Creating a Framework for a Humanitarian Response Capacity Index

by

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Abstract

Humanitarian logistics encapsulates all supply chain efforts in response to a disaster or emergency. Despite the increased focus on humanitarian supply chains, there is not a general method for measuring the supply chain response capacity. We propose a model for humanitarian response capacity based on the stock levels and supplier capacity of an organization. We evaluate the model using inventory stock level data from the United Nations Humanitarian Response Depots (UN HRD) and a combination of inventory stock level and supplier contracted replenishment time data from the New York City Office of Emergency Management (NYC OEM). Model results in response to four simulated disaster events graphically show the approximate number of people that can be served as well as the oscillations in capacity during the response and replenishment phases. Given the span from global (UN HRD) to municipal (NYC OEM) contexts, this response capacity model provides a framework for developing a more general index that can aid organizations in making important investment decisions in order to save lives with more efficient disaster response.

Thesis supervisor: Jarrod Goentzel

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Table of Contents

List of Figures

List of Tables

1 Introduction, Motivation, and Background

The Humanitarian Response Sector

Humanitarian response is conducted by various organizations: not-for-profit organizations, governmental agencies, and private companies. These agencies receive funding from donors to purchase and mobilize relief items to victims of disastrous events in various countries or regions. According to The Sphere Project (2011), which includes guidelines on humanitarian response created by an interagency coalition, a humanitarian disaster event is any natural disaster or armed conflict that causes needs greater than can be fulfilled by the local economy and government. These events can approach rapidly, such as a hurricane or flood, or approach slowly, such as a drought or political conflict. Once an event occurs, organizations typically conduct a rapid needs assessment within the first days after a disaster. This assessment is typically a survey of a statistical sample of the affected population in order to determine the needs of the community affected.

After the rapid needs assessment is completed, organizations send items, volunteers and employees to the affected area in order to facilitate disaster response and recovery. In most humanitarian crises, there is some sort of displacement of affected population from their homes. The responding organizations establish shelters or camps for the displaced populations and this is typically where the distribution of the items and the recovery work occurs. In these shelters and camps, there are normally stations where those in need have access to items they need, such as food, water, or medical treatment, and organizations establish methods for monitoring fair distribution of the items.

According to The Sphere Project (2011), the four categories of humanitarian response are Water Supply, Sanitation, and Hygiene promotion (WASH); Food Security and Nutrition; Shelter, Settlement, and Non-Food Items; and Health Action. Each of these categories covers a broad variety of items provided, and the categories must have support functions, such as basic accounting, management, and logistics. In a typical response, the organizations involved with establish a prioritization order of the categories based on the needs of the affected population. In the next section, we will explore the role of logistics in humanitarian response.

How Humanitarian Logistics Supports Humanitarian Response Efforts

Humanitarian logistics describes the specific aspect of humanitarian response that coordinates the shipment and delivery of relief goods to the organizations and people that need the goods. Logistics plays a crucial part of humanitarian response efforts, and without efficient logistics processes, lives can be lost waiting on much-needed supplies. Humanitarian logistics is primarily responsible for procuring items from the supplier, whether that is a product manufacturer or distributor, to the warehouse, and from the warehouse to the distribution point in the event response region. Depending on the location of the warehouse, also known as a distribution center (DC), and on the location of the event response, items may travel by airplane, by truck, by rail, by ocean, or by animal.

The modes have tradeoffs which can be seen in Table 1-1. Shipping items by airplane is the fastest way of transport. However, it typically costs the most and holds the least amount of items. Moving items by truck is a little slower than an airplane and is subject to the condition of the roads. Yet, it holds more goods than an airplane and can drive anywhere, whereas an airplane must land in an airport. Railroads are similar to trucks in that they are somewhat fast and hold more goods. However, they can only travel where the railroad has been laid and require transportation from the rail station to the distribution point. Ocean is by far the slowest method of transport. Yet it holds a decent amount of goods and is normally the least expensive shipment method.

Table 1-1 Comparison of Shipping Methods

	Airplane	Truck	Railcar	Ship
Cost	High	Medium	Medium	Low
Flexibility to DC	Medium	High	Low	Low
Holding capacity	Low	High	Medium	Medium
Speed of shipment	Fast	Medium	Medium-Slow	Slow
Global pervasiveness	High	High	Low	Low

Logistics in humanitarian response is different that logistics in the normal business environment. In a normal business environment, companies can somewhat predict the time and amount of product their customers will want. In a humanitarian response, there is little or no warning of when an event will occur and, when the event occurs, how many people will be in need of relief efforts. This makes holding the right amount of inventory, especially items with expiration dates, very tricky. If there is too much inventory, donors feel they are wasting funds on storage; yet if there is too little inventory, organizations receive criticism for not being prepared for a disaster.

In addition to very uncertain demand, humanitarian supply chains must operate in a different transportation context. Most companies have relatively stable shipment times and mostly secure, stable transportation infrastructure. Humanitarian logistics, however, typically requires short lead times, in order to get supplies to the disaster-affected regions quickly, and works in settings with insecurity and unstable infrastructure. Roads and airports may be in poor condition depending on the level of investment of the government and may be affected by the disaster event. Thus they can provide challenges in shipping items quickly.

Creating a Measurement for Humanitarian Logistics Response Capacity

Since humanitarian response efforts happen quickly after a disaster is identified, most humanitarian logistics efforts center on getting the right items to the people in need as fast as possible. Thus far there has been little emphasis on measuring any aspect of humanitarian logistics in the sector. Individual organizations may have internal measures for logistics, but these measures are not suitable for the sector as a whole. The lack of consistent measuring methodology has left organizations to guess at their capacity to respond to a disaster and their efficiency in responding to a disaster. In this research, capacity is meant as the ability and quantity of organizations to respond to a disaster event with goods. This thesis will focus on creating a framework for measuring the capacity of organizations to respond to a disaster.

Humanitarian organizations typically hold quantities of key items in warehouses in order to ship the items immediately after a disaster need arises. This concept is commonly referred to as stockpiling goods. Capacity to respond to a disaster comes mainly from these inventory stockpiles. The capacity for the entire supply chain also includes the capacity of the suppliers which can be measured by their inventory stockpiles, their manufacturing volume capabilities, their lead times to deliver goods, and the location of their manufacturing and warehouse facilities.

The goal of this thesis project is to create a method of measuring response capacity that can be used in humanitarian organizations and that can be expanded in the future to create a sector index for measuring sector-wide capacity to respond to a disaster in various regions. This capacity information can assist organizations in planning their response efforts, including inventory stock levels, location of distribution centers, and estimating the time and cost to serve those affected by disaster events. Better assessment of response capacity can lead to more efficient investments and decisions which can ultimately save more lives in disaster response.

For this research, we focused on two organizations which operate on different geographic scales of humanitarian response: the United Nations Humanitarian Response Depots (UN HRD) on a global response scale, and the New York Office of Emergency Management (NYC OEM) on a municipal scale. In the next section of this thesis, we will review the current literature on humanitarian logistics, describe other humanitarian indices, and review principles to developing a mathematically sound index. This will be followed by the methodology and data analysis for assessing capacity. The thesis then closes with insights gained from the capacity assessment and thoughts on how the methods could be extended to form a sector-wide index.

2 Literature Review

Each organization must have its own way to measure and plan for capacity; however, there has not been a consistent method of measuring the capacity of supply chains in the humanitarian sector. Because of these reasons, there is little literature on humanitarian logistics measurements compared to literature of other areas of humanitarian response. This section will first introduce available literature on the sectors of humanitarian response and humanitarian logistics, then review other humanitarian assistance indices, and finally explore literature on forming an index. Since this thesis focuses on methods to assess capacity that could in turn be the basis of an index, we researched literature on forming an index in order to create a framework that is conducive to future index formation.

2.1 An Overview of the Humanitarian Logistics Sector

A humanitarian response requires certain standards to be upheld in order to provide fair distribution of goods to the people in need. As Iyer and Zelikovsky (2011) point out in their case on the United Nations Joint Logistics Center (UN JLC), there are three important pillars of humanitarian response that must be upheld during coordination efforts:

1. Identifying and assisting victims of a disaster event
2. Remaining separate and objective from political interests in the humanitarian response
3. Showing no partiality in assisting people in need

These principles are extremely important in the humanitarian context to continue providing relief and to work in socio-political contexts. For example, if an organization only distributed items to people of one people group affected by a conflict, other affected people in the opposing people group would suffer, and the humanitarian organization might be accused of supporting a political interest in the conflict.

As mentioned in the introduction and background, humanitarian response can be categorized many ways. Tomasini and Wassenhove (2009) describe three general stages of humanitarian logistics: ramp up, sustain, and ramp down. As Table 2-1 shows, moving through the stages, the focus for supply chain professionals shifts from speed, during the immediate response, to lead time and cost reduction, during the sustain and ramp down phases. They also state that an organization can increase preparedness by focusing on the impact that a supply chain has on a response.

Table 2-1 Stages of Response and Focus

Stage of Response	**Response Focus (in order of priority at each stage)**
Ramp up (immediate response)	Speed
Sustain	Lead time reduction, cost reduction
Ramp down	Cost reduction

According to Tomasini and Wassenhove, the response methods do not differ significantly based on the nature or causes of the events. This statement reflects a basic assumption of this thesis: since similar items are needed in a disaster response and since methods of responding are similar for all disaster events, it is possible to measure the response capacity needed for a variety of situations.

During each stage of humanitarian response; ramp up, sustain, and ramp down; there must be coordination within an organization and among responding organizations. In addition to describing the basic requirements of any humanitarian response, Iyer (2011) also describes the challenges that face the UN JLC, the organization that was primarily responsible for coordinating logistics operations among all humanitarian agencies responding to a disaster event until the cessation of the center. These challenges include reacting to requests from the host countries that are receiving the aid; facilitating receipt of goods into the country in order to prevent a backup of goods waiting to get into the country, also known as a bottleneck; and coordinating how organizations make group decisions: by command, with one organization breaking a tie; by consensus, with all organizations agreeing on a decisions; or by default, with each organization deciding independently. Bottlenecks and lack of coordination commonly delay goods being distributed in a timely manner, and is one reason that the logistics aspect of humanitarian response is an area of focus.

2.2 Humanitarian Indices

Recently there has been an increased focus on measuring humanitarian response. Instead of just measuring the number of people served, organizations have begun focusing on consistently measuring more areas of their humanitarian response and donors have begun asking for evidence to support their funding decisions. This trend will lead to a more efficient use of donor funds and, with great discipline, more lives saved by more efficient humanitarian response. The following sections describe some indices and measurements of humanitarian organizations already in existence.

2.2.1 Humanitarian Response Index

Development Assistants Research Associates (DARA) (2011) created the Humanitarian Response Index in order to measure the adherence of government donors to a previously agreed upon set of donor best practices. These best practices, formally titled Principles and Good Practice of Humanitarian Donorship, were determined in 2003 at a convention of the world's largest government humanitarian donors. The five categories of best practices include the following:

1. Objectivity of needs assessment, basing donorship on actual needs of people not on political interests
2. Strengthening local response capacities while helping to prevent future disasters
3. Making policies that support the efforts of humanitarian organizations
4. Abiding by international humanitarian law and supporting humanitarian access into all countries
5. Maintaining humanitarian accountability and promoting humanitarian education

DARA independently creates the index each year in an effort to provide each government donor with a benchmarking tool as well as provide accountability, transparency, and positive influence on humanitarian donor funds. For example, in the 2011 index, DARA found that disaster preparation and prevention has been overlooked in funding decisions and that donors have become less transparent in their funding practices. Donors and organizations might find these insights useful in establishing better donor practices for 2012 and beyond.

2.2.2 Human Development Index

The United Nations Development Programme (UNDP) (2011) publishes the Human Development Index which measures the education, health, and living standards of every country. The UNDP focuses on people who have lower income and living standards to assess how humanitarian efforts are impacting the development of these people. Instead of taking one aggregate measurement from each country, it is measured for various people groups in the country. This index might indicate that one area of a country is better educated than another or that one people group has poorer health care systems than another people group. This index helps humanitarian organizations visualize where their efforts are most effective and locate areas in need of more humanitarian aid.

2.2.3 Humanitarian Access Index

The Humanitarian Access Index is a recent effort begun by the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) (2011) to measure the ease of accessibility into a country. Thus far, the index has only been completed for Yemen. Each region, as determined by state lines of the country and operations within the area, is given a different rating of accessibility. Accessibility is determined by the following:

- The number of incidents that target aid workers
- The stability of the area's government
- The number of landmines in the area
- The number of road permits that have been denied to humanitarian organizations
- The number of checkpoints on roads

- The perception of the humanitarian community in the area

This index is used by humanitarian organizations working in or travelling through Yemen to know which areas are the most accepting of or most hostile toward humanitarian workers. If this index is expanded to other countries, it could be very useful for humanitarian agencies responding to disaster events in those countries to give an idea of the lead times to get supplies to specific regions of countries, based on the region's accessibility.

2.3 Forming an Index

Various methods can be used to form an index, ranging from entirely quantitative data-based indices to entirely qualitative indices. The most common quantitative-based index is a price index and most literature on quantitative indices explores methods for forming a price index. The sections below review literature on quantitative, price indices and indices which incorporate qualitative data. Since the framework depicted in this thesis includes quantitative data about inventory stock levels and more qualitative data about supplier capacity, various types of index formations are explored in the following sections.

2.3.1 Price Indices

A price index is a simple, quantitative comparison of item prices, or combined prices for an aggregate mix of items, across time periods. One of the most common price indices is, in the United States, the Consumer Price Index (CPI), which is used to measure the rate of inflation in the country.

There are many approaches to forming the CPI, or any price index. Reinsdorf (2007) describes the three approaches: axiomatic, stochastic, and economic. The axiomatic approach has maxims that dictate what mathematical properties the index should have. A stochastic approach, a more statistically based approach, relies on data and statistical distributions to form an index. The economic approach tries to optimize the incomes and prices. He does not give an opinion on which method is best, but instead simply lists the approaches as acceptable methods of creating an index.

