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Strategies for Logistics in Case of a Natural Disaster

28 September 2011

by

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Abstract

The need to effectively and efficiently provide emergency supplies and services is increasing all over the world. We investigate four policy options—prepositioning supplemental resources, preemptive as well as phased deployment of assets, and a surge of supplies and services—as potential strategies for responding to a disaster. We illustrate the linkage between our four policy options and a disaster classification based upon disaster localization (dispersed or local) and speed of disaster onset (slow or sudden). We summarize our work by introducing a matrix that aligns logistics strategies with disaster types in order to assist policy-makers in their resource management decisions.

Keywords: logistics, natural disaster, humanitarian assistance, humanitarian aid, disaster response

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I. Introduction

In 2009 there were 335 natural disasters reported worldwide that killed 10,655 persons, affected more than 119 million others, and caused over $41.3 billion in economic damages (Vos, Rodriguez, Below, & Guha-Sapir. 2009). The number of natural disasters reported between 1900 and 2010 has increased significantly and, with it, the number of requests for aid and humanitarian assistance (see Figure 1). While the trend in the number of disasters reported shows an increase, it is not clear that there has been a commensurate response in terms of preparedness. The United States Agency for International Development (USAID) reports that of all funds used to support disaster operations, 90% are spent for response, whereas 10% are spent on preparedness activities and investments and risk reduction (A. Giegerich, personal communication, September 21, 2010). The United Nations estimates that every dollar spent to prepare for a disaster saves seven dollars in disaster response (United Nations Human Development Program, 2007).

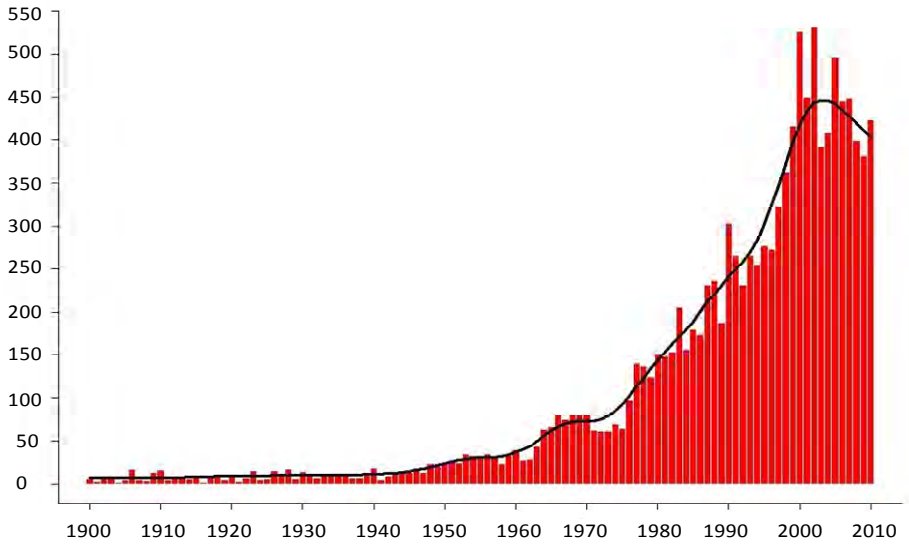

Figure 1. Number of Disasters Reported from 1900–2010
(EM–DAT, 2011)

Although the objective of all the organizations and agencies involved in humanitarian assistance is to reduce human suffering and casualties, the duration and severity of the human toll during a natural disaster is largely dependent upon the speed and scope of the response, which is often a function of the level of preparedness that has been established prior to the disaster event. While there are no internationally agreed upon metrics by which to judge or measure the effectiveness of a response to a disaster, scholars working in the humanitarian and disaster response research area have found that improvement is desirable (Apte, 2009; Van Wassenhove, 2006). An effective and efficient humanitarian response depends "on the ability of logisticians to procure, transport and receive supplies at the site of a humanitarian relief effort" (Thomas, 2003). In this research we focus on the response to a disaster area in the form of distributing supplies, and strategies that will enhance the effectiveness of such a response. For the purpose of this research, we accept the Center for Research on the Epidemiology of Disasters' (CRED) definition of disaster, which is "a situation or event which overwhelms local capacity, necessitating a request to a national or international level for external assistance."

The unpredictability of the timing of a disaster, as well as the scope of its human and material destruction, raises several serious questions for emergency planners and first responders. For example, how can a state of supply preparedness be established and maintained? How should adequate prepositioned disaster relief inventory be established and sustained over time, to include the rotation of perishable stocks? How can information regarding the location, quantity, and condition of prepositioned inventory be shared, and what effect would this information sharing have on the total investment of prepositioned stocks? Is prepositioning the best strategy for all types of disasters? How reliable are the potential supply lines if it is determined that supplies should be virtually stockpiled (that is, a detailed list or database of supplies by type and quantity is created and maintained, as well as reliable sources that can provide the supplies quickly)?

Should the supplies be sourced locally or from outside the disaster zone? Answers to these questions depend on the expected onset speed of the disaster, the volume and weight of supplies to be moved, the expected magnitude of humanitarian relief required, and the expected likelihood of a disaster in the area.

As part of our investigation we explore four policy options: (1) prepositioning supplemental resources in or near the incident location; (2) proactive deployment of assets in advance of a request; (3) phased deployment of assets and supplies, analogous to the “just in time” inventory control philosophy practiced by many commercial manufacturers; and (4) “surge” transportation of manpower and equipment from locations outside the disaster area.

