NPS-LM-14-180

ACQUISITION RESEARCH PROGRAM
SPONSORED REPORT SERIES

Optimizing Resources of United States Navy for Humanitarian Operations

26 August 2014

Dr. Aruna Apte, Associate Professor

Dr. Keenan Yoho, Assistant Professor

Graduate School of Business & Public Policy

Naval Postgraduate School

The research presented in this report was supported by the Acquisition Research Program of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

Abstract

The United States Navy (USN) can rapidly respond to disasters due to high levels of readiness that are maintained on a constant basis The USN's unique capabilities allow the Department of Defense (DoD) to engage in global humanitarian operations. We study optimization of the USN's assets based on the existing work that analyzes USN disaster relief operations. In light of budget cuts, the realignment of forces, and the restructuring of the services, there is need for research identifying specific naval assets and their utility for conducting humanitarian operations. Our research is another step in that direction.

Keywords: USN, humanitarian assistance, disaster relief

THIS PAGE INTENTIONALLY LEFT BLANK

About the Authors

Dr. Aruna Apte is an associate professor in the Operations and Logistics Management Department of the Graduate School of Business and Public Policy at the Naval Postgraduate School in Monterey, CA. Her research interests are in the areas of developing mathematical models and algorithms for complex, real-world operational problems using techniques of optimization.

Dr. Aruna Apte
Tel: (831) 656-7583
E-mail: auapte@nps.edu

Dr. Keenan Yoho's primary research activities are in the area of analysis of alternatives for capital purchases under conditions of resource scarcity, supply chain management, risk analysis, humanitarian assistance and disaster response, and resource management in environments that exhibit high degrees of uncertainty. Prior to joining the Naval Postgraduate School, Yoho was an operations researcher and principal investigator with The RAND Corporation, where he led studies for the Army, Air Force, and TRANSCOM to improve the effectiveness of logistics, acquisition, and sustainment operations and to develop policy guidance for supply chain operations. Yoho has several years of experience teaching and developing master's students and executives in the U.S. and Europe in principles of supply chain management and manufacturing operations. He has served as an intelligence analyst for the U.S. Customs Service in the area of international money laundering and has worked large litigation cases representing Lloyd's of London in insurance defense. He was the National Research Coordinator for Manufacturing Skills Standards as part of an initiative funded by the United States Congress to develop national skill standards for the U.S. industrial manufacturing economic sector. He has advised U.S. and European firms for several years in the petrochemical, semiconductor, paper and pulp products, and steel industries, focusing on enabling corporate strategy by using the supply chain as a competitive weapon. Yoho holds a PhD in operations management, an MBA in operations and information management, and an MS in industrial relations from the University of Wisconsin-Madison. He also holds a BA in religion with a concentration in Chinese and Japanese Buddhism from Temple University.

Dr. Keenan D. Yoho
Tel: (831) 656-2029
E-mail: kdyoho@nps.edu

THIS PAGE INTENTIONALLY LEFT BLANK

NPS-LM-14-180

ACQUISITION RESEARCH PROGRAM
SPONSORED REPORT SERIES

Optimizing Resources of United States Navy for Humanitarian Operations

26 August 2014

Dr. Aruna Apte, Associate Professor

Dr. Keenan Yoho, Assistant Professor

Graduate School of Business & Public Policy

Naval Postgraduate School

THIS PAGE INTENTIONALLY LEFT BLANK

Table of Contents

THIS PAGE INTENTIONALLY LEFT BLANK

List of Figures

THIS PAGE INTENTIONALLY LEFT BLANK

List of Tables

THIS PAGE INTENTIONALLY LEFT BLANK

Optimizing Resources of United States Navy for Humanitarian Operations

Introduction

The goal of the organizations that provide humanitarian assistance and disaster relief is to reduce suffering and fatalities. Estimating the quantity and type of demand is difficult, but what is even more difficult is assessing .where and when the relief is needed (Apte, 2009). However, providing relief depends on the speed of the response, and matching the supply with the need assessed (Apte, 2014). This is often a function of the capabilities and competencies of the organizations (Apte & Yoho, 2011a).

The maritime strategy outlined in the Cooperative Strategy for 21st Century Seapower states that the USN will focus on partnerships with all the key players in Humanitarian Assistance and Disaster Relief (HADR) to safeguard United States'interests. The USN has made significant contributions toward HADR. Though this is possible due to the USN's many unique and critical capabilities, in the past, not all of the USN's efforts have been as efficient and effective as they could have been.

