rather than have their supplies delivered. However, distribution should still be considered by grassroots organizations, as they will still have to distribute supplies to survivors who come to the relief site.

Distribution for the grassroots organization will look very different from distribution for traditional relief organizations. While traditional relief groups often deliver supplies directly to survivors, grassroots relief groups often require survivors come to the relief site to access the supplies they have available. So, while distribution logistics for a traditional relief organization is focused on route planning, a grassroots organization should be focused on the layout of the relief site. A proper layout will ensure survivors collecting supplies will quickly flow through the process of picking up supplies, allowing the most survivors to receive the supplies they need. A good layout will also help relief workers quickly locate supplies and identify what supplies are needed, which helps the Inventory Management work discussed below.

Beacon's role in distribution is communicating the location of relief sites to survivors. As survivors must travel to a grassroots relief site to get the aid that site has, they need as much information about the location of relief sites and the supplies those sites have available. This communication can take place via social media, but Beacon offers a significant improvement on the information available to survivors. While social media posts usually only identify the location of a

relief site, Beacon allows survivors to search a radius they define for the supplies they need. This allows the survivor to be sure the site they go to has what they need, without wasting time travelling to sites that might not have the necessary supplies.

Inventory Management is the other major task in Immediate Recovery. Like traditional relief organizations, grassroots organizations must track what supplies they have, what supplies they need, and how to handle unusable donations. Tracking the supplies they have available is perhaps the biggest challenge for a grassroots organization, as they often have no experience managing inventories. Without software to assist in tracking, these organizations should attempt to track supplies as closely as possible in some written form. An organized layout of the relief site can assist with this type of tracking, as it allows relief workers to visually identify the inventory levels of various items.

The labeling problem discussed above exacerbates this problem, as similar items with very different packaging could cause extra, unneeded categories to be created. These extra categories result in more work for individuals attempting to track inventory and create a more complicated layout that makes visual inventory tracking a challenge. As a result, organizations with the appropriate manpower should be sure to label every item they carry in inventory to ensure each item is included in the proper category.

Inventory Management is Beacon's most important role. Beacon provides grassroots organizations with the resources they need to properly handle current inventories and request donations. Beacon allows organizations to enter their initial inventories and continue to track the inflow and outflow of supplies from that initial value. This will allow the organization to identify the items and quantities they need at various times, which they can request from volunteers in the app. The request system also helps reduce unusable or excess donations, as volunteers will be made aware of what supplies a relief site needs.

Beacon also helps fill the gaps identified in the United Nation's Logistics Support System. As discussed above, LSS is a system designed to facilitate the sharing of resources between relief organizations. However, only select traditional relief organizations have been given access to LSS, meaning the system cannot have an accurate listing of all supplies available in the area. An unknown but significant percentage of relief supplies are provided by groups that do not participate in LSS, so their supplies are not included in the system. As Beacon is available to all organizations, it can have a more complete listing of the supplies in the area. It can be improved to better facilitate coordination between organizations and ultimately should be linked with LSS and other government systems to maximize the sharing of information.

Beacon can be improved to make it more effective during the Immediate Recovery phase. Currently, Beacon only offers a platform for recording inventory and communicating what relief supplies are needed to volunteers. However, a more effective system would assist relief organizations in determining the appropriate quantities of supplies to request to reduce the holding costs related with those supplies and prevent having large quantities of unused supplies once the disaster is over. Beacon could implement a modified version of Beamon and Kotleba's Inventory Management model discussed above to help calculate the correct quantities to request from volunteers. The model would have to be adapted to handle the uncertainties that come with donation driven order fulfillment. Both standard and emergency lead times would be uncertain and volunteers may deliver the wrong quantity or fail to meet their commitment altogether. However, including the model would improve inventory levels and help reduce the amount of unused supplies at the end of a disaster, while maintaining a high service level to survivors.

Beacon could also do a better job of solving the coordination problem discussed above. The current design offers no way for relief organizations to request or transfer supplies between organizations. Beacon could provide a tool in the app that would facilitate the transfer of supplies between relief organizations. This section of the app would allow organizations to post their excess

supplies for other organizations to claim, and organizations would go to this section of the app to look for supplies before requesting them from volunteers. The app could then provide each organization's contact information to the other organization to facilitate the transfer. This feature would greatly improve Beacon's effectiveness, as it would help smooth out unreliable supply from donations through more reliable transfers between relief organizations.