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II. Literature Review

One of the major issues in a response supply chain in case of a natural disaster is to coordinate the operations and relief inventories over a large number of stages, locations, and organizations. This has to be done while providing the emergency supplies and services to the affected population under extreme conditions. Decisions regarding the types of provisions that should be prepositioned, as well as their location, should be made well before a disaster strikes in order to provide quick response. To some extent, without such a high level of uncertainty and an adverse environment, it is similar to the core question in supply chain management of coordinating activities and inventories over a spectrum of stages of the supply chain and facility locations of the inventory (Schoenmeyr & Graves, 2009).

In the private sector, it has been found that if each individual stage in a serial-system of the supply chain operates with a designated base stock policy with service guarantees, then the optimal safety stock strategy is to maintain inventory at certain key locations, which results in separating the stages of the supply chain; this type of policy allows each stage to operate independently by minimizing the need for communication and coordination amongst players (Simpson, 1958; Graves & Willems, 2002). Models available in supply chain management literature are predominantly with unlimited capacity for storage. In cases where there is unlimited capacity, the amount of safety stock needed is less than the level needed with capacity constraint (Schoenmeyr & Graves, 2009).

The determination of the optimal placement of safety stock in a supply chain has been addressed by Simpson (1958) and Schoenmeyr and Graves (2008), where there are evolving or predetermined forecasts, and by Graves and Willems (2002), where there is uncertain, as well as non-stationary, demand. This concept can explain the response supply chain where there exists uncertainty for the quantity required, as well as what is required (Apte, 2009; Ergun, Karakus, Keskinocak,

Swann, & Villareal, 2009). Rawls and Turnquist (2010) developed a model for determining the location and quantity of supplies that should be prepositioned when there is uncertainty with respect to whether a disaster will occur and where it will occur, and built upon this work by adding service quality constraints (Rawls & Turnquist, 2011) to ensure the probability of meeting demand and the average shipment distance is within a specified parameter. In addition to the prepositioning of relief inventories, a disaster response may require the formulation of policies that require the expansion of warehouses, medical facilities, and temporary shelters, while infrastructure preparation may include the provision of airstrips and ramp space at existing airfields (Salmeron & Apte, 2010). Koavacs and Spens (2009) weighed the difference between traditional commercial logistics and humanitarian logistics. With humanitarian logistics, it is imperative to go beyond the profitability of commercial logistics. Within the domain of humanitarian logistics, suppliers have different motivations for participating, and customers do not generate voluntary demand. It is clear that in most cases a "repeat purchase" is not a possibility. Thus, supply networks must take into account the lack of true demand. Demand is dictated by the relief agencies that are the primary actors within this framework. Therefore, it is the responsibility of the agency to "push" the supplies to the disaster location in the immediate response phase, which is different from the commercial philosophy of pull-based demand. Humanitarian logistics focuses on getting the greatest volume of supplies to the points where they are needed, and there may be lessons learned in the commercial sector that could be used to improve the planning and execution of strategies that could be implemented during a disaster response.

III. Disaster Life Cycles

The life cycle of a disaster from the perspective of Humanitarian Assistance and Disaster Relief (HADR) is divided into three stages (as illustrated in Figure 2): being prepared in the pre-disaster stage, response as the disaster strikes, and recovery in post-disaster (Apte 2009; Van Wassenhove, 2006).

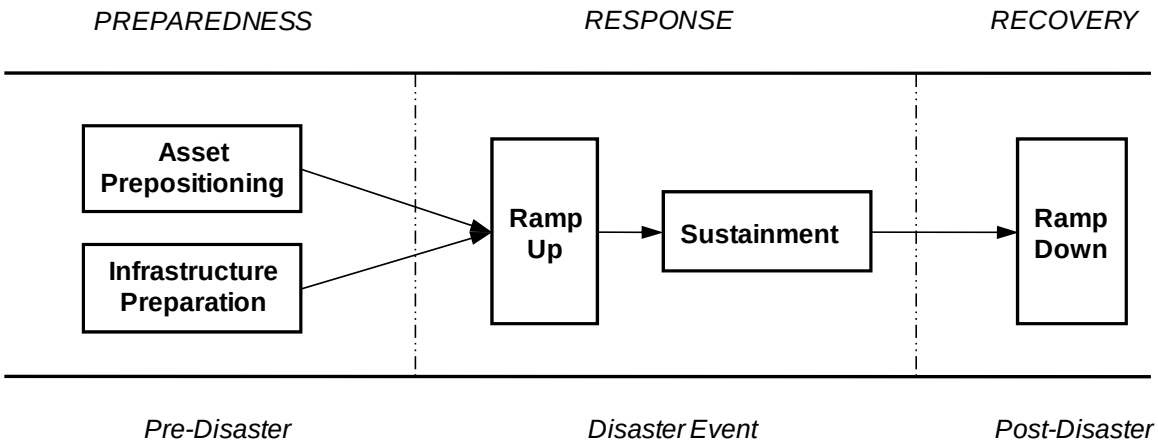

Figure 2. Life Cycle of Disasters
(Apte, 2009)

Disaster preparedness is the first step in mitigating the adverse impacts of any unforeseen catastrophic event. Preparedness on an individual level is defined by the creation of an escape and survival plan, as well as the procurement and storage of supplies that will enable an individual to act on the plan. Preparedness at an organizational or institutional level translates to the planning and pre-establishment of adequate capacity and resources that will enable efficient relief operations. Prepositioning of war reserve and contingency stocks, such as that practiced by each of the U.S. Armed Services, has proven an effective means of increasing the speed of response to a conflict (Abell et al., 2000; Button, Gordon, Hoffmann, Riposo, & Wilson, 2010; Hura & Robinson, 1991). The private commercial sector, too, has been involved in prepositioning strategic safety stocks in supply chains with evolving forecasts (Schoenmeyr & Graves, 2008), capacity

constraints (Schoenmeyr & Graves, 2009), and non-stationary demands (Graves & Willems, 2002, 2008).