A sample of a price index is given by Carlson and Thorne (1996). They give equations for a simple index and for a weighted index. A simple index accounts for everything equally, while a weighted index assigns weights, or value percentages, to specific aspects. They also provide some widely debated criticism of the CPI. For example, the CPI might not be valid from one year to another, because it does not consider changes in consumption patterns. It also does not consider inverse relationships that exist between products. For example, as electric car purchases increase, gasoline purchases decrease. Both of these criticisms can be useful for the index that might be created from this thesis research by helping to avoid the same validity questions. For example, in this response capacity research, it might be important to note that as the capacity for shelter items increase, the capacity for blankets might decrease.

2.3.2 Indices Incorporating Qualitative Data

Qualitative data can be hard to express in a way that is easily measured and integrated with quantitative data into an index. Qualitative data may include degrees of quality of text, judgments of characteristics, or market research data. This data may not initially be in numeric format but frequently can be turned into a number with some formatting or ranking scales.

One such qualitative characteristic is productivity. Vrat (2009) argues for the importance of indices and economic utility models in evaluating productivity. In his review of indices, he includes equations for rentability, market effect, productivity, price of products, price of input factors, output of products, and total input factors. In this analysis of productivity, Vrat succinctly provides advice for the type of index that this thesis framework aims to support. The important process steps highlighted in his work are: comparing current levels against base levels, comparing performance units to other performance units, and comparing current response to target response. These three comparisons will all need consideration in the final index that will be created by the framework in this thesis.

Another example of qualitative index formation is explained in a book by Wright (1986). In this book, Wright explains the importance of the index of qualitative variation, which measures the spread of qualitative data for a system. This index measures on a nominal level and on an ordinal level across different categories. Instead of measuring by dollars or sales, this index includes things that are more qualitative, such as quality of work completed. The index described here will provide tips for formulating any qualitative aspects that might arise in the expansion of this research of the humanitarian response capacity index. The qualitative index also measures the spread of the data across the various categories, which is useful for variables in the response capacity index that tend to be spread among different categories.

3 Methodology

This section explains the methods used in collecting and analyzing data to assess response capacity and provides a basis to create an index measuring humanitarian response capacity for different organizations. Inventory stock levels were gathered from each of the two organizations, United Nations Humanitarian Response Depots (UN HRD) and the New York City Office of Emergency Management (NYC OEM). We chose the UN HRD and the NYC OEM as organizations to research, because they represent two extremes of disaster response: the global response (UN HRD) and the municipal response (NYC OEM). Each extreme has very different supply networks and response methods. The extremes were chosen to demonstrate capacity response measurements for broadly and narrowly defined regions as well as evaluate this framework for creating an index for capacity response for any level of response.

As described in earlier sections, capacity is defined as the ability and quantity of organizations to respond to a disaster event with goods. The most available source of data needed for this capacity framework is inventory stock levels. The UN HRD (2012) inventory stock levels are available as public information on their website, whereas the NYC OEM inventory stock information was obtained through contacts in the NYC OEM. Information about supplier contracts were also collected from NYC OEM and incorporated into their results. Supplier contract information was not collected form the UN HRD, because it houses inventory belonging to dozens of organizations, which each have their own supply chain structure. Finding supplier data for each organization was too large scale for this project.

Inventory stock levels were collected, because they indicate the immediate capacity to respond to a humanitarian event. Supplier manufacturing capacity levels were collected because they indicate a larger portion of the entire supply chain's capacity to respond to a humanitarian event. Since the type of data collected from each organization differs and the scales of response of the two organizations differ, two models were developed: one for a global response and one for a municipal response.

3.1 UN HRD Capacity Analysis

In order to measure how the capacity to respond to a disaster changes over time, three disasters were simulated using the inventory stock level data gathered from the UN HRD. These simulations provide a representation of the capacity to respond to a real disaster and can be analyzed to provide guidance on inventory levels that account for average need for an average event in certain regions. In the next sections, the assumptions of the simulation are explained followed by the actual data used in the simulations, and the results of the simulations.

3.1.1 Disaster Simulation Assumptions

In order to make the simulation applicable to multiple organizations, the simulations incorporate averages of people affected, of items needed, and of lead times from distribution centers to the country of the event. These assumptions and averages are explained in the following sections. The simulations reflect shipments of one event's worth of supplies for non-consumable goods and one month's worth of supplies for consumable goods. We assumed from general knowledge of the sector that organizations typically ship out 3-4 weeks' worth of supplies immediately after a disaster. The amount of items needed for that shipment is calculated during their initial needs assessment, described below. After that time, the organizations can better reassess the needs, because the number of people affected has been more accurately estimated and the demand for items is typically steadier. This simulation focuses on the capacity to respond to a disaster immediately after it occurs.

3.1.1.1 Disaster Selection Method

Simulations of different disasters were executed for the UN HRD data: a hurricane in the Caribbean, a drought in Northern Africa, and a flood in Southeast Asia. These disasters were chosen, because they are common events in each of the various areas. Since the UN HRD operates in every area of the world, we wanted to simulate disasters in different regions of the globe. The simulations are identified by regions, not by countries, in order to maintain the integrity and duplicability of the simulation. We wanted to exclude any country-specific and changing factors, such as political climate or economic stability, which are less relevant when measuring the general capacity to respond with supplies to the event.

3.1.1.2 People Affected Assumptions

Data were collected from the EM-DAT disaster database operated by the Centre for Research on the Epidemiology of Disasters (2012) in order to determine the average number of people affected by similar disasters in the same regions. The EM-DAT data tracks the number of weather events per year and the number of people affected by those events per year in different regions of the globe. We assume that other non-governmental-organizations will also be responding to each disaster and that approximately 40% of the people affected receive UN HRD-supplied items. The 40% is an assumption made by the authors based on general knowledge of the sector. An example of these assumptions from the UN HRD hurricane scenario simulation is shown in Table 3-1 below. The orange areas indicate numbers that can be altered. Using the average number of people affected, the average number of storms per year, and the percentage of people that benefit from UN HRD-provided items, we arrive at the expected people affected that will benefit from UN HRD-provided items for this hurricane simulation of 34,286.

Table 3-1: Average People Affected by a Hurricane in the Caribbean

People affected per time period	702,857	people		
Number of storms	8.2	average storms per time period	85,714	people
Percentage served by UN	40%		**34,286**	people

3.1.1.3 Items Needed Assumptions

During each event, organizations conduct a needs assessment, which measures the amount and type of goods needed to respond to the event. The organization then creates an appeal to donors to fund the purchase and deployment of the goods needed. Appeals from the International Federation of the Red Cross (IFRC) to donors for goods were collected from public sources in order to determine the average number of supplies needed for similar disasters response efforts in the same regions. The IFRC appeals show the number of items requested for people affected by a specific event, displayed as items needed per person or per family. Some items are once-per-event items, such as blankets and tents, whereas some are recurring monthly items, such as soap and water purification satchels. We then multiply the items needed per person by the total people to get the total items needed. For items with recurring need, we estimate replenishment needs based on months. Since the simulation represents shipments of one month's worth of supplies, the recurring items are calculated for one month. An example of these assumptions from the UN HRD hurricane scenario is given in Table 3-2 below. The bolded numbers in the last columns show the quantity needed of each item during the time period, either for the entire event or for one month.

Table 3-2: Items Needed for a Hurricane in the Caribbean

Event Needs	Units per person per time period	Time period	Equivalent units	Total need (in units)
Water tanks	0.002	event	**1/500 people/event**	**69**
Blankets	0.4	event	**2/family/event**	**13,714**
Jerry cans	0.4	event	**2/family/event**	**13,714**
Sleeping items	1	event	**1/person/event**	**34,286**
Tents	0.2	event	**1/family/event**	**6,857**
Tarpaulins	0.2	event	**1/family/event**	**6,857**
First aid kits	0.01	month	**1/100 people/month**	**343**
Water purification kits	4	month	**1/person/week**	**137,143**
MREs/food items	1.2	month	**1/50 people/day**	**41,143**
Soap	1	month	**1/person/month**	**34,286**

In addition to calculating the total items needed, the simulation shows the number of events or months of supply available of each item, an aggregate of all distribution centers, to enable the organizations to easily see how under- or overstocked they might be based on their internal stocking policy levels.

Table 3-3 shows an example of the supply availability calculated for the UN HRD Hurricane in the Caribbean simulation. For non-consumable items, the supply availability is given as a percentage of the event needs that the UN HRD can fulfill. Notice that for all items except sleeping items, the availability is above 100%, which indicates that the UN HRD has enough inventory to fulfill more than the needs for the simulated hurricane. For consumable items, supply availability is given in the number of months of need the inventory will fulfill, given that the need stays the same. Notice that the UN HRD has over ten months' worth of water purification kits but less than one month' worth of food items available.

Table 3-3: Supply Availability for a Hurricane in the Caribbean

Item	Appeal covered by inventory	Units
Water tanks	354%	event
Blankets	2144%	event
Jerry cans	1335%	event
Sleeping items	43%	event
Tents	144%	event
Tarpaulins	718%	event
First aid kits	1.56	months consumables
Water purification kits	10.34	months consumables
MREs/food items	0.95	months consumables
Soap	6.80	months consumables

3.1.1.3.1 Items Needed Selection

In order to make the framework general enough to duplicate and representative of most disaster responses, the most common and key items were chosen to be measured. The items were chosen based on the principles in *The Sphere Handbook,* which is the product of an inter-agency disaster response collaboration that establishes humane guidelines for disaster response. Sphere has 4 categories of standards: Water Supply, Sanitation, and Hygiene Promotion (WASH); Food Security and Nutrition; Shelter, Settlement, and Non-Food Items; and Health Action. Widely-accepted common items from each category were chosen for the simulation in order to represent all areas of need during a disaster response.

3.1.1.4 Lead Time Assumptions

Average lead times via air and ocean to the event country are assumed based on general distances. Since the UN HRD has five depots strategically placed around the globe, the lead times reflect proximity to the simulated disasters. Table 3-4 below gives an example of assumed lead times for the hurricane simulation. In the simulations, the capacity to respond to an event for that particular item decreases when the item reaches the distribution center in the destination country. It is assumed that, although costly, the items can be diverted during shipment. Thus the capacity to respond to events, including the particular one in the simulation, is not reduced until the item actually reaches the country of the event.

Table 3-4: Assumed Response Lead Times to a Hurricane in the Caribbean

Lead time to the Caribbean	Panama	Accra	Brindisi	Dubai	Subang
Air	2	3	3	3	3
Ocean	4	14	14	21	21

Since the UN HRD real-time inventory levels are available online, we assumed that the organization has access to order supplies from any distribution center. This means that when the nearest distribution center has run out of items, the next distribution center can prepare shipment of needed items the next day. Thus, there is no delay of communication between distribution centers built into the simulations.

3.1.1.5 Replenishment Assumptions

We assumed replenishment of items occurs and added replenishment to the simulations based on adjustable replenishment lead times. Items are replenished up to a base stock level, which was estimated based on inventory levels at each depot available from January 2009 to December 2010. The assumed replenishment lead times for the UN HRD response to a hurricane in the Caribbean are given in Table 3-5 below.

Table 3-5: Assumed Replenishment Lead Time to the Caribbean

Replenishment Lead Time	Panama	Accra	Brindisi	Dubai	Subang
Water tanks	32	29	21	20	9
Blankets	31	31	24	20	8
Jerry cans	34	35	22	22	9
Sleeping items	37	34	25	22	11
Tents	35	33	22	22	10
Tarpaulins	31	33	23	23	10
First aid kits	32	32	22	24	10
Water purification kits	38	31	24	21	11
MREs/food items	36	30	21	22	12
Soap	30	34	21	18	9

3.1.1.6 Excluded Items

The simulation does not directly take into consideration capacity for any item existing in the region of the event. For example, food markets in the area may have enough capacity to entirely respond to the event needs without assistance from the UN HRD. The IFRC figures of average number of supplies needed indicate that some items are provided in country. For example, in these simulations, we assumed, based on general knowledge, that only 4 MREs are needed per person per month, signifying that the rest of the meals are provided by sources in the country.

3.1.2 Simulation Details

Capacity is measured during each day of the year, and the simulation graphs depict the first 45 days, as the replenishment is completed by day 45. Since the day of the event may not be the same day that supplies ship, the simulation is based on the day the supplies ship, as that is tied directly to the shipping lead times and does not depend on the rapid response assessment timeframe, which can vary depending on other factors outside the scope of this research.

Capacity is measured for each item category at each UN HRD distribution center. The number of items shipped for items measured by a unit of months is enough to satisfy the previously-determined number of people to be aided by UN HRD items for one month. This number, which can be changed if the simulation is duplicated, is based on general knowledge of the sector which typically ships enough items at the beginning of a disaster to satisfy needs for approximately a month following the disaster.

3.2 NYC OEM Capacity Analysis

The NYC OEM has jurisdiction to respond to a disaster exclusively in the City of New York, which encompasses five boroughs: Manhattan, Brooklyn, Queens, The Bronx, and Staten Island. Because the area of disaster response is narrower than the UN HRD area of disaster response, only one disaster simulation was performed for the NYC OEM. This simulation reflects a disaster response in a heavily metropolitan area. In the following sections, assumptions and response methods unique to the NYC OEM and a city-based disaster response are outlined as well as the methodology of the executed simulation.

3.2.1 Assumptions

The same assumptions as the UN HRD simulations apply to the NYC OEM analysis with three exceptions: where five distribution centers exist in the UN HRD analysis, only two distribution centers exist for the NYC OEM analysis; where three simulations of various disasters in various regions were performed for the UN HRD, only one disaster simulation in one area was performed for NYC OEM in New York City, because this is where the NYC OEM has jurisdiction to respond to a disaster; and supplier contracted replenishment lead times are used instead of assumed replenishment lead times. The amount of items needed is calculated based on Sphere Project (2011) standards and interviews with Erin Bores and Jonathan Jenkins of the NYC OEM (personal communication, April 26, 2012). The base stock levels were also pulled from NYC OEM interviews and files that indicate base stocking levels.

3.2.2 NYC OEM's Unique Response Method

Since New York City is very densely populated with scarce open land, the NYC OEM hosts shelters in the public school buildings instead of creating shelters out of tents as is more common in international humanitarian response settings. The NYC OEM has contracts with the Department of Education to provide shelter, water, and food from the school's cafeteria during a disaster. The schools with active contracts are strategically located to provide service to all parts of the city if necessary. These schools are designed to serve as shelters for a few hours up to two days. NYC OEM assumes that buildings in some areas of the city will remain functional, and those in need can find more permanent shelters in the form of hotels or apartments. As noted above, tents are not a viable option for disaster response in New York City because there is no open land on which to set them up; the shelters must come from existing buildings.