There is plenty of evidence that proves the USN's willingness to provide assets in disaster relief efforts. However, there has always been a need to perform HADR smartly and economically. It will be even more important in the future when budget reductions and uncertainty are likely to be the norm. Therefore, given the substantial costs incurred, the important question is whether the USN deploys or diverts the *right* ships for HADR. The experience off the coast of Bangladesh suggests that sometimes, it does not (Apte, Yoho, Greenfield, & Ingram, 2013). This research develops a mathematical model to optimize the deployment of USN assets during HADR operations (Apte et al., 2013).

U.S. forces have been diverted from original missions 366 times for humanitarian assistance as opposed to 22 times for combat from 1979 to 2000, according to the fact sheets of United States Agency for International Development (USAID) and Center for Naval Analysis, as shown in Figure 1. If the ships sent are not capable of handling the humanitarian operations, the quick deployment of such ships does not serve the objective of delivering relief. For this purpose, it is necessary that we understand which vessels contribute what capability for HADR.

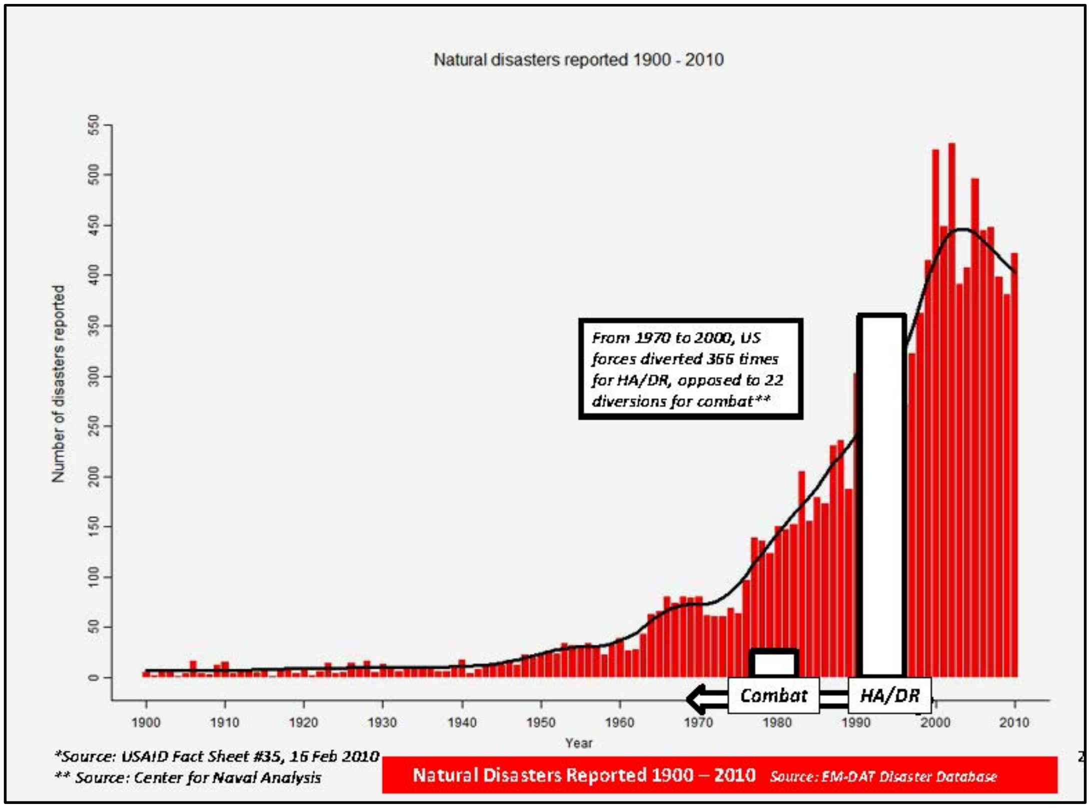

Figure 1. USN Ships Diverted for Humanitarian Operations

The vessels that the USN deployed for HADR in the 2004 Indian Ocean tsunami were the entire Abraham Lincoln Carrier Strike Group (CSG), which included two fast attack submarines (SSN) and two Flight I DDGs. During the response efforts following Hurricane Katrina, the USN sent nine Minesweepers. In 2007, in order to help Bangladesh with the Category 5 cyclone, Sidr, the ship that was diverted to help was the USS *Hopper* (DDG 70). Based on platform capabilities (Apte et al., 2013), some of these vessels did not play a substantial role in the relief process, yet they were tasked with these missions without accounting for their existing capabilities.