Disaster response is a function of the preparation that took place prior to the disaster event, as well as the coordination of available supplies and distribution capacity. The first part of the response consists of gaining situational awareness of events and conditions on the ground in the disaster area through the collection of available information, and then using this information and awareness to generate an operational picture that will inform the nature, scale, and timing of the response. The result of this collection of information and establishment of situational awareness is a needs assessment or requirement for assistance. The response itself is largely comprised of the tactical activities that must take place to move needed supplies to those parts of the disaster area that have the most critical demand, given the available resources at hand.

Disaster recovery consists of stabilizing the disaster area and improving the living and economic conditions of those affected by the catastrophic event. The recovery phase means different things to different organizations. For the military, the recovery phase likely signals the beginning of drawn-down or redeployment operations, whereby military personnel and equipment are withdrawn and responsibility turned over to civil authorities. For non-governmental and non-military aid organizations, the recovery phase may consist of establishing semi-permanent camps, aid stations, or warehouses to shelter displaced persons; delivering critical services that cannot be provided by other civil authorities; and coordinating the storage and distribution of supplies that are otherwise unavailable or in short supply to the local population.

Studying the life cycle of recent disasters offers insight into both short-term and long-term consequences. It also provides us with numerous lessons to form effective strategies for mitigating future disasters. However, in order to formulate such strategies, we need to understand disasters in terms of their speed and scope.

IV. Disaster Classification

Disasters are often classified based on the speed of onset and the source or cause of the disaster (Ergun, Heier, & Swann, 2008; Van Wassenhove, 2006). However, in our research we focus on four disaster scenarios that are combinations of the geographic dispersion of the disaster (dispersed or localized) and its speed of onset (slow or sudden), as discussed by Apte (2009) and described in Figure 3. We differentiate local from dispersed disasters in terms of the number of civil administrative districts impacted, such as cities, counties, townships, parishes, prefectures, provinces, or states. As the number of civil administrative districts increases, so does the geographic area impacted, resulting in an increase in the complexity associated with responding to the disaster. It is the coordination of effort across multiple districts, coupled with the size of the relief requirement, which frustrates the effectiveness of humanitarian assistance and disaster response operations. Slow-onset disasters are defined as those that allow potentially affected populations time to react in order to mitigate the impact of the disaster, whereas sudden-onset disasters allow little to no time to react to the disaster event. The disaster classification suggests that the level of difficulty in the logistics execution is less onerous in the case of localized, slow-onset disasters (depicted in quadrant III of Figure 3) because there may be adequate lead-time and local resources to prepare for the response.

We next discuss four specific disaster cases that exhibit different onset and localization characteristics, as illustrated in Figure 3, and serve as exemplars of strategies that are appropriate to specific disaster types, as described in the discussion section.

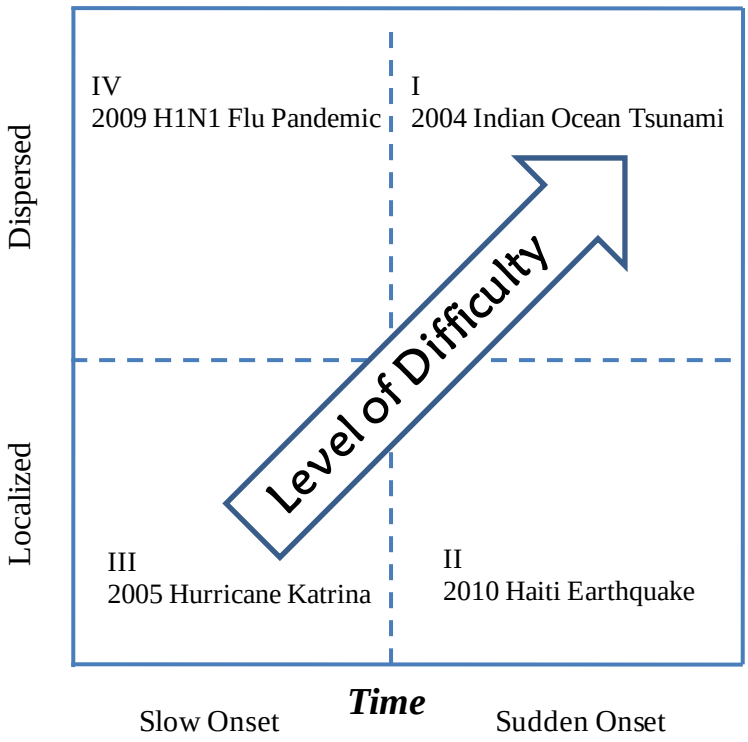

Figure 3. Classification of Disasters
(Apte, 2009)

A. Indian Ocean "Boxing Day" Tsunami of 2004

Dispersed and sudden-onset disasters (depicted in quadrant I of Figure 3) tend to be the most catastrophic in humanitarian terms because they lack warning in advance of their onset, and they impact large geographic areas that often cross multiple civil administrative areas, making coordination critical and difficult. The Indian Ocean Tsunami of 2004 was the result of a 9.1 magnitude earthquake and was responsible for more than 227,000 deaths, more than 500,000 injured, over 2 million missing, and more than 1.5 million displaced persons across more than 12 countries (Greenfield & Ingram, 2011). The destruction was primarily limited to the coastal regions (Samek, Skole, & Chomentowski, 2004), but was dispersed across so many countries that relief efforts were frustrated by the lack of complete reports of the damage to those countries affected and of the specific types of aid and assistance needed most.