3.2.3 Supplier Contract Replenishment Additions

The NYC OEM analysis factors in the contracts with suppliers for replenishment of goods to respond to the disaster through NYC OEM. In the UN HRD models, these replenishment times are assumed, but with accurate supplier contracted replenishment times, the results show a better response capacity and can be more useful in helping to determine appropriate inventory levels.

3.2.3.1 Lead Time Adjustment

NYC OEM has a warehouse in the city of their jurisdiction and response: New York City. Thus the lead times from the NYC OEM distribution centers are measured in time by truck, not by air or ocean. Lead times from the suppliers are measured by air or truck and are adjusted in the simulation according to the proximity to New York City. In practice, the NYC OEM contracts with a third-party logistics (3PL) provider to deliver the goods to the shelter centers from the warehouse. NYC OEM contacts the company approximately 2 days before an expected disaster event, and the 3PL has 1 day to deliver the goods to the shelters.

3.2.3.2 Recovered Items Adjustment

According to the NYC OEM's internal plans, the schools are designed to be used as shelters for up to seven days after an event. At this time or after an event, whichever occurs first, remaining items are to be returned to the NYC OEM warehouses, where the NYC OEM filters through the items to find recoverable inventory. Any items that can be reused are added back to the inventory stock levels. In the simulation in this research, we assumed that the replenishment items would be ordered at the base stock levels before the recovered inventory is counted. Thus, the recovered inventory is added to the replenishment base stock inventory levels after an event to determine the response capacity.

3.2.4 Simulation Details

As with the UN HRD simulations, capacity is measured for each day of the year. The capacity reduces at the day of inventory deployment from NYC OEM, as lead time to the event site is zero days, or at the day of arrival at NYC OEM for supplier-supplied goods. The replenishment time is calculated based on supplier contracts and interviews with E. Bores and J. Jenkins of the NYC OEM.

4 Data Analysis and Results

To begin our analysis, we created four scenarios of disasters: a hurricane in the Caribbean for the UN HRD, a flood in Southeast Asia for the UN HRD, a drought in Northern Africa for the UN HRD, and a hurricane in New York City for the NYC OEM. Each of these scenarios shows the capacity, or the ability with inventory, to respond to the disaster. The models incorporate lead times to the event locations from the respective distribution centers (DC) and time to reorder and replenish the items from the supplier.

4.1 Base Assumptions for the Scenario Models

The assumptions for the scenario models are outlined in the previous chapter of this thesis and summarized in Table 4-1 below.

Table 4-1: Scenario Assumptions

Assumption	Basis	Adjustable?
Items needed	Donor appeals from IFRC	Yes
People affected	Em-Dat data from past events	Yes
Lead time to event	General knowledge estimates	Yes
Replenishment lead time	General knowledge estimates/ Supplier contracts	Yes

4.2 Scenario 1: Hurricane in the Caribbean (UN HRD)

The scenario model is formulated to send goods from the nearest DC to the event country, then proceed to the next nearest DC if the previous DC does not fully fulfill the need request. It continues to the next nearest DC, and so on until all of the DCs have been contacted or until the need request if fulfilled, whichever comes first. In this hurricane model, the order of

DCs in proximity to the Caribbean is: Panama, Accra, Brindisi, Dubai, Subang. When a need is established from an event, the model first pulls items from Panama, then Accra, then Brindisi, and so on until the need request is fulfilled through the goods being allocated for that event response. The model assumes a delay in notification of the next DC of one day. For example, in this scenario, Brindisi is notified on the third day, after Accra is notified on the second day, and Panama is notified on the first day.

The capacity graphs for each item, located below, show the levels of inventory, an aggregate of all the DCs, that the UN HRD has remaining to respond to other disasters after the allocation to the hurricane response. The red line indicates the day the need is presented to the first DC, Panama. The inventory levels decrease after the response and increase after replenishment of the goods to a base stock level. There is a delay in the capacity decreasing, because we assume that the capacity does not decrease until the arrival of the goods in the country of the event. We assume that a shipment can be diverted to another event, although at a high cost, during transport. The capacity levels reflect the delay of lead times to the country of the event.

The graph shows only from day 1 through day 45. The following graphs are based on an event occurring on day 4 with replenishment completed before day 45, and only one event occurring per year. The graphs are shown only until day 45. In most of the items, the base stock level is higher than the beginning inventory since the base stock is estimated to be higher than the beginning inventory levels used—January 2009. Thus, the capacity after replenishment is higher than the capacity before the event response.

Figure 4-1 shows that the capacity for the UN HRD to respond to other disaster events with water tanks, based on the assumed need for a hurricane disaster response, until day 45. The red lines in all figures indicate the first day of the order shipment from the first DC. Notice that after the event, the replenishment grows in steps. This is due to the variety of replenishment lead times.

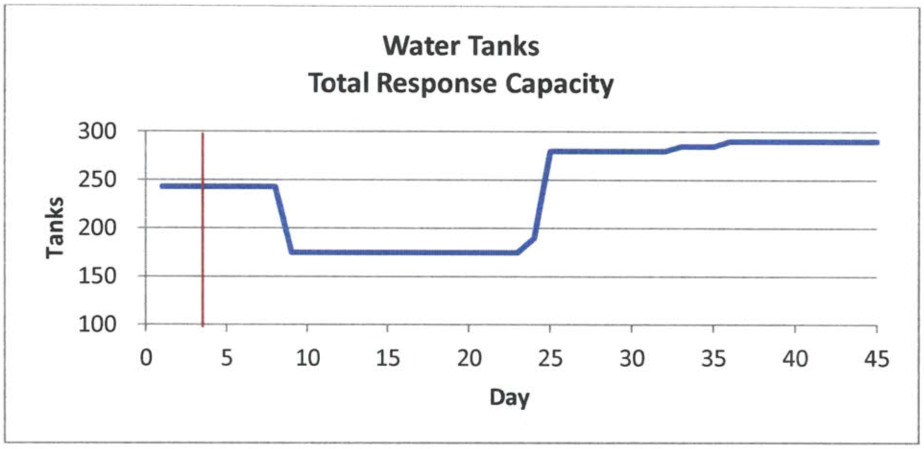

Figure 4-1: Water Tanks Response Capacity—Hurricane

The figures that show the response capacity for blankets, jerry cans, tents, first aid kits, water purification kits, Meals Ready to Eat (MRE) and food items, and soap are located in the Appendix. Notice that the capacity decreases in different increments for each items and increases at different increments. This is due to the items being positioned in different DCs and having different replenishment lead times.

Figure 4-2, shows that the capacity reduced to 0, which indicates that there were not enough items in all of the DCs to meet the need that arose from this simulated hurricane. This also occurs with MREs/Food Items located in the Appendix.

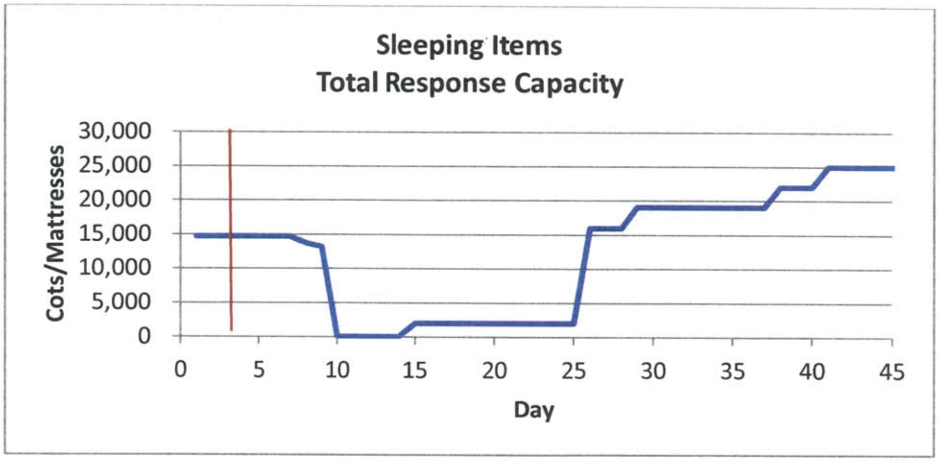

Figure 4-2: Sleeping Items Response Capacity—Hurricane

Figure 4-3 shows the response capacity for Tarpaulins which decreases a small amount, stays level, then decreases again. This is a good example of how inventory is positioned in the DCs. All of the tarpaulins in Panama are shipped, followed by tarpaulins in Accra.

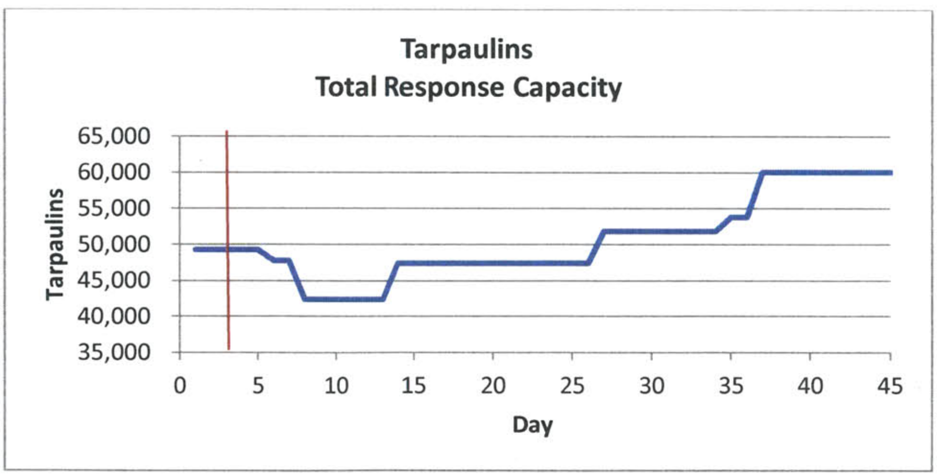

Figure 4-3: Tarpaulins Response Capacity—Hurricane

The next figure, Figure 4-4, shows the number of people served by each item for day 4, the day of the event, through day 11, past the last day of shipment of all the items. From this figure, it is evident that for most of the items, the UN HRD can fully serve their target number of affected people; however, they cannot serve the total amount of people with sleeping items or MREs, even after taking the local supply into account. It is interesting to note how quickly some items reach total people fulfillment and how slowly others build to their maximum number of people served.

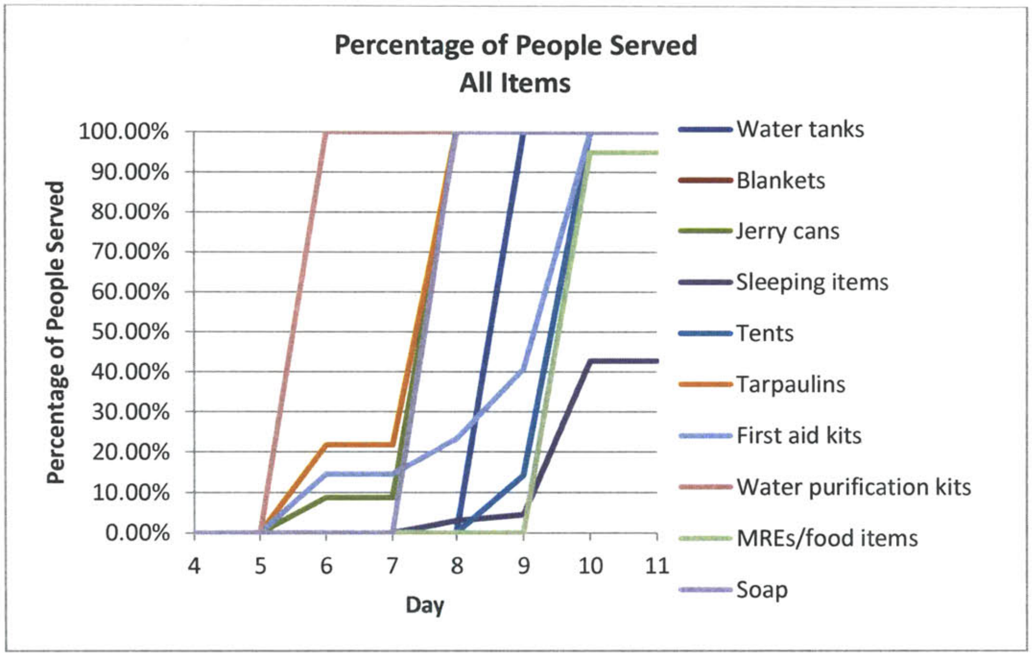

Figure 4-4: All Items Percentage of People Served—Hurricane

These response capacity figures can be used in organizations to aid in making decisions about inventory levels or in decisions about where to preposition inventory. They are useful for helping to determine the adequacy of base stock levels and determining where the rapidity of replenishment times can be improved. For example, the UN HRD may want to evaluate the inventory levels of soap, since it fulfilled less than 50% of the target population need.

4.3 Scenario 2: Flood in Southeast Asia (UN HRD)

The second scenario model uses past data from humanitarian responses to floods in Southeast Asia to map the capacity of the UN HRD to respond to a similar flood in Southeast Asia. As in the hurricane scenario, the event occurs on day 4 and there is only one event per year. The figures show days 1 through 45, because after day 45 the capacity remains the same through the end of the year. The flood model also follows the hurricane model in that it incorporates lead time to the region of the event and replenishment lead times of goods.

The figures that show the inventory capacity of each item that remains to respond to other disasters after the flood response are located in the Appendix. The items are water tanks, blankets, jerry cans, sleeping items, tents, tarpaulins, water purification kits, MREs and food items, and soap. Like the figures in the hurricane model, some of the figures show varying rates of decrease and increase in response capacity due to the positioning of items in the five DCs and the varying replenishment lead times of goods. Notice that more items have a response capacity of 0 at some point. This shows that the UN HRD DCs were depleted before the need request from the assumptions of this model could be fulfilled.

The first aid kits, in Figure 4-5, present an interesting result. Every DC has inventory of first aid kits, unlike some items, but relatively low levels of the kits. The replenishment assumption varies from 8 days to 37 days. The result is that first aid kits are shipped from every DC until the need is entirely allocated, which shows a steadily decreasing capacity, and some kits are replenished quickly, which shows an initial increase in response capacity on day 12.