Apte et al. (2013) investigated and identified the capabilities of USN vessels deployed to meet the HADR mission requests. The different platforms of the ship classes were studied and their HADR-related characteristics analyzed to find the relative utility of each vessel type using ordinally scaled expert ratings. The experts were USN surface warfare officers. We studied every ship that was deployed to respond to certain disasters. Apte et al. (2013) studied the 2004 Indian Ocean tsunami, the 2005 Hurricane Katrina, and the 2010 Haiti earthquake (National Geographic, 2005; National Geophysical Data Center [NGDC], 2011; VanRooyen & Leaning, 2005; Congressional Research Service [CRS], 2005; Louisiana Department of Health and Hospitals [LDHH], 2006; National Oceanic Atmospheric

Administration [NOAA] Public Affairs, 2007; Plyer, 2013; Wooldridge, 2010). In addition, the 2011 earthquake and tsunami in Japan also prompted significant support from the USN (Kaczur, Aurelio, & Joloya, 2012).

Disaster	Number of vessels deployed	Number of days of assistance provided
2004 Indian Ocean Tsunami	29	81
2005 Hurricane Katrina	34	42
2010 Haiti Earthquake	31	72
2011 Japan Earthquake/Tsunami	22	32

Table 1. Response from USN
(Greenfield & Ingram, 2011; Kaczur et al., 2012)

Table 1 shows the response from the USN in the disasters, Indian Ocean tsunami of 2004, Hurricane Katrina in 2005, Haiti earthquake in 2010, and Japan earthquake and tsunami in 2011. Table 2 shows the categories of the ships sent. The ship platforms referred to in this research are those that have been deployed or diverted for HADR in the past. Their descriptions are given in Appendix A.

Category	2004 Indian Ocean Tsunami	2005 Hurricane Katrina	2010 Haiti Earthquake	2011 Japan Earthquake/Tsunami
CG/DDG/FFG	6	0	4	11
LPD/LSD	3	3	5	15
LHA/LHD	2	2	3	6
CV/CVN	1	2	1	0
T-AH	1	1	1	0
MSC/Misc (w/o T-AH)	14	17	17	15
SSN	2	0	0	0
MCM/MHC	0	9	0	0
HSV	0	0	0	1

Table 2. Categories of the Ships in USN Response
(Greenfield & Ingram, 2011; Kaczur et al., 2012)

We developed an optimization model based on the parameterized rating system (Apte et al., 2013) for selecting the optimal assets of the USN. Such methodology can provide an optimal mix of the ships that should be sent for HADR based on available supply, demand, and capabilities through a portfolio of vessels in terms of best composition for the future force structure.

The article is organized as follows: The next section describes the problem and the parameters used in addition to developing and defining the model. In the section following, we provide the results of this computational experiment followed by the discussion section. Finally, we offer our conclusions in the last section

The Problem

Before we propose the model of our current research, we first need to understand the demand due to disaster traits and relief requirements and, on the supply side, mission requirements and capabilities for those missions of the ships. Figure 2 describes the conceptual model on which we anchor our methodology (Apte et al., 2013). In the process of studying various disasters in our exploration of the topic of HADR, we have identified certain disaster traits that lead to specific relief requirements.

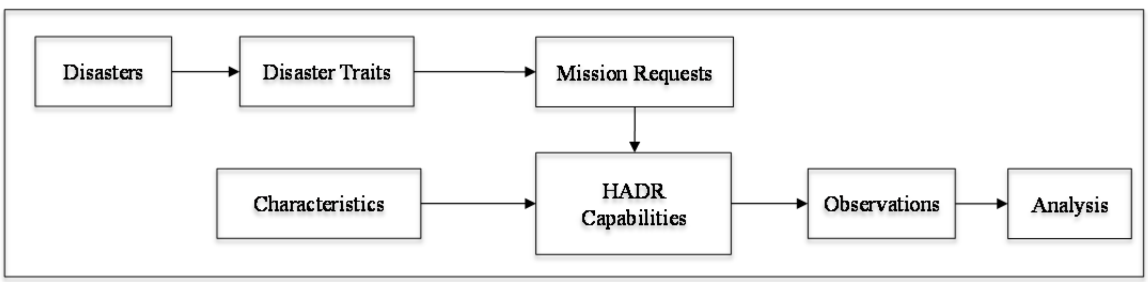

Figure 2. Conceptual Model
(Apte et al., 2013)

The capabilities of the ships to be deployed or diverted have been evaluated for a given relief requirement (Apte et al., 2013). Some capabilities are critical and some, though beneficial for the relief, are not critical. For example, one obvious relief requirement—the need for medical supplies, water, and food to be delivered—calls for a ship with the critical capability of *lift capacity*. Whereas, population dispersion requires *search and rescue* and *personal transfer* capabilities. Figure 3 depicts the interaction between Disaster Traits and Relief Requirements. This is not an exhaustive list by any means, but we want to show the underpinnings of the development of the optimization model.