Most of the people affected by the tsunami did not actually know it was coming. Because the earthquake occurred far offshore, those affected on land were not aware of it and had no way of knowing the tsunami was coming. The earthquake occurred so far away that it was not felt. The key problem was notification. Agencies that did sense the earthquake were not able to effectively notify those areas that might be potentially affected and even if they did the agencies did not have adequate means of disseminating the potential threat of a tsunami to all those that might be affected. It should be noted at this juncture that there was no tsunami warning system in the Indian Ocean. Some areas, particularly the Banda Aceh region of Sumatra in Indonesia, lacked a basic, functioning transportation infrastructure, which imposed severe capacity constraints on the flow of inbound supplies.

B. Haiti 2010 Earthquake

A sudden-onset disaster, even if localized (depicted in quadrant II of Figure 3), creates operational difficulties that are greater than circumstances where the onset is slow, but less than if the catastrophe were both rapid in its onset and geographically dispersed. Sudden-onset disasters deny authorities and the public time to prepare for the consequences of the disaster event and, therefore, tend to exact a much higher human cost. The earthquake that struck Haiti on January 12, 2010, measured 7.0 in magnitude on the Richter scale, resulting in more than 200,000 dead (United Nations, 2010). Poorly designed and constructed buildings, bridges, and other infrastructure resulted in significant losses, the creation of large debris fields and obstructions to transportation, and a need for large-scale rescue efforts of those trapped alive underneath concrete and steel wreckage.

The government of Haiti was immobilized with a significant percentage of the national leadership dead or missing as a result of the earthquake. With little ability to assess damage or mobilize and manage the few resources that were not destroyed in the quake, the surviving population were left to rely on the response of other nations to help rescue those trapped in collapsed buildings and to provide

food, water, medicine, and shelter. Lack of physical infrastructure, especially in underdeveloped and poor countries, causes long lead-times in transportation, which was evident in Haiti. The consequences of poor governance and weak institutions were evident in the Haiti disaster, and so, in spite of the proactive deployment from the rest of the world, suffering persists.

C. Hurricane Katrina

On August 29, 2005, Hurricane Katrina struck the city of New Orleans. It was known days in advance that the hurricane might make landfall in New Orleans, and although the city had warned residents, there were many who remained and were killed, stranded, or left homeless as a direct result of the storm's violence or the failure of the levee system that otherwise protected the city from flooding. Hurricane Katrina was a slow-onset, localized disaster (see quadrant III of Figure 3) and one of the most devastating and costly hurricanes to strike the United States. Once the storm had passed, more than 80% of the city of New Orleans was under water, approximately 1,700 people were dead, 1 million persons were displaced, and an estimated $135 billion in damage along the Gulf coast was incurred (Plyer, 2010). The official plan for the city was for displaced residents to gather in the New Orleans Superdome football arena in the downtown center as a refuge of last resort. However, due to failed infrastructure and lack of planning for needed supplies to be delivered to the affected area, those who sought refuge during the critical first week following the landfall of the storm found thousands of people confined in a large open building whose roof was torn open and which had no functioning utilities, such as electricity or water. The state of Louisiana activated the National Guard and after several days, buses were organized to begin evacuating those still in the city to outlying areas.

D. Influenza "Swine Flu" Epidemic of 2009

Quadrant IV describes a context where the onset is slow but the affected area is geographically dispersed. When the disaster area consists of a large or scattered

geographical area, it may take substantial planning, resource allocation, and coordination among the military, humanitarian organizations, and local, federal, and perhaps even foreign, government representatives. The 2009 influenza epidemic is an example of a slow-onset, geographically dispersed disaster event affecting multiple countries (see Figure 4). The epidemic was responsible for more than 14,000 known deaths (European Centre for Disease Prevention and Control [ECDC], 2010), which occurred throughout the world. Subsequent research has shown that the seriousness of the influenza cases was not necessarily greater than other influenza outbreaks (Centers for Disease Control and Prevention [CDC], 2010), but the population affected was different, with children affected in much higher numbers than other influenza outbreaks on record at the time (Belongia et al., 2010). Although the numbers of people who have died from the H1N1 influenza have been modest since the pandemic in 2009, there remains a significant threat that the disease could mutate into an antibiotic resistant strain that could eventually kill millions of people worldwide; the CDC has stated that H1N1 and H3N3 influenza strains are both highly resistant to two of the four licensed influenza antiviral agents (CDC, 2011).

The public health response to the 2009 pandemic faced challenges in the form of educating the public about the severity of the epidemic, managing initial shortages of vaccine inventories in the initial weeks of the declared pandemic (*Responding to the 2009–2010 Influenza Season*, 2009), as well as determining distribution points for the vaccines. Effective vaccine distribution is dependent upon the ability of public health officials to detect virulent strains that might result in a pandemic. Once a strain is identified that might result in a pandemic or once a pandemic has been declared, public health officials must decide when to begin the mass production of a vaccine. Because influenza mutates rapidly, it is not feasible to stockpile vaccines for long periods in anticipation of a particular, currently identified strain. Instead, surge capacity must be established to respond to a potential pandemic, and then distribution networks must be capable of moving the vaccines to where they are needed.