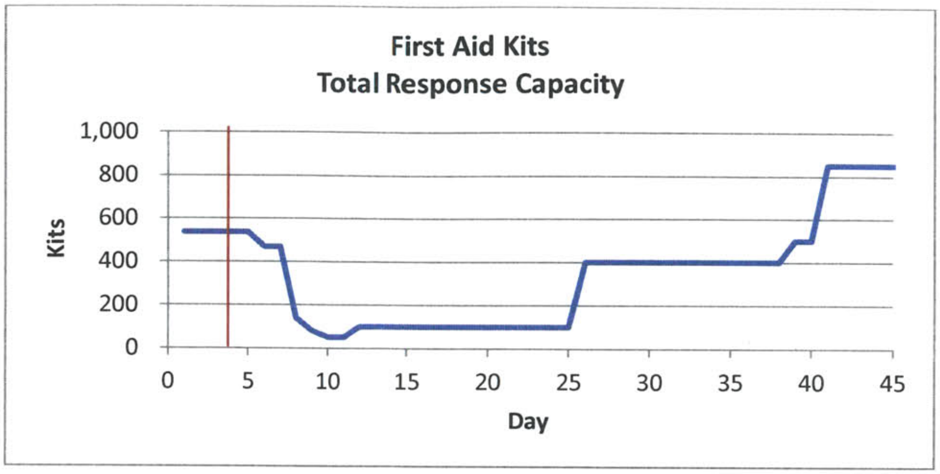

Figure 4-5: First Aid Kits Response Capacity—Flood

Figure 4-6 depicts the number of people served for day 4, the first day of the event response, and day 11, after the last items have shipped. From the figure, we can see that the UN HRD can serve nearly the total target population of people affected for blankets and jerry cans but cannot approach the total number of people affected for the rest of the items.

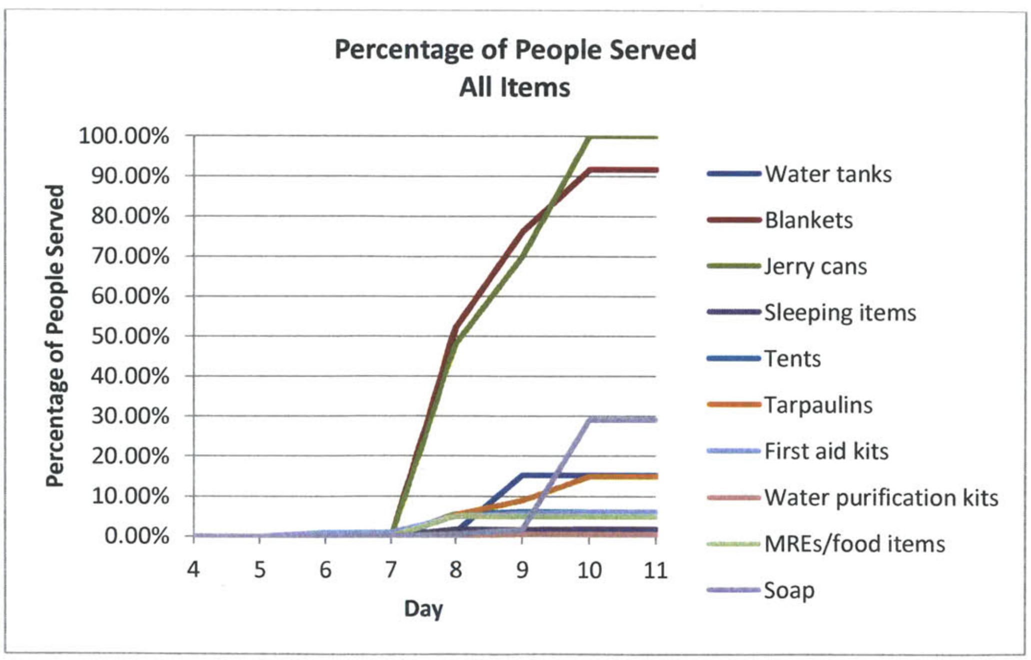

Figure 4-6: All Items Percentage of People Served—Flood

Like the results from the hurricane model, these figures can aid organizations in creating policies for inventory base stock levels, for prepositioning of items in DCs, and for lead time requirements for replenishing items. In this example, the UN HRD would want to evaluate the inventory stocking policies for all of the selected items except blankets and jerry cans.

4.4 Scenario 3: Drought in Northern Africa (UN HRD)

This drought scenario models the first needs requirement notification on day 4. The following figures reflect the capacity to respond to a disaster other than the drought from day 1 through day 45. The initial decrease is due to inventory being allocated to the drought response, and the increases are due to the arrival of the replenishment goods. The model only has one event per year, and the replenishment is complete by day 45. The goods in the figures, located in the Appendix, are as follows: water tanks, blankets, jerry cans, sleeping items, tents, tarpaulins, first aid kits, water purification kits, MREs and food items, and soap.

Figure 4-7 illustrates the number of people served by each items for day 4, the first day of the disaster response, through day 11, after all items have shipped. From the figure, it is clear that, based on the simulation assumptions, the UN HRD only has enough inventory of jerry cans and blankets to serve near the total target population. This result is similar to Figure 4-6 above, but it differs in that the UN HRD is more prepared with water purification kits to respond to a drought than a flood.

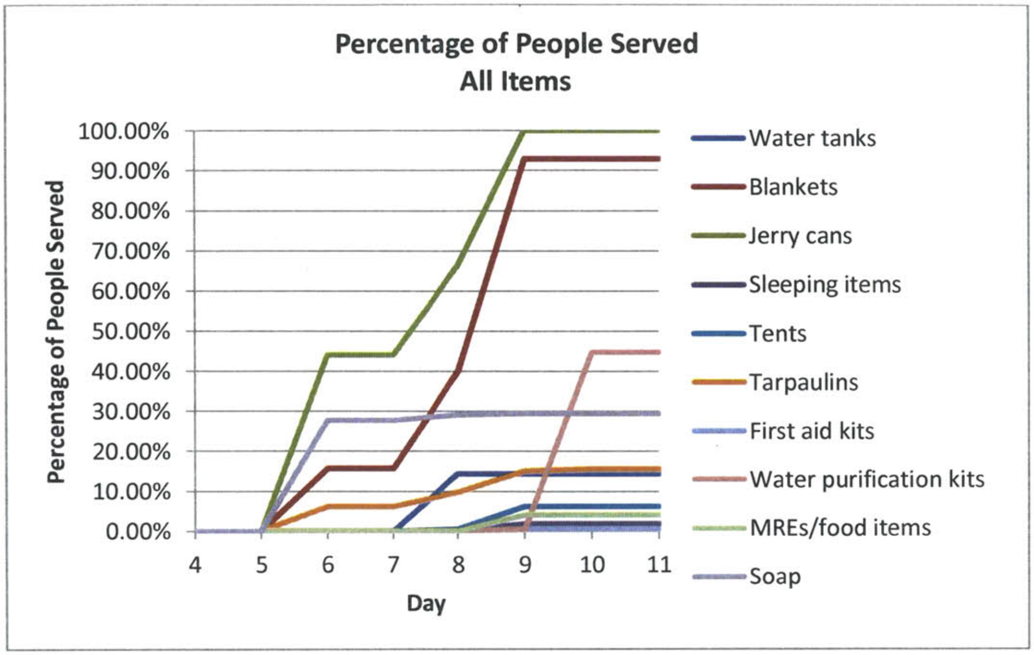

Figure 4-7: All Items Percentage of People Served—Drought

These results have similar uses as the hurricane and flood scenario results: they can aid in determining base stock levels, inventory positioning strategies, and replenishment lead time requirements. Having three scenarios of common disaster events to which the UN HRD responds can help the UN HRD and other international organizations to visually see the impact of the needs of different disasters on their inventory levels and on their capacity to respond to other disaster events. For example, if we use the drought response capacity scenario and if there was another disaster event that occurred on day 20, the UN HRD would most likely not be able to fulfill the needs requests directly of the new disaster event from their DCs. This is because their capacity to respond was decreased by the drought and most replenishment items will have not arrived yet.

4.5 Scenario 4: Hurricane in New York City (NYC OEM)

This scenario differs from the scenarios conducted for the UN HRD in that the NYC OEM only has jurisdiction to respond to the five boroughs of the city of New York: Manhattan, Brooklyn, Queens, The Bronx, and Staten Island. The figures below show NYC OEM's capacity to respond to a disaster in the city from day 1 through day 45. As with the UN HRD scenarios, the response capacity after day 45 remains constant since the model assumes only one event per year and since replenishment is complete by day 45. The following figures and those in the Appendix show the response capacity of each item for an event response beginning on day 4 and ending on day 12. This 7-day event response length follows the procedures established in the Costal Disaster Plan used by NYC OEM.

The NYC OEM model incorporates the inventory levels, the lead time to the distribution and response points, the recoverable inventory items, and the replenishment lead time, which is based on actual supplier contracts. The items chosen for this scenario are as follows: water box, food items, baby formula, hygiene kit, soap, cots, blankets, nursing kits, and face masks. The red lines on the figures represent the beginning of the response at day 4 and the end of the response at day 12. Notice that some of the items are replenished to base stock levels above their current inventory level and some are replenished to base stock levels below their current inventory level.

The first three figures in the Appendix—water boxes, food items, face masks— and the figure below show items that have daily consumption. As a result, the response capacity decreases each day until the end of the supply is reached or until the end of the response is reached.

The next figure, Figure 4-8, shows the use and replenishment of baby formula, which is a daily use item with a replenishment lead time of 7 days. Since the response is 7 days long, beginning on day 4, replenishment is received on day 11. Replenishment is also received on day 18, since baby formula is used through day 12 and the inventory level would be below the base stock level at the end of the response. These factors result in a graph which decreases during the response, increases at day 11, decreases until day 12, and increases again at day 18.

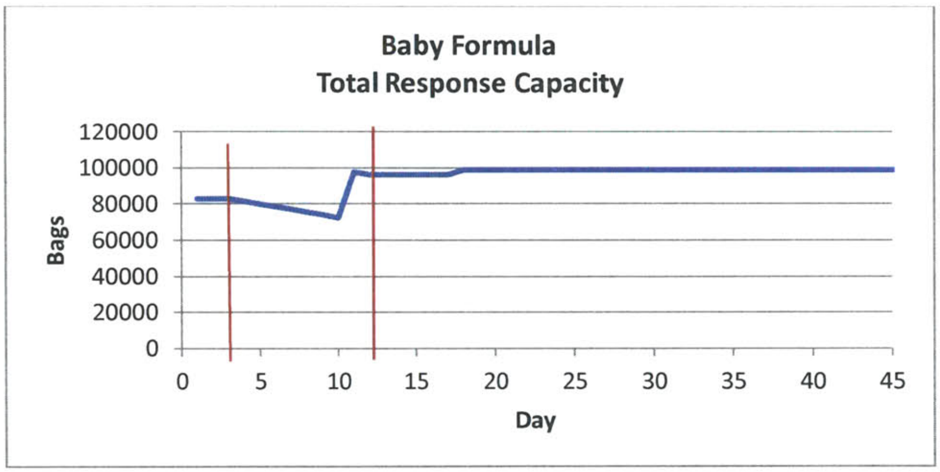

Figure 4-8: Baby Formula Response Capacity—NYC OEM

The figures for the remaining items show items that are once per event responses which result in an initial decrease in response capacity at the beginning of the response and an increase in capacity after the replenishment lead time.

Figure 4-9, which shows the response capacity for soap, has a replenishment lead time of 1 day, since NYC OEM can purchase the liquid soap from the central storehouse of the city. This results in an initial decrease in capacity at the beginning of the response and an immediate increase in capacity the next day.

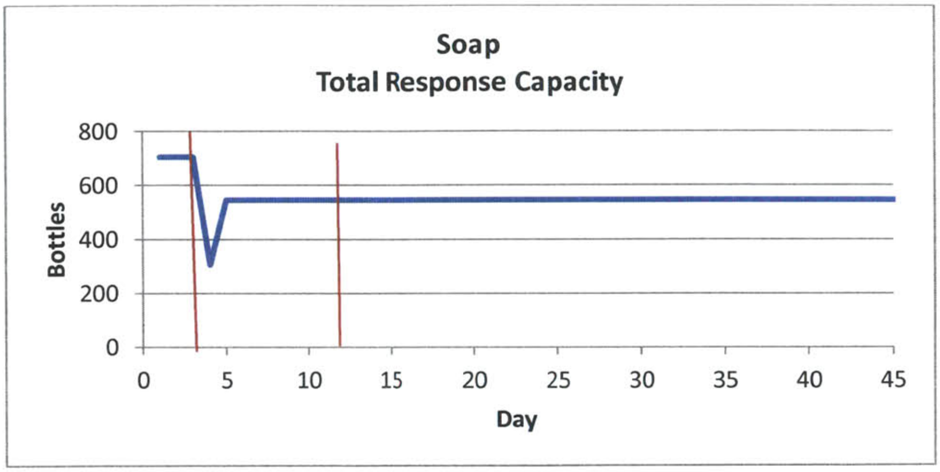

Figure 4-9: Soap Response Capacity—NYC OEM

In the previous scenarios, a figure depicting the percentage of people served would be shown; however, according to the scenario assumptions, the NYC OEM serves 100% of the target population with all items. Instead of the percentage of people served, the next figure, Figure 4-10, shows the percentage of the inventory used to respond to the event for each item. It does not entail replenishment amounts, only beginning inventory data. From this figure, we can easily see that some items reach 100% use, which indicates that the inventory levels were exactly the amount of the need. Other items, such as nursing kits, face masks, and baby formula, reach less than 30% inventory use, which indicates that the NYC OEM had a lot of excess inventory of these items. This information would be crucial in helping the NYC OEM to evaluate the effectiveness of current inventory stocking policies.