Reconstruction

While not generally their primary purpose, grassroots relief organizations are often more involved with Reconstruction than traditional relief organizations. Grassroots relief groups are often active members of the community who have a vested interest in the recovery of the community. While traditional relief groups desire to assist fully in reconstruction, their limited resources often require they move on to the next disaster before full recovery is achieved. As a result, the grassroots organizations frequently provide the most assistance to survivors in the reconstruction phase.

Grassroots organizations also have more topics to consider than the traditional relief organization. In addition to managing waste and excess supplies, grassroots organizations often need to manage reconstruction projects and volunteers. Grassroots organizations are often the front line of the clean-up of private property after a natural disaster. This includes debris removal following a hurricane or tornado and "mud-outs" following a flood. Much of this work is simple manual labor, which a group of volunteers can complete with minimal training.

Managing a grassroots relief project during reconstruction looks very similar to traditional project management. The relief organization needs to plan timelines for the project, determine the resources they need, and manage the volunteers working on the project. While some grassroots organizations may have access to individuals with project management experience, many will not. As such, grassroots organizations should aim to keep reconstruction projects as simple as possible

and limit what they offer to do for a survivor. They should aim to select projects that do not need specialized skills not possessed by volunteers, as attempting to complete projects without the requisite skill could leave the survivor in a worse position than when the project started.

Managing volunteers is important in both the Immediate Recovery and Reconstruction phases, but is only a primary task for relief organizations during the Reconstruction phase. During Reconstruction, the relief organization must ensure they have the appropriate quantities of volunteers with the requisite skills for the projects they have selected. They must also ensure the volunteers are properly trained in any safety procedures pertinent to the project. Many of the clean-up projects relief organizations are involved with pose health or safety hazards to omtrained volunteers. Proper training on the precautions to take and the symptoms to look for can reduce the risk of injury or sickness to volunteers.

Beacon offers a powerful tool for the recruitment and scheduling of volunteers, but lacks project management functionality that would greatly benefit relief organizations. Beacon's volunteer recruitment section functions similarly to the donations section. Relief organizations will be able to post the time and location of a project and the number of volunteers they need. They will also be able to post restrictions and requirements for volunteers, which the volunteer should ensure they meet. Volunteers will be able to search a predefined radius and their available times for a project, and commit to helping projects they select.

Beacon could do more to assist in the project management aspects of the Reconstruction phase. Rather than establishing projects just for managing volunteers, it could offer an array of tools for each project. This function could also give relief organizations a way to manage timelines and resources. The timeline section would help organizers determine how long the entire project will take and identify the critical steps of the project. The resource management section could be

combined with the donation and volunteer request functions to allow the relief organization to find specialized tools and volunteers for projects that need them.

For projects requiring more intense work, Beacon will eventually offer ways to connect survivors with various service providers. In our long-term business plan, Beacon will sell advertisements within the app to relevant local service providers. Much of the work in the reconstruction phase requires professional work, such as tree removal, electrical work, or plumbing. These advertisements will assist survivors in identifying and contacting the service providers they need to help them complete repairs to their home. The ads will also help fund the management of Beacon and the addition of the improvements recommended in this paper and elsewhere.

Finally, Beacon could be improved to handle unused relief supplies once a disaster is over. The primary way this will occur is by transferring supplies to relief sites in other disaster areas. While such a transfer may not be immediately available, it will typically be possible within an acceptable span of time. As the number of disasters each year continues to rise, the time between disasters is decreasing, making these transfers more likely to occur. Beacon could also help connect relief organizations with local food pantries, where they could donate their unused supplies as well.

Conclusion

Humanitarian Logistics provides a beneficial model for grassroots organizations and Beacon. Grassroots organizations benefit from applying models in Humanitarian Logistics, even when those models are not designed for grassroots relief. Beacon is a powerful tool to assist grassroots organizations in applying the concepts of Humanitarian Logistics, especially concerning the Inventory Management of relief supplies and distributing those supplies to survivors.

Improvements to Beacon are necessary, however, to provide the greatest benefits to its users. Users would benefit from the addition of project management tools, tools for communication between organizations, and the inclusion of specific models to improve efficiency for relief organizations. With these improvements, Beacon has the potential to become a critical tool in Disaster Relief.

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