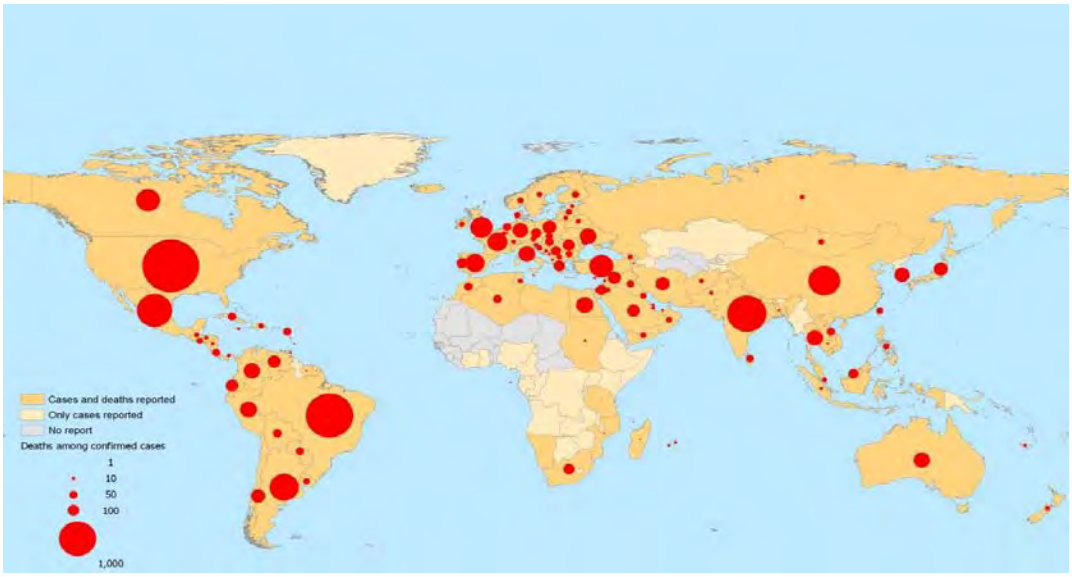

Figure 4. 2009 Confirmed Cases of H1N1 Flu by Country
(ECDC, 2010)

One of the key problems with vaccines for influenza is that they cannot be prepositioned far in advance because the influenza strains mutate, making it necessary for epidemiologists to forecast what they believe will be the dominant strain of influence in advance. So, essentially the responders must rely upon availability of the vaccines. If there is none available it has to be produced and then distribute the produced vaccine as quickly as possible and ensure that the most vulnerable and/or necessary people get it first. The Strategic National Stockpile (SNS), which is jointly run by the CDC and the Department of Homeland Security (DHS), contains an inventory of antibiotics, antidotes, and vaccines for rapid deployment in case of an emergency.

V. Discussion

The disasters we have discussed in the previous section illustrate the strategic, as well as operational, difficulties faced when responding to a disaster. Though the disasters are classified into four quadrants, we believe the terms *slow*, *sudden onset*, *localized*, and *dispersed* are relative. A hurricane is slow in onset because there is some forecast available and, hence, it is imminent but not necessarily sudden. A pandemic, on the other hand, is very slow compared to the time between when a hurricane is identified and when it makes landfall. At the other end of the spectrum is an earthquake, which is instantaneous, with aftershocks in the category of slow, since they are imminent.

The geographic dispersion of a disaster is also relative since a disaster can be considered to be localized if only one governing entity or administrative district (such as a city, town, or county) is involved or several communities are affected. Such granular classification could be a topic for further research; however, in our work we confine our analysis to the general categories of sudden and slow when discussing onset, and to localized and dispersed when considering geographic dispersion.

We next consider four fundamental strategies an organization could employ to respond to natural disasters in the context of the exemplars presented in the previous section: prepositioning, proactive deployment of assets in advance of a request, phased deployment of assets and supplies, and "surge" capacity planning of manpower and equipment from locations outside the disaster area to the area of most need.

A. Prepositioning

The success of the military in using prepositioned stocks has developed interest in the prospect of using such a strategy to support operations other than war (Brown, Schank, Dahlman, & Lewis, 1997; Salmeron & Apte, 2010). Prepositioning

supplemental resources in or near the incident location most resembles the military practice of storing defense inventory ashore or at sea to be used in the event of a conflict; the Army prepositioned stocks (APS) in southwest Asia (APS–5), Korea (APS–4), and the Indian Ocean (APS–3) are good examples (see Figure 5).

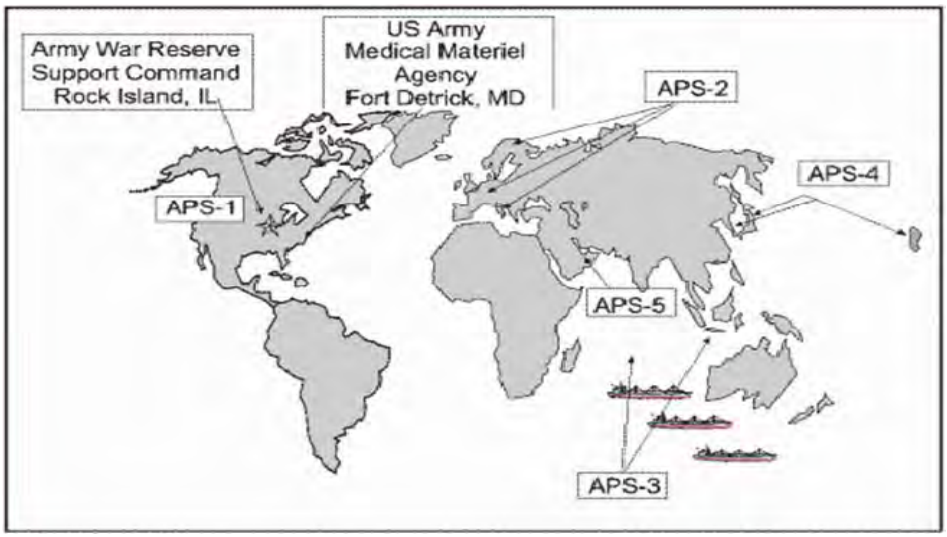

Figure 5. Army Prepositioned Stock Locations
(Headquarters, Department of the Army, 1999)