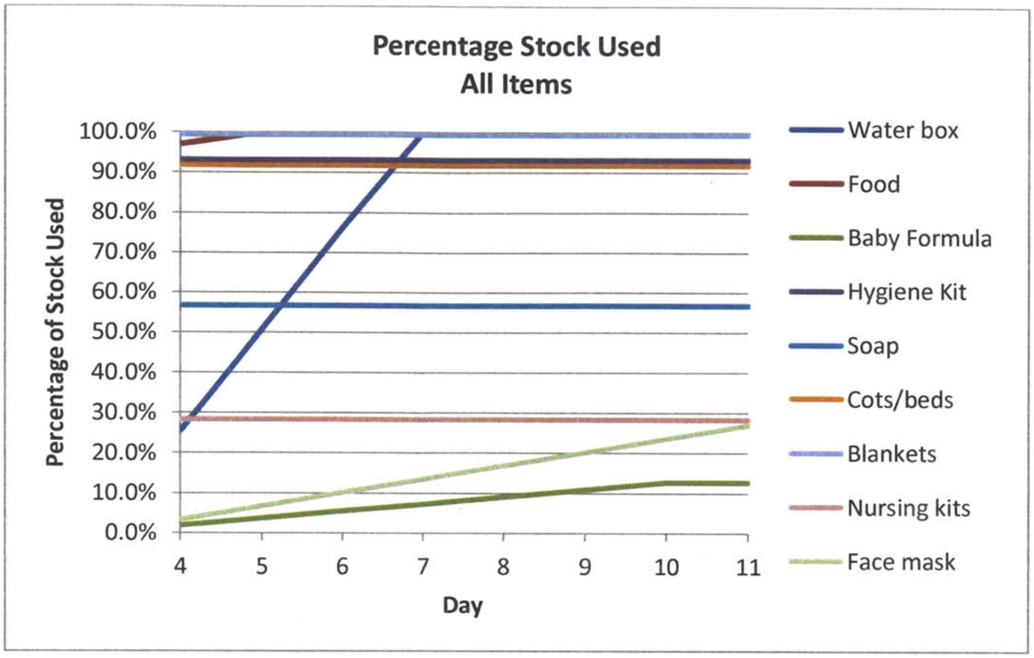

Figure 4-10: All Items Percentage Stock Used—NYC OEM

These results can help the NYC OEM to determine the adequacy of current inventory policies and aid in reevaluating base stock levels. These figures provide a simulated method of determining the response capacity of key goods, which can help determine inventory levels needed, which can increase the number of beneficiaries and decrease the number of lives lost during a disaster event.

4.6 Supplier Capacity Additions

In order to measure the capacity of the entire supply chain of NYC OEM to respond to a disaster, the manufacturing and distribution capacities of the suppliers of the NYC OEM must be added. By adding the suppliers' capacity, we can measure not only the supplies that NYC OEM has to respond but also the supplies that their suppliers can contribute, either through NYC OEM procuring the inventory or through the supplier donating the inventory. Additional supplier contributions may come from the supplier's inventory stockpile in their own warehouses, from the supplier increasing manufacturing while still manufacturing the demands of other customers, or from the supplier increasing manufacturing in order to provide all the manufactured goods to NYC OEM. Obtaining this level of information requires cooperation from suppliers to divulge detailed information, which we have been unable to procure during this research. We were able to integrate the supplier lead time that are contracted with the NYC OEM, which are included in the NYC OEM disaster scenario in the previous section. However, adding the suppliers' capacity is essential to understanding the full capacity an organization to respond to a disaster and should be pursued in future research.

5 Conclusion

This thesis establishes a framework for further development into a humanitarian capacity response index, and it provides information to organizations about their inventory capacity to respond to various disasters. In this thesis, we have identified three immediate contributions to organizations: 1) to aid in developing better policies for inventory base stock levels, 2) to aid in determining adequate replenishment lead times to negotiate with suppliers, and 3) to aid in determining the effectiveness of current inventory positioning across DCs.

The humanitarian response sector has recently been focusing on the role and importance of logistics in providing aid to people affected by disaster events, and the results of this thesis can further research into humanitarian logistics by providing ways to analyze the ability and inventory quantity of organizations to respond to the needs of a disaster event. Through this analysis, organizations can save money through reducing excess inventory and save lives through increasing key inventory items.

The basis for the analysis of the inventory quantities can be found in the four scenarios presented in this research: a hurricane in the Caribbean, a flood in Southeast Asia, a drought in Northern Africa, and a hurricane in New York City. The hurricane in the Caribbean showed that, based on the assumptions of the scenario model, the UN HRD was able to provide for almost 100% of the target population of people affected. The flood and drought models showed a more severe response capacity reduction, with almost all of the items remaining under 50% fulfillment of the need. This information can be useful to the UN HRD or similar organizations, for reconsidering the base stock levels or replenishment lead times of the key items examined in these scenarios.

The scenario model for the hurricane in New York City showed that they can respond to 100% of the need for all items. It also showed that for some items, 100% of the inventory is used and for other items, less than 30% of the inventory is used. This information can be useful to the NYC OEM or similar organizations for reevaluating the inventory base stock levels, for prompting a deeper exploration of the capacity of suppliers in the region, or for reexamining the replenishment lead times in the contracts with suppliers.

The models also showed the effect of a quick replenishment lead time in aiding the response efforts. Quantities of baby formula, which has a replenishment time of 7 days, were steadily depleting each day of the response but received a replenishment shipment during the disaster response which caused an increase in the response capacity during the response. If the same results were replicated with other items, the items could be immediately deployed if needed and could save the lives of the people receiving the goods.

Overall, the scenario models found that some inventory items cannot fulfill the needs requested in the simulated disaster events, that some current inventory quantities are higher than the base inventory quantities, and that other inventory quantities are currently much lower than the base inventory quantities. These results can be useful in the humanitarian sector to aid organizations in supply chain planning.

5.1 Further Research

This thesis serves a framework for further work which will expand this research on humanitarian response capacity to include other important aspects, such as cost of transportation and the manufacturing and distribution capacity of suppliers. The current simulation models include three aspects of the total capacity measurement: stock levels, response time, and replenishment time. However in order to get a full picture of the capacity to respond, the cost of transportation and the capacity of suppliers must be added to the simulation models.

Incorporating this next step of cost into the system will allow organizations to evaluate decisions regarding from where to send goods after a disaster event and the transportation method of sending those goods. The next model will give a full view of time, cost, and quantity, which can aid organizations in determining how to respond to a disaster in a way that optimizes efficient use of donor funds, quick response time when needed, and maximum amount of people served.

Another aspect to include in further research is the capacity of the suppliers of humanitarian organizations to respond to a disaster. NYC OEM currently has contracts with suppliers to provide goods on call and has connections to people in the Defense Logistics Agency (DLA), who can provide extra response capacity to NYC OEM during a disaster. The goal of adding the supplier capacity to the NYC OEM capacity is to capture the full capacity of the entire supply chain to respond to the disaster.

Once a cost aspect and a supplier capacity aspect are added to the model, more organizations can be measured using their inventory stock levels, supplier contracts, and transportation cost information. After a to-be-determined adequate number of organizations are measured with the model, an aggregate index should be formed to create an easy way to compare the response strategies of different organizations.

As focus on humanitarian logistics increases, an index created with the research in this thesis will become more useful in aiding decisions about inventory stockpiling and response methods. Using an index to compare response strategies of organizations can lead to better response decisions and, ultimately, more lives saved through faster shipment of essential goods.