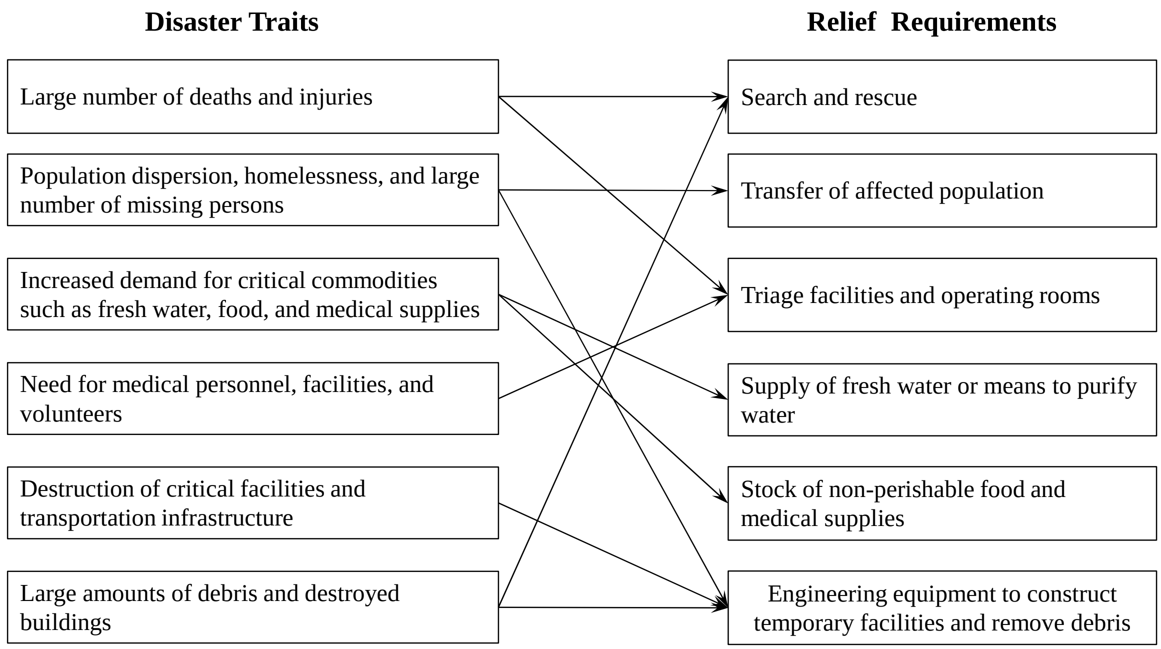

Figure 3. Basic Disaster Traits and Relief Requirements
(Apte et al., 2013)

On the supply side, the ships diverted or deployed must have the ability to satisfy the relief requirement. A ship's capability to conduct a certain HADR mission set is derived from the vessel's characteristics. The USN has many types of vessels with different capabilities. When a request for mission is received, a mission request process is generated by the officers of the Navy. There are different types of missions that operational commanders may be requested to conduct based on the capabilities of the ship. For example, aircraft support and freshwater production are some of the capabilities a ship may need to have to fulfill the mission request. Table 3 describes the critical and non-critical capabilities.

Critical Mission Capabilities		Non-Critical Mission Capabilities
Aircraft support capability		Transit speed
Amphibious Landing Craft support		Hydrographic survey
Search and Rescue (SAR)		Salvage operations
Cargo Capacity	Dry goods storage	Towing capability
	Refrigerated goods storage	
	Fresh water storage	
	Roll On Roll Off (RORO)	
	Fuel storage & dispensation	
	Self-sufficient; no need for external cranes	
Personnel transfer		
Fresh water production		
Personnel support for cleanup and recovery efforts		
Berthing capacity		
Medical support		

Table 3. Critical and Non-Critical Mission Capabilities
(Greenfield & Ingram, 2011)