Non-governmental organizations also preposition items in advance of a disaster to reduce the response time of providing relief (Duran, Gutierrez, & Keskinocak, 2011). Prepositioning supplies is appropriate when the lead-time to respond with supplies exceeds the time frame in which the supplies are needed, or when it is important to preserve transportation assets, such as airlift, for other purposes, such as personnel or higher priority movement. When determining where to preposition supplies, organizations must consider the trade-offs between placing stocks close to a potential disaster area so that the distribution time is reduced, and the risk associated with being adversely impacted by the disaster if they are too close to the potential danger zone. Campbell and Jones (2011) described a method for determining where to preposition supplies in anticipation of disaster, considering several different scenarios. The authors sought to incorporate the risk associated with placing supplies in an area that might be affected by the disaster, as well as the

inventory that is required to respond effectively to a disaster. Prepositioning would be a desirable logistics strategy for disaster events such as the 2004 Indian Ocean tsunami, the 2010 Haiti earthquake, and Hurricane Katrina because it would shorten the lead-time to provide supplies. However, locating the supplies outside the potential disaster impact zones would be necessary, and the investment in such inventories could be large. The feasibility of maintaining large stocks of food, water, and other emergency supplies for a long period of time in countries that are poor and have high levels of corruption should also be considered; if the stores of prepositioned stocks cannot be secured, then prepositioning is ineffective.

Prepositioning vaccines, antibiotics, and antidotes is desirable when the biological or chemical agent to be combated is stable and not mutating. The key questions of interest are where, exactly, to position the stocks, and who shall receive treatments. When it is impracticable to preposition supplies well in advance of a disaster, it may be desirable for excess production capacity to be obtained through capital planning, contracting, or collaboration so that capacity itself is "prepositioned" to respond in the time of need. In cases of an influenza epidemic, for example, it is not known well in advance which strain might be dominant and, therefore, excess production capacity has been established at the national level to produce the right vaccine when needed. In cases where it may be economically infeasible to preposition supplies, it may still be possible to arrange for excess production or distribution capacity to be established in order to support a rapid, or "surge," response, which we discuss later in this section.

B. Proactive Deployment

An alternative to prepositioning is the early deployment of assets in advance of a local government request. For example, as federal government officials see a hurricane approaching the Gulf of Mexico, they could mobilize food, water, and temporary shelters and stage them close to, but not in, the expected disaster zone so that when these supplies are needed, the lead-time necessary to deliver them is reduced (see Figure 6).

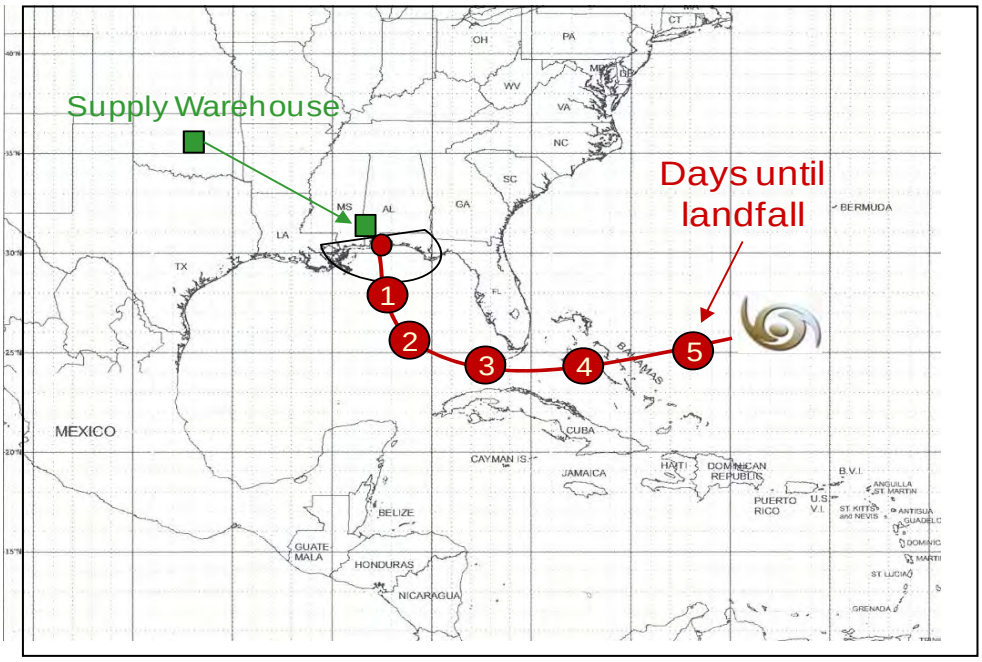

Figure 6. An Example of Proactive Deployment of Supplies in Advance of a Hurricane

It was known that Hurricane Katrina might make landfall in New Orleans days in advance of the disaster, and this offered time for the proactive deployment of supplies. Unfortunately, public authorities tended to be reactive rather than proactive and did not effectively preposition medical supplies prior to the hurricane's landfall (U.S. House of Representatives, 2006).

Another problem is related to displaced persons. Companies may take care of the shortage of private goods but cannot adequately manage or deal with the shortage of public goods such as shelters for the displaced population.

C. Phased Deployment

Phased deployment of assets refers to timing the delivery of inventory to a disaster area as it is needed and in the quantity in which it is needed. This disaster response is analogous to "just in time" inventory control practiced by commercial manufacturers and has the advantage of not committing excess inventory to a specific region before knowing precise types and quantities of supplies needed.

Phased deployment also prevents the disaster zone from being inundated or saturated with inbound materiel that might otherwise reduce the overall effectiveness of the disaster response due to inadequate infrastructure or limitations in personnel, handling equipment, storage space, or some combination of all three. Following the earthquake in Haiti in 2010, the lack of runway capacity, as well as equipment, slowed the movement of supplies and specialized personnel such as physicians, nurses, and search and rescue teams. Additionally, there were capacity limitations at the ports, in terms of the number of containers that could be processed and the amount of available dry warehouse space (see Figure 7). It was undesirable to push supplies into the area because the ports were not capable of handling the flow of materiel.