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Appendix

Hurricane Response Capacity Graphs by Item

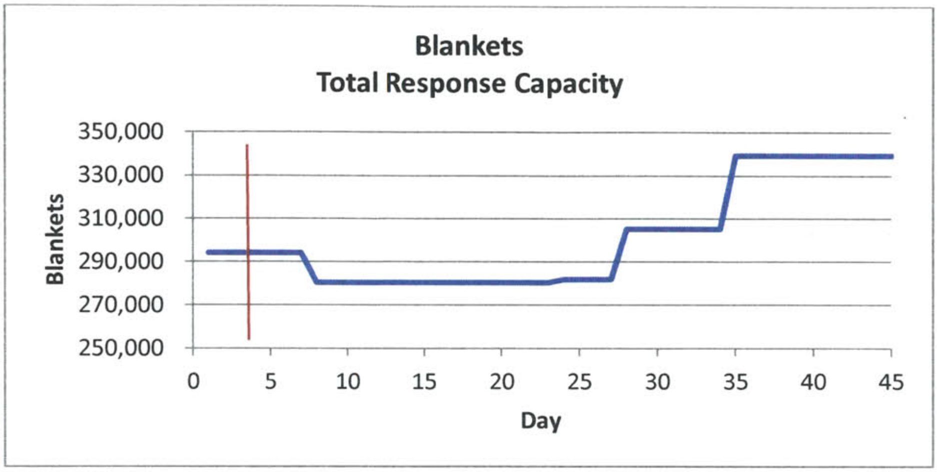

Figure 4-11: Blanket Response Capacity—Hurricane

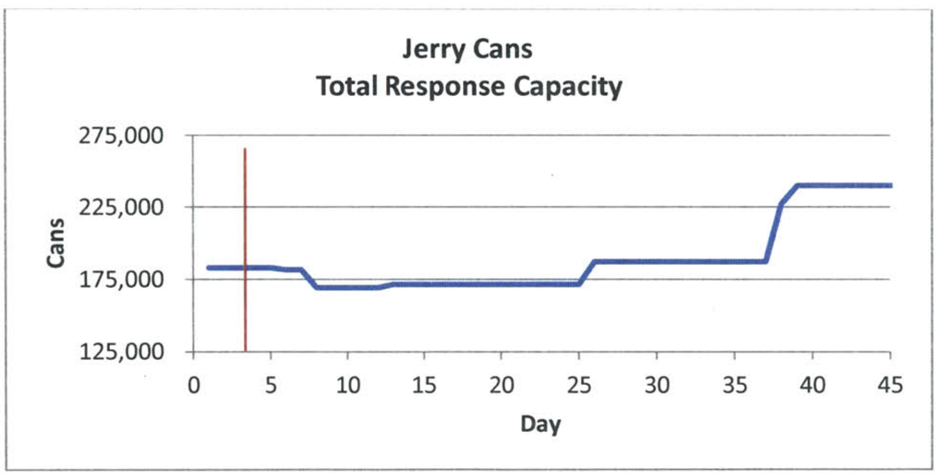

Figure 4-12: Jerry Can Response Capacity—Hurricane

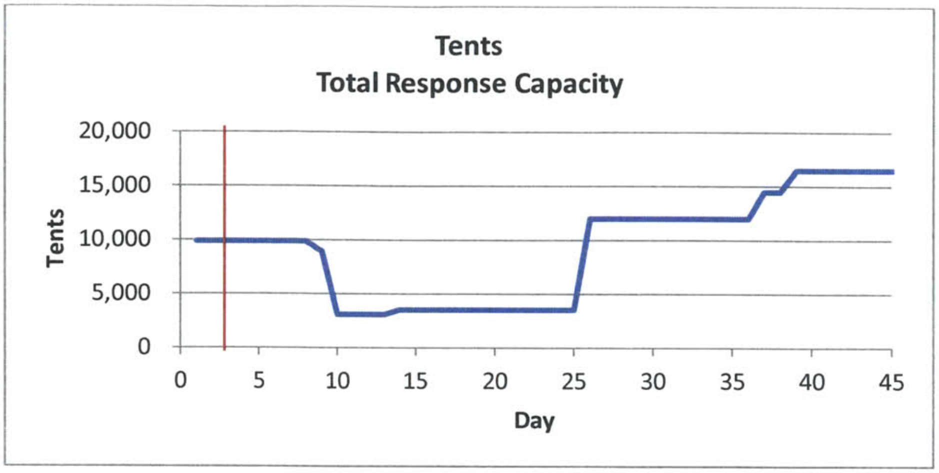

Figure 4-13: Tents Response Capacity—Hurricane

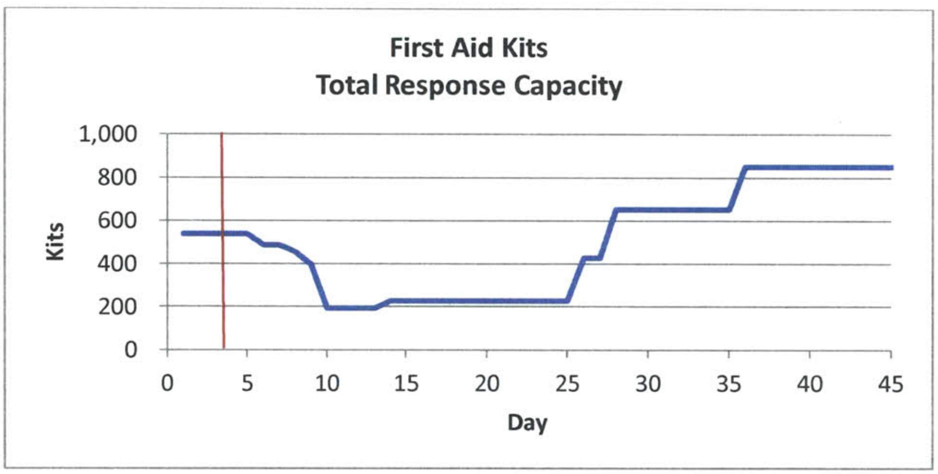

Figure 4-14: First Aid Kits Response Capacity—Hurricane

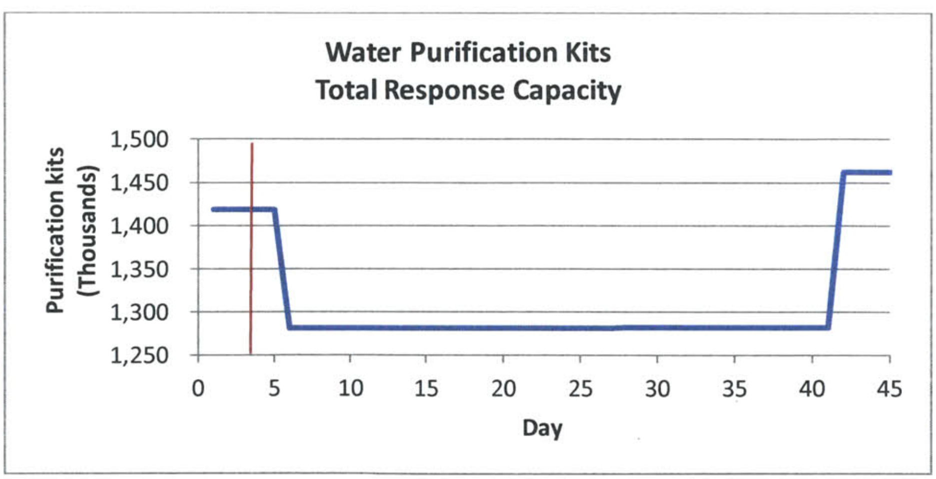

Figure 4-15: Water Purification Kits Response Capacity—Hurricane

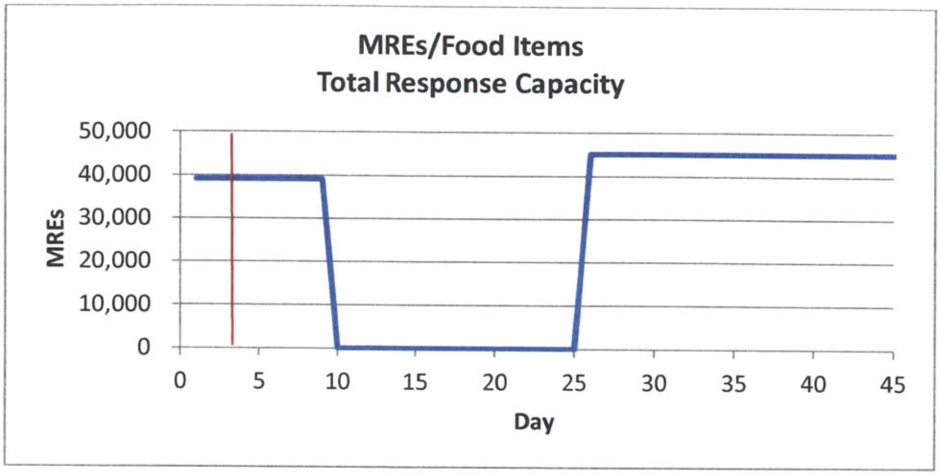

Figure 4-16: MREs/Food Items Response Capacity—Hurricane

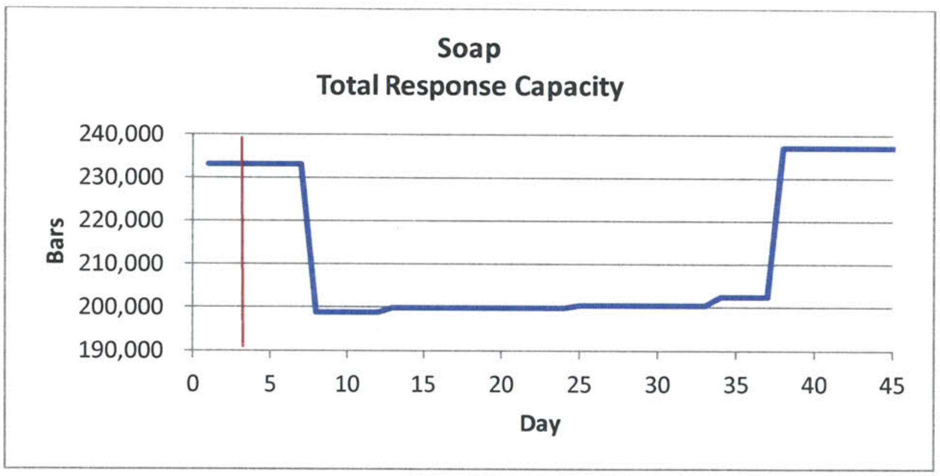

Figure 4-17: Soap Response Capacity—Hurricane

Flood Response Capacity Graphs by Item

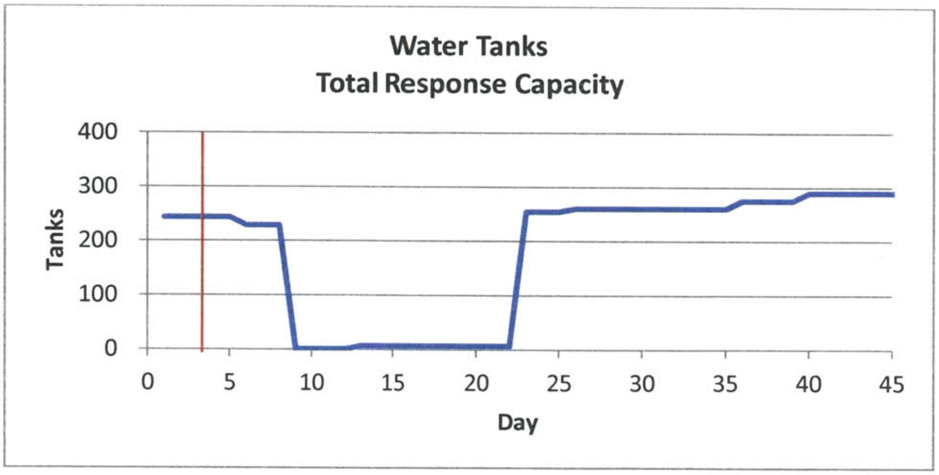

Figure 4-18: Water Tanks Response Capacity—Flood

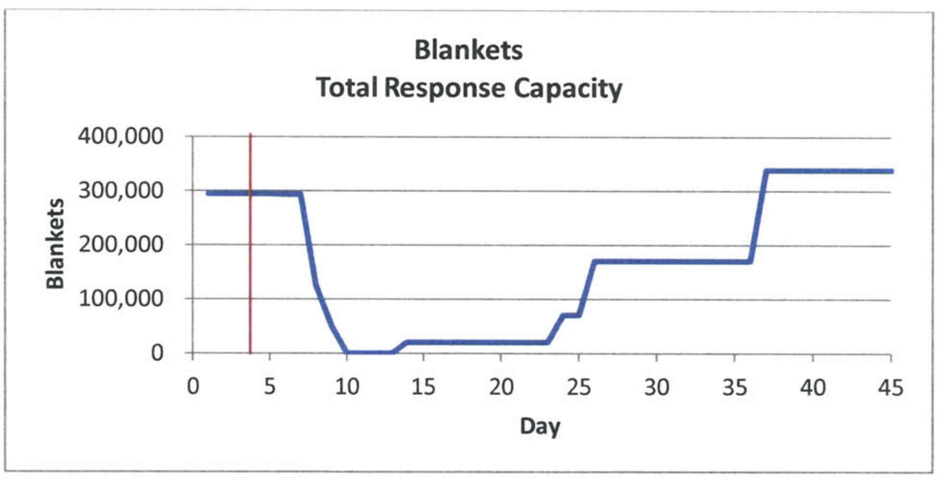

Figure 4-19: Blankets Response Capacity—Flood

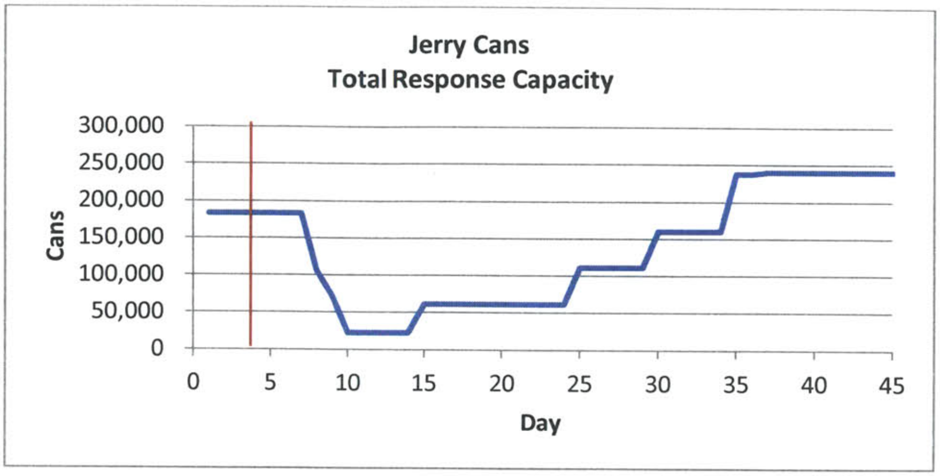

Figure 4-20: Jerry Cans Response Capacity—Flood

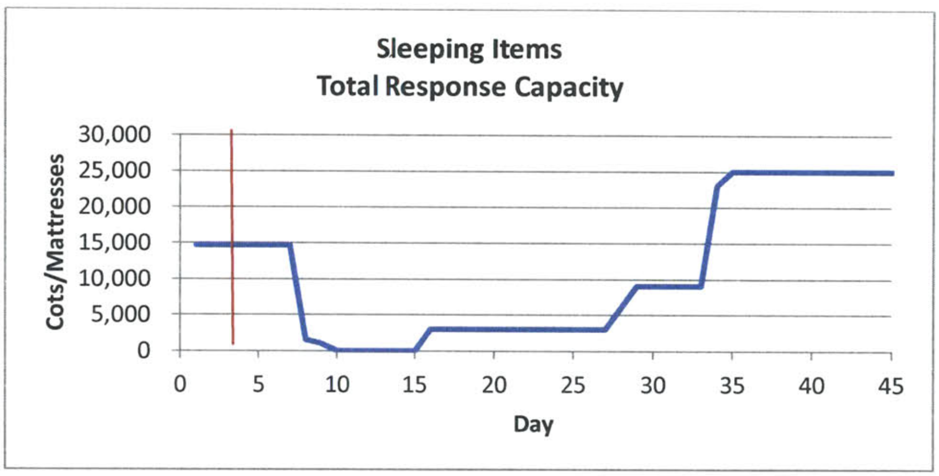

Figure 4-21: Sleeping Items Response Capacity—Flood

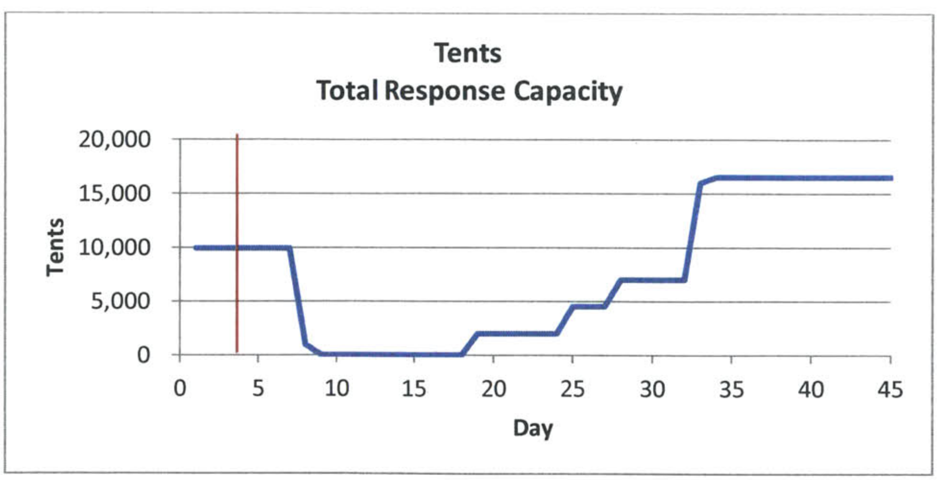

Figure 4-22: Tents Response Capacity—Flood

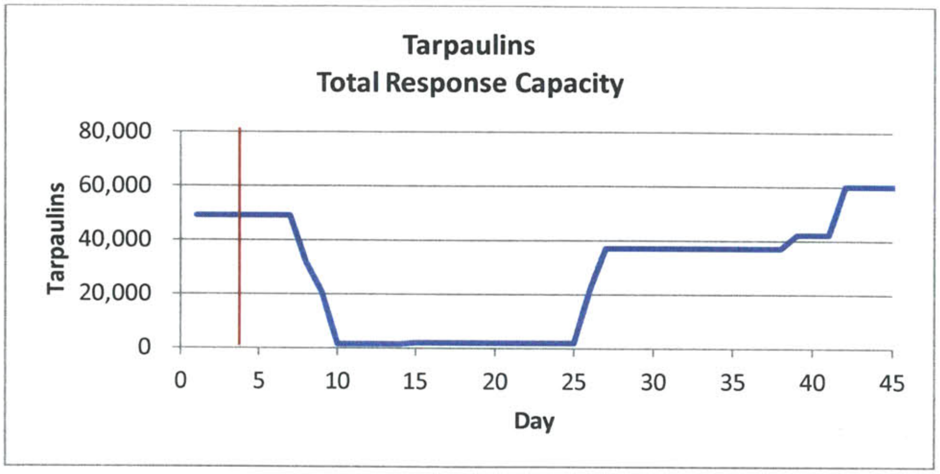

Figure 4-23: Tarpaulins Response Capacity—Flood

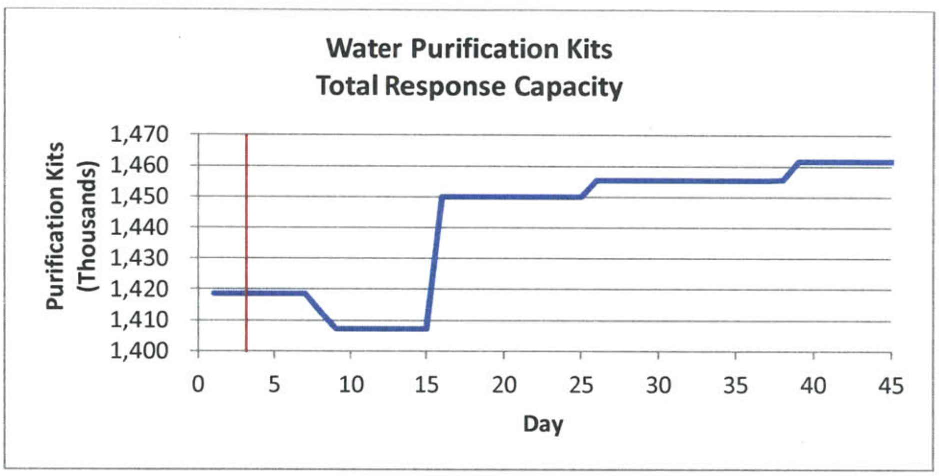

Figure 4-24: Water Purification Kits Response Capacity—Flood

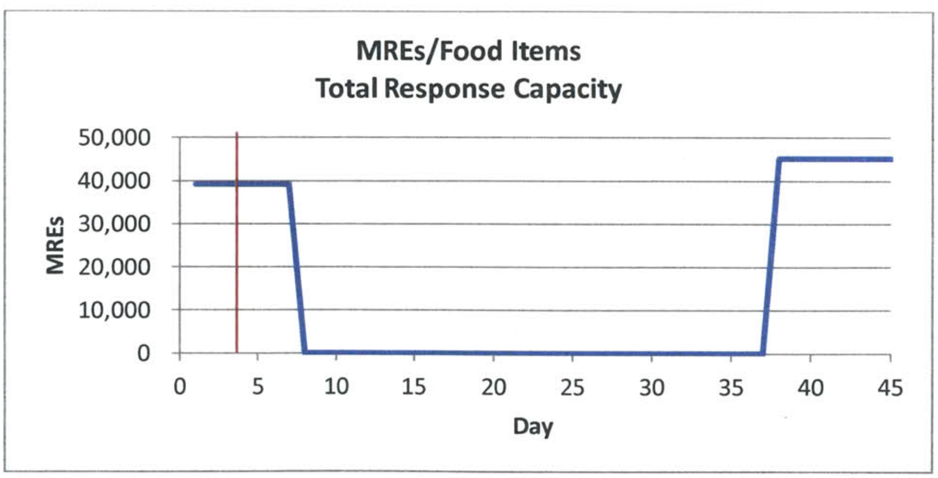

Figure 4-25: MREs/Food Items Response Capacity—Flood

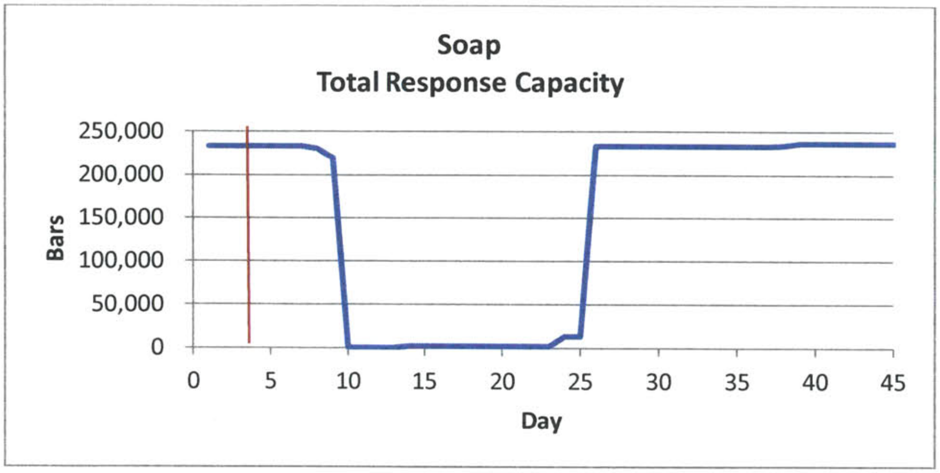

Figure 4-26: Soap Response Capacity—Flood

Drought Response Capacity Graphs by Item

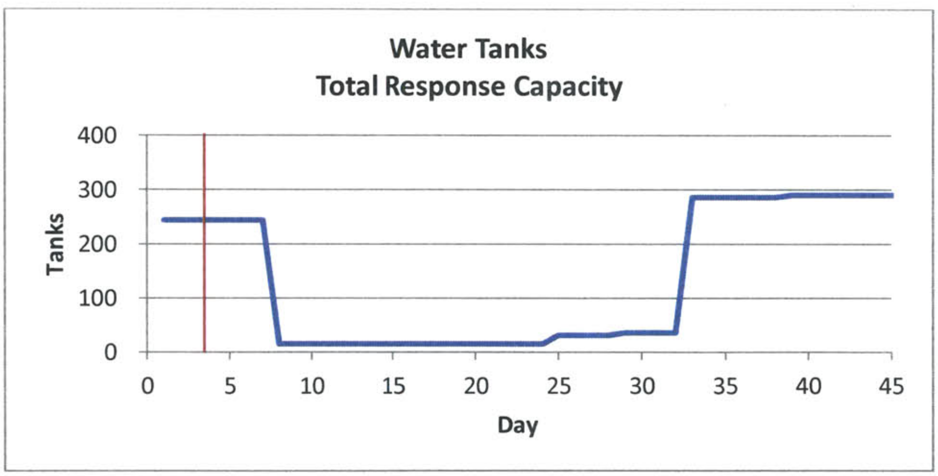

Figure 4-27: Water Tanks Response Capacity—Drought

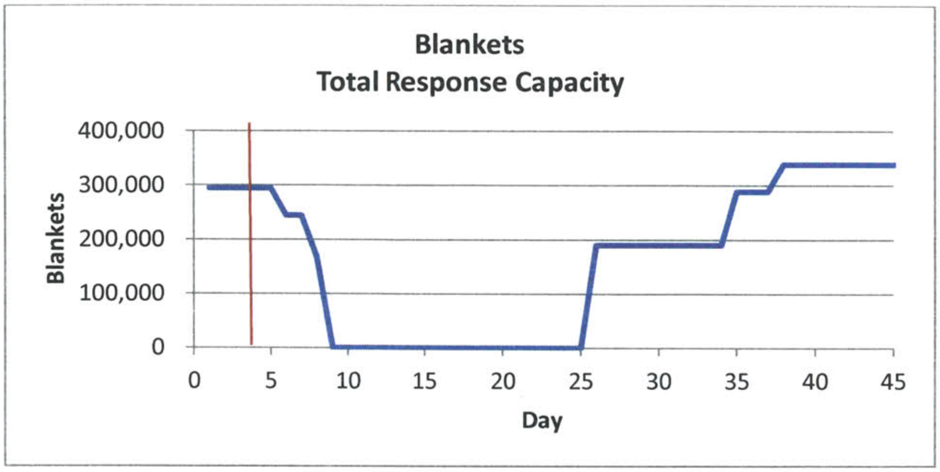

Figure 4-28: Blankets Response Capacity—Drought

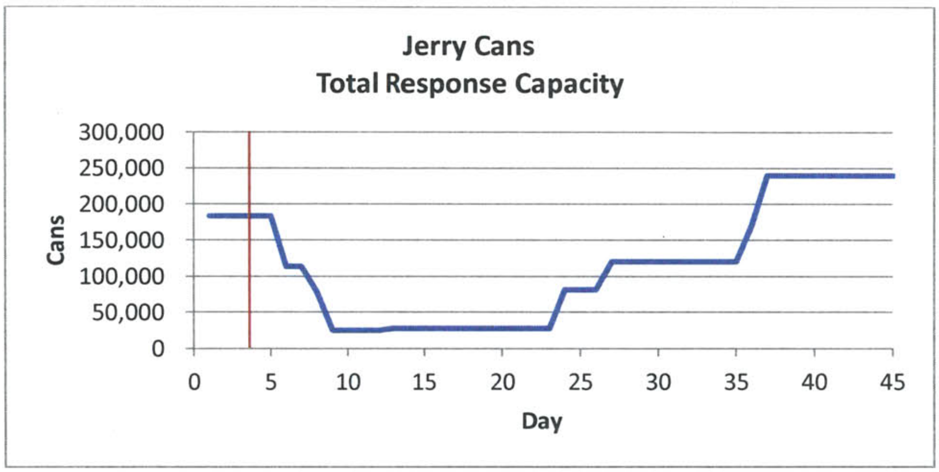

Figure 4-29: Jerry Cans Response Capacity—Drought

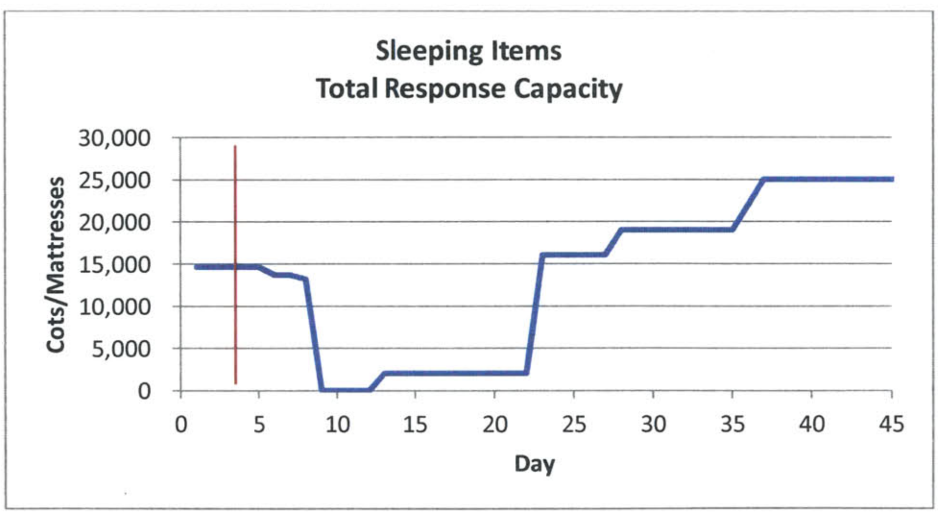

Figure 4-30: Sleeping Items Response Capacity—Drought

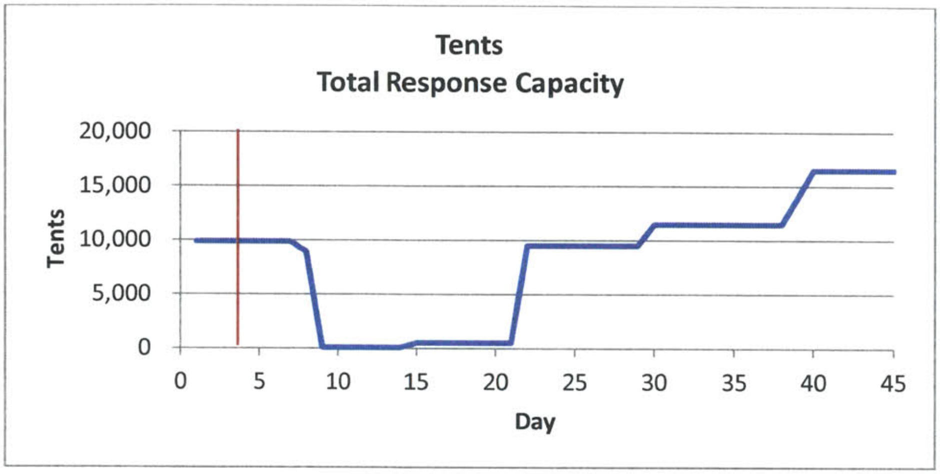

Figure 4-31: Tents Response Capacity—Drought

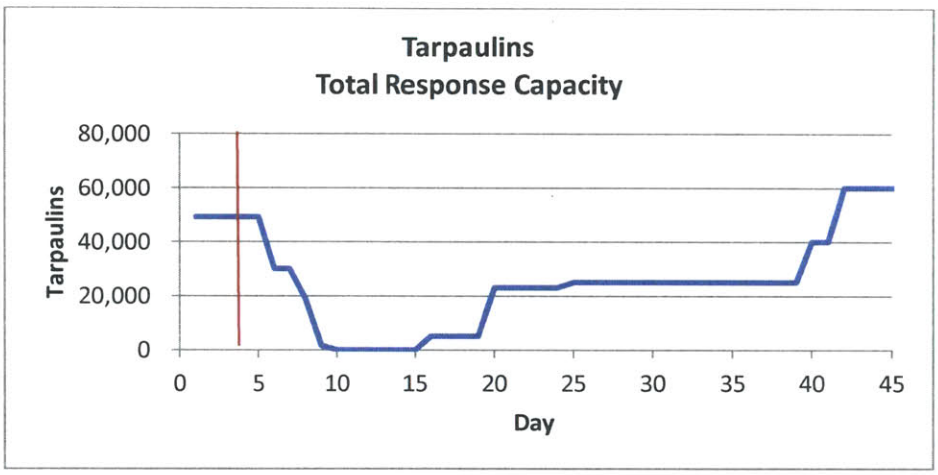