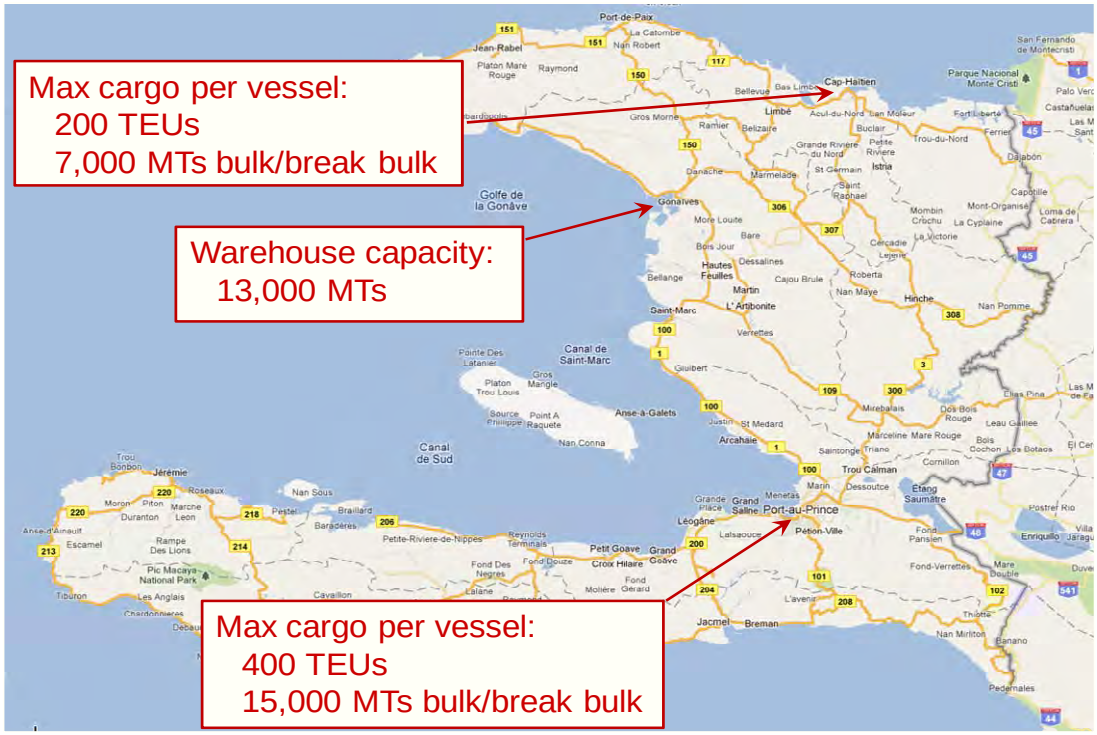

Figure 7. Limited Port and Warehouse Capacity May Necessitate Phased Deployment

After the tsunami in the Indian Ocean, there were enough supplies donated by the world's richest countries, but there was only one airstrip and one forklift in Banda Aceh, the regional capital of Aceh, Indonesia. When disaster strikes an area

with limited port capacity, the phased deployment of supplies is not only prudent, but necessary, in order to prevent the cessation of the flow of supplies.

D. Surge Capacity

A surge in transportation of manpower and equipment from locations outside the disaster area is a final alternative that, rather than relying on prepositioned physical inventory, plans for excess capacity to deliver personnel and materiel in case of an emergency; in this instance, the "prepositioning" is with respect to capacity rather than inventory. Figure 8 illustrates an example where there is surge capacity reserved at specific locations, labeled "Supply Warehouse," outside of an anticipated disaster zone. In this instance the disaster is a hurricane that has or will very soon make landfall. Surge capacity to distribute resources from these warehouses that lie outside the anticipated disaster impact area may be utilized to respond quickly while avoiding the risk of staging goods inside the potentially affected area.

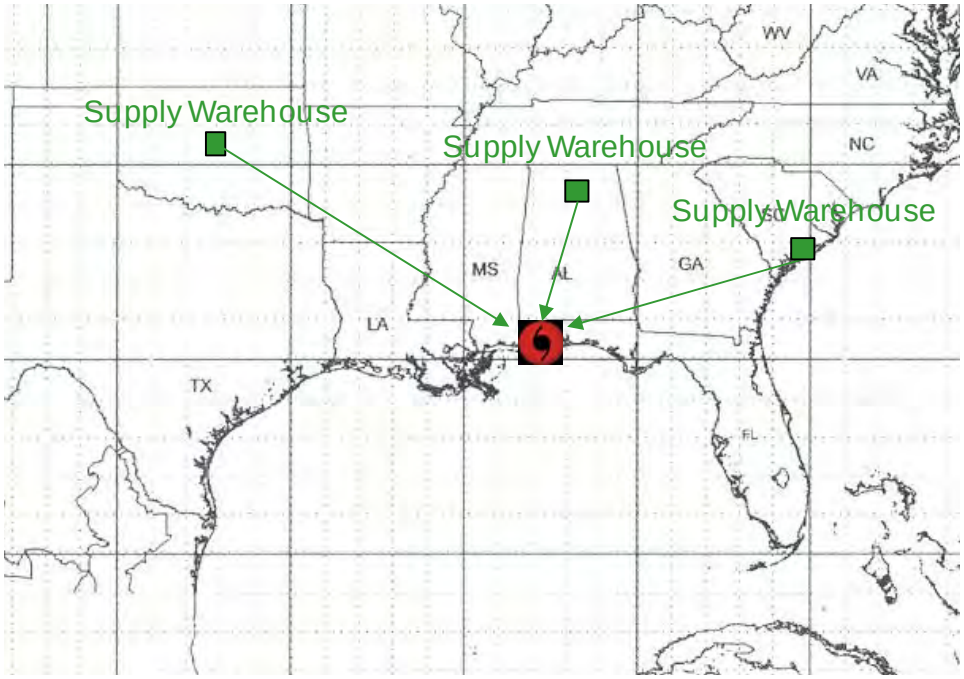

Figure 8. Surge of Supplies From Regional Warehouses in Response to a Disaster

VI. Conclusion

Localized, slow-onset natural disasters are at one end of the spectrum with respect to the level of difficulty for humanitarian logistics whereas dispersed, sudden-onset disasters are at the other. We base our policy models on the classification of disasters.

Disasters that are classified as slow onset provide time for humanitarian logisticians to plan and prepare for relief operations. A disaster that strikes suddenly can pose difficulties for response since no organization—military or humanitarian—can fully prepare for every need that emerges during such an event. However, prepositioning strategies, such as asset placement, resource allocation, management of disaster relief inventory, and location of such warehouses may help. It is clear that whether the disaster is localized or dispersed over a large geographical area dictates the level of difficulty involved in disaster response.

To assist policy-makers in their understanding and decision-making, Figure 9 illustrates which logistics strategies are very desirable, desirable, or undesirable, when considering the four disaster classifications. The fully darkened circles indicate that a strategy is very desirable for a particular disaster type. A partially darkened circle indicates that a strategy is desirable for a particular disaster type, and an unfilled or hollow circle indicates that the strategy is undesirable for a particular disaster type. Studying the exemplars of the disasters leads us to one conclusion: in all the disasters, slow or sudden onset and localized or dispersed, there is likely to be some type of prepositioning of supplies, but that does not mean this is the most desirable policy because prepositioning is always costly. Prepositioning may also be difficult for policy-makers to justify since investments in prepositioned stocks cannot show an immediate return. Additionally, it is difficult to estimate which supplies to stockpile, as well as how much will be needed or can be reasonably afforded. Therefore, we propose that prepositioning is a very desirable policy for sudden-onset disasters (Classifications I and IV) where logistics

transportation response lead-times exceed the time in which the supplies are most needed following a disaster (see Figure 9). Prepositioning is desirable in those cases where the disaster may be localized and slow (such as in a hurricane zone) or when the disaster is dispersed and slow, such as a pandemic. Critical supplies that are prepositioned in likely disaster zones or in those areas where they will most likely be needed (such as high-density population centers) will require fewer transportation assets to move those supplies when the disaster strikes, and the lead-time is reduced between the time needed and the time they are available. However, in cases of a dispersed, slow-onset disaster, it might be cost prohibitive to preposition large quantities of supplies over broad geographic areas. Therefore, we propose that prepositioning is a somewhat desirable policy for Classification IV (dispersed and slow). In case of Classification IV, localized but sudden, it may not be that cost prohibitive to preposition since the disaster is anticipated to be contained, and the faster speed of onset deems it critical to reach the affected region due to time sensitivity. Thus, when the transportation lead-time or time necessary to increase the capacity is in excess of the anticipated need, prepositioning may be the suitable strategy. Prepositioning will also help since transportation means can be spared for use after the disaster, due to critical and time-sensitive issues in the affected area and the community.

We propose that proactive deployment is the most desirable policy that should be implemented for slow-onset disasters (Classifications II and III). Slow-onset disasters allow for planning and response and, therefore, allow for authorities and agencies to deploy resources in anticipation of a disaster, rather than waiting for the request from the potential impact area. Advanced knowledge of the location of a disaster allows the use of proactive deployment, whether the disaster area is localized or dispersed. Proactive deployment is particularly desirable when it is anticipated that the affected region will be unable to mitigate the effects of a disaster. The director of the Federal Emergency Management Agency (FEMA) recently stated that the federal government should be more proactive in its approach to an imminent disaster and not wait for a local request for help (The White House, 2011). In the

case of sudden-onset disasters (Classifications I and IV), proactive deployment is likely to be less effective, simply because there is not ample lead-time to place resources in advance of the disaster event. However, in those instances where there are disasters that are seasonal or imminent, proactive deployment may be both an efficient and effective means of mitigating adverse impacts.

Both of the policies discussed, prepositioning and proactive deployment, assume that there are resources or capacity to store supplies, and that personnel are available to distribute the supplies during the time of need. However, if there are capacity constraints for receiving the necessary supplies, phased deployment may be a better strategy for getting supplies to the disaster area. When the needs in the disaster area are unknown or emerging, a phased deployment strategy may be desirable because supplies that are not needed or are in sufficient quantities will not be sent to the area; as time passes, the needs in the disaster area become more clear, and better information can be used to select the right supplies in the appropriate quantity.

Surge is the last resort policy when prepositioning or proactive deployment is not feasible or affordable. If one takes into account just the cost, this is not the policy choice for slow-onset disasters. However, this is the most likely policy for sudden-onset disasters, whether localized or dispersed. This is especially true if there is inadequate capacity for response and the last resort is surging the capacity for supplies and services.

Logistics Strategy

Surge	●	●	○	○
Phased Deployment	●	◑	◑	◑
Proactive Deployment	○	○	●	●
Prepositioning	◑	●	◑	◑
Disaster Category	I	II	III	IV
	Dispersed & Sudden	Localized & Sudden	Localized & Slow	Dispersed & Slow

Disaster Classification

○ Undesirable
◑ Desirable
● Very Desirable

Figure 9. Proposed Policies

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