Figure 4-32: Tarpaulins Response Capacity—Drought

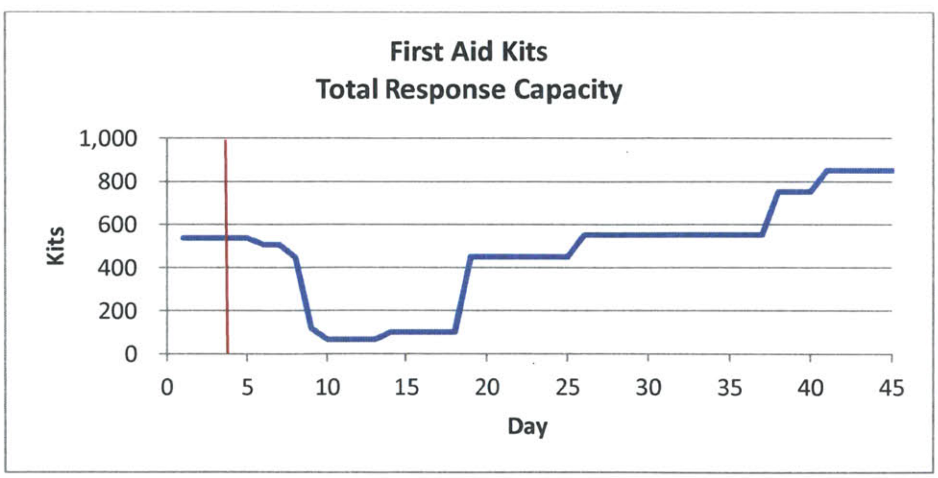

Figure 4-33: First Aid Kits Response Capacity—Drought

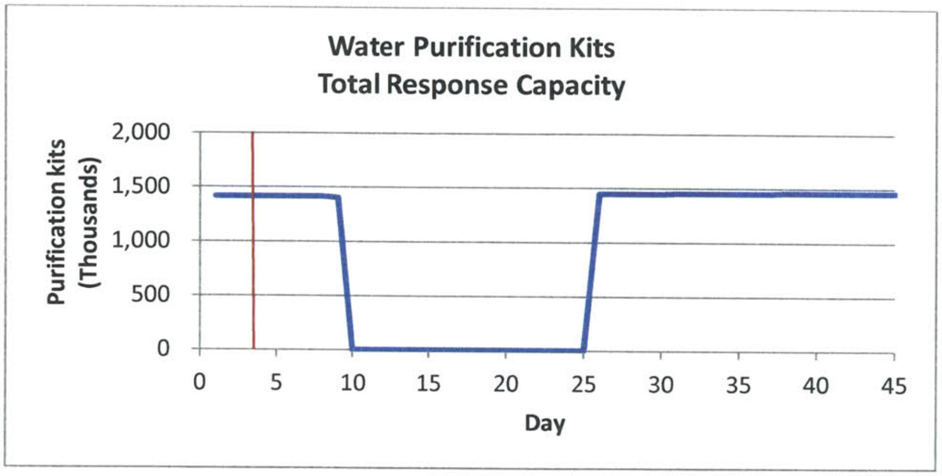

Figure 4-34: Water Purification Kits Response Capacity—Drought

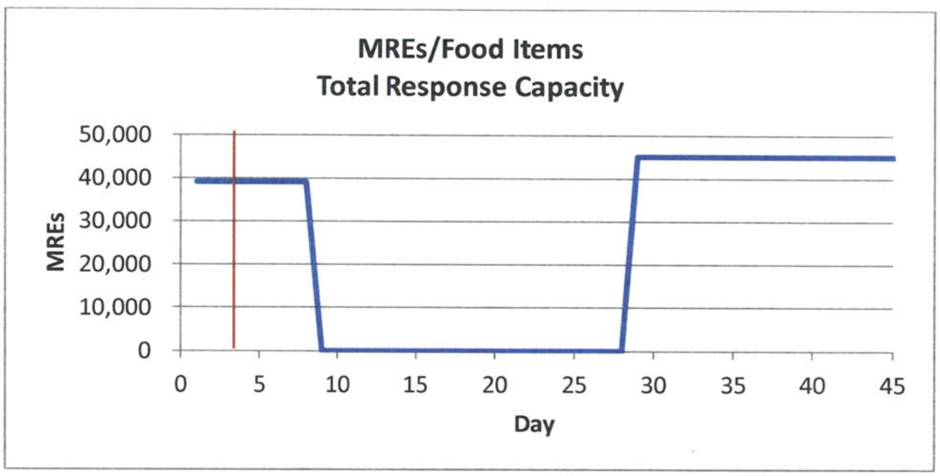

Figure 4-35: MREs/Food Items Response Capacity—Drought

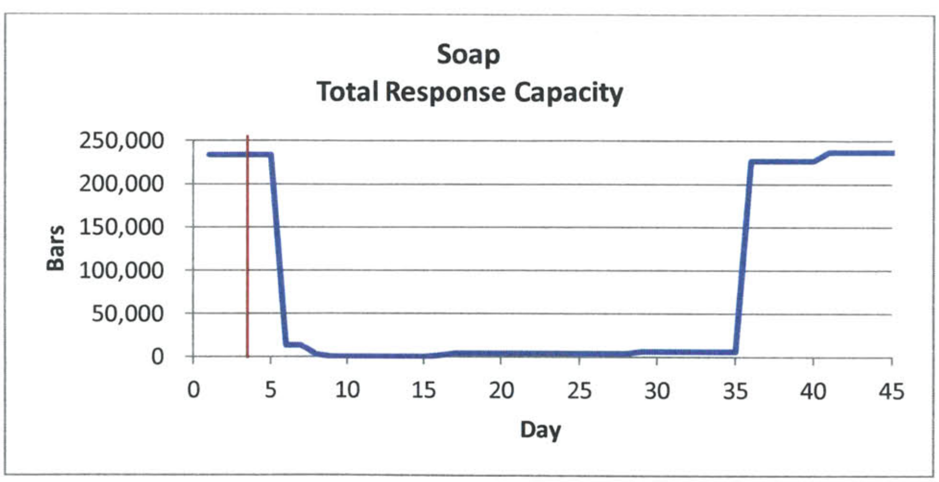

Figure 4-36: Soap Response Capacity—Drought

NYC OEM Response Capacity Graphs by Item

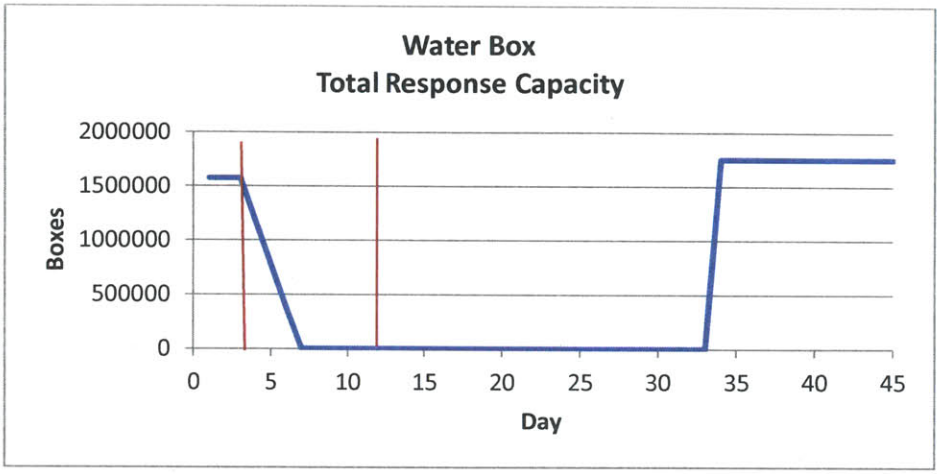

Figure 4-37: Water Box Response Capacity—NYC OEM

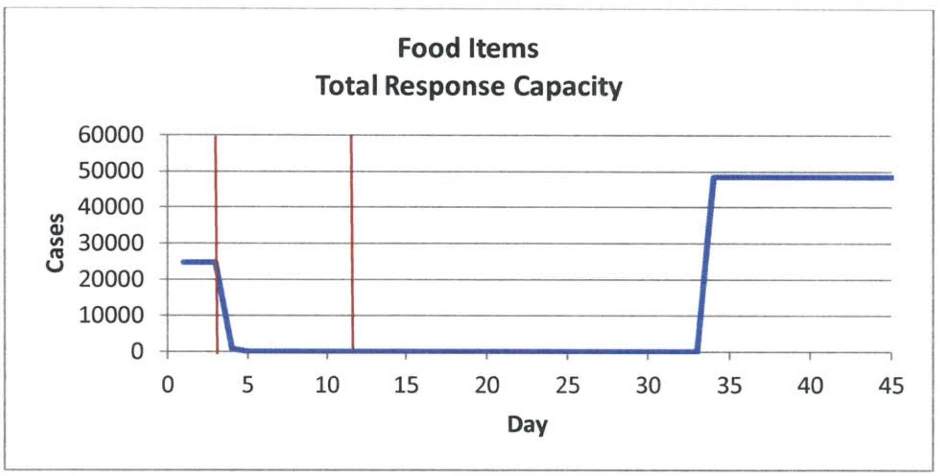

Figure 4-38: Food Items Response Capacity—NYC OEM

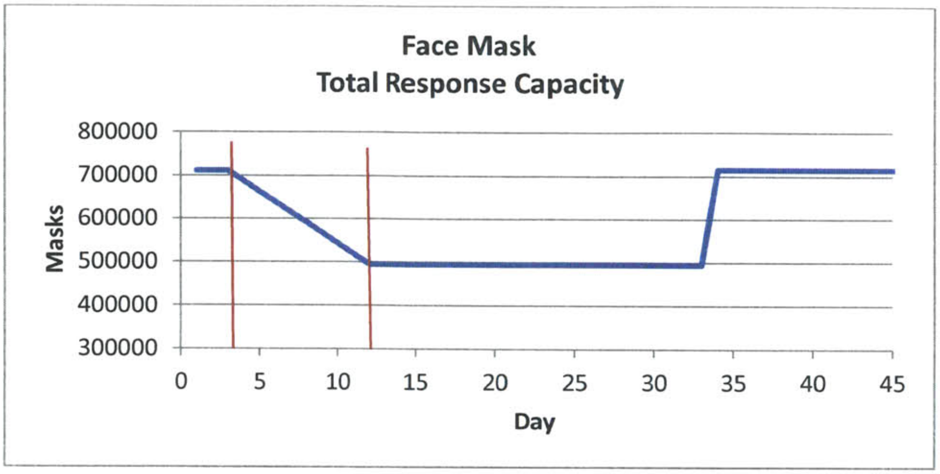

Figure 4-39: Face Mask Response Capacity—NYC OEM

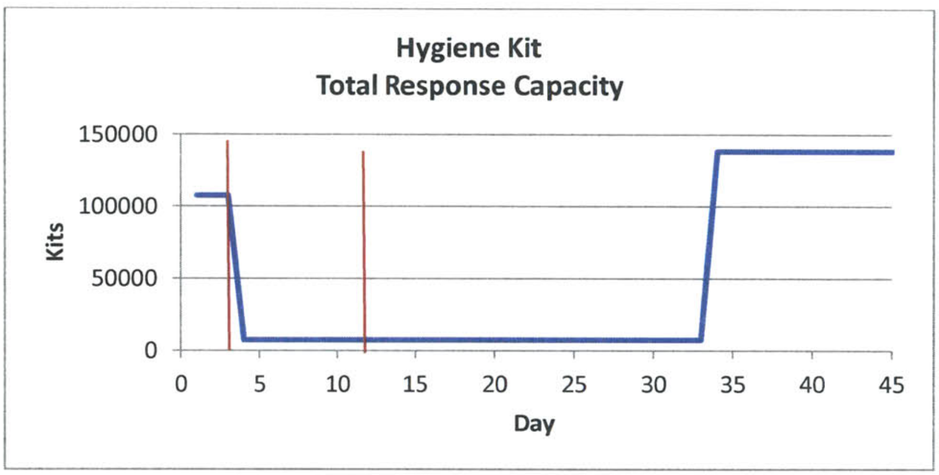

Figure 4-40: Hygiene Kit Response Capacity—NYC OEM

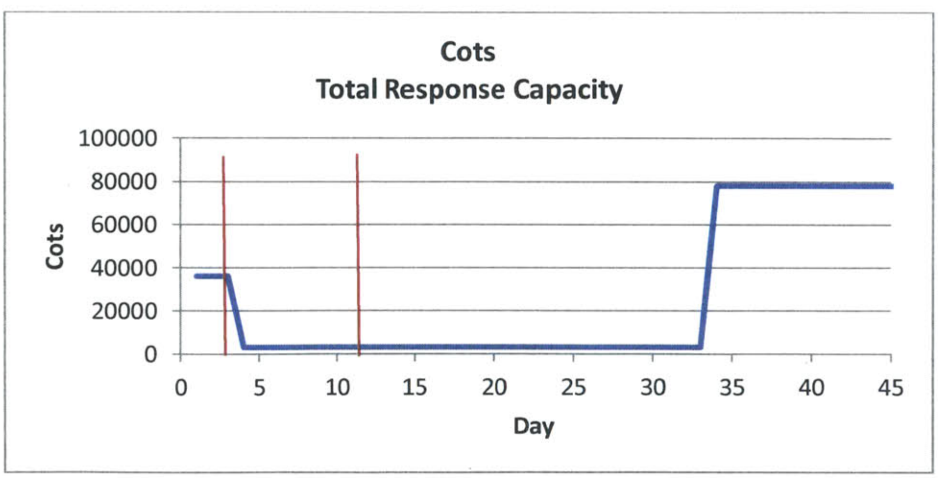

Figure 4-41: Cots Response Capacity—NYC OEM

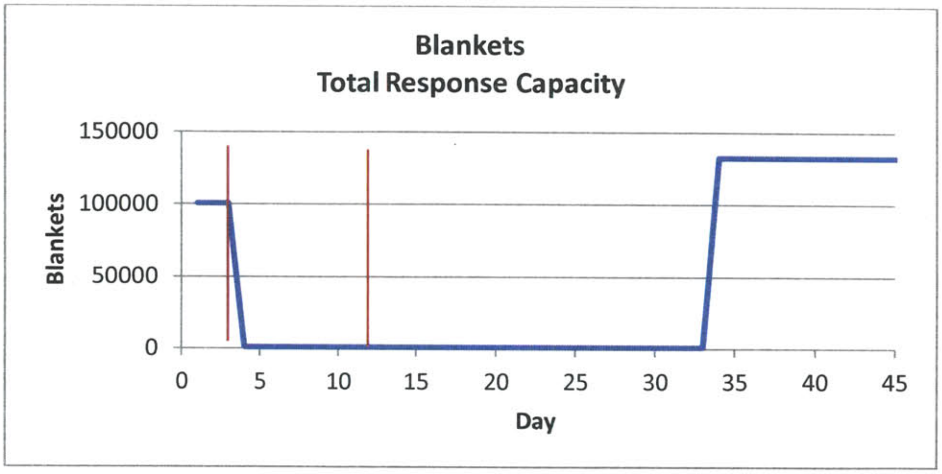

Figure 4-42: Blankets Response Capacity—NYC OEM

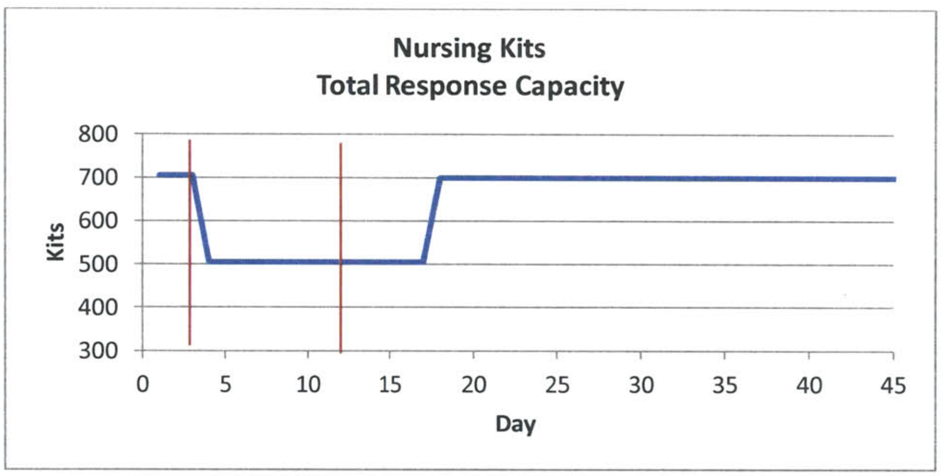

Figure 4-43: Nursing Kits Response Capacity—NYC OEM