The Environment

Our problem posits a potential disaster in a littoral environment. The problem for the discussed scenario uses previous disasters such as the 2004 Indian Ocean tsunami, 2005 Hurricane Katrina, 2010 Haiti earthquake, and 2011 Japan earthquake and tsunami with the corresponding responses provided by the USN. Based on the extent of destruction and casualties, the affected host country (AHC) has requested HADR from the United States. While the State Department is ultimately responsible for the United States' response to such requests they do not have the means to conduct HADR operations, but have the budget for HADR. Our notional costs are derived based on budget and the funding model of the State Department (Ures, 2011; Herbert, Wharton, & Prosser, 2012) and input from the subject matter experts. The USN is the leading organization in fulfilling the gap between who should and who can provide HADR. Given this history, in our scenario, the USN is getting ready to deploy and/or divert certain vessels to the affected country. Grounded in the previous experience and available analysis of the capabilities of the fleets (Apte et al., 2013), we developed the optimization model to decide what optimal mix of ships should be deployed to respond to this disaster.

A Notional Scenario

The AHC has suffered devastation due to high winds, torrential rains, and flood. There are many casualties and many more are injured, displaced, or missing. Due to landslides, buildings, such as hospitals, some administrative buildings, and telecommunication towers, are down. Certain roads are not traversable and bridges have collapsed. There is no potable water available. There is the fear of outbreak of diseases like cholera and malaria. The representative list of relief requirements consists of medical support and supplies, humanitarian supplies such as water or water purification facilities, search and rescue teams, temporary shelters, salvage operations, and engineering support for infrastructure. Based on these relief requirements, Table 4 describes a plausible set of demands for capabilities that are needed in the AHC.

Aircraft support	*Landing Craft support*	*Search and Rescue*	*Dry goods*	*Refrigerated goods*	*Fresh water*
10	5	3	7	2	2
Fuel	*Personnel transfer*	*Freshwater Production*	*Personnel support*	*Berthing capability*	*Medical support*
4	2	1	4	2	2

Table 4. Demands for the baseline model

These are the demands on the notional scenario defined in the problem for the AHC. The demands are units of demand on a relative scale. The capabilities that can provide the relief needed are given in Table 5.

Relief Requirement Capability	Medical support	Medical supplies	Humanitarian supplies	Search and rescue	Temporary shelters	Salvage operations	Engineering support
Aircraft support		1	1				
Landing Craft support	1			1	1	1	1
Search and Rescue				1			
Dry goods		1	1		1		
Refrigerated goods		1	1				
Fresh water			1				
Roll On Roll Off	1			1		1	1
Fuel						1	1
Personnel transfer					1		
Freshwater Production			1				
Personnel support	1			1		1	1
Berthing capability	1				1		
Medical support	1						
Salvage Ops						1	

Table 5. Capabilities for relief requirements

Platforms Capability	Nuclear Carriers	Amphibious	CRUDES	LCS	PM-1	PM-2	PM-3	PM-5	RRF	Landing Craft
Aircraft support	2	2	1	1	1	0	1	0	1	0
Landing Craft support	0	2	0	0	0	0	0	0	0	0
Search and Rescue	2	2	1	1	0	0	0	0	0	0
Dry goods	1	1	0	0	1	0	2	2	2	0
Refrigerated goods	1	0	0	0	1	0	2	2	2	0
Fresh water	1	1	0	0	1	0	2	2	2	0
Roll On Roll Off	0	0	0	0	0	0	1	1	1	0
Fuel	1	1	0	0	2	0	2	2	2	0
Personnel transfer	2	2	1	1	0	0	0	0	0	2
Freshwater Production	1	1	0	0	0	0	0	0	0	0
Personnel support	2	2	1	0	0	1	0	0	0	0
Berthing capability	2	2	0	0	0	0	1	0	0	0
Medical support	2	1	0	0	0	0	0	0	0	0
Salvage Ops	0	0	0	0	1	1	0	0	0	0

Table 6. Ship platforms and capabilities

Table 6 describes the type of ships and their corresponding capabilities. A value of 2 means that the ship is capable, a value of 1 means the ship is somewhat capable, and a value of 0 means the ship is not capable for that type of demand.

Notation for the Model

Index Sets

I set of resources (ships), for $i \in I$

J set of capabilities, for $j \in J$

Inputs

D_j demand for capability $j \in J$

$\{\eta_{ij}\}_{IxJ}$ capability $j \in J$ of ship $i \in I$

c_{ij} cost of functional capability $j \in J$ of ship $i \in I$

$$\eta_{ij} = \begin{cases} 2 \text{ if } i \text{ is capable for } j \\ 1 \text{ if } i \text{ is somewhat capable for } j \\ 0 \text{ if } i \text{ is not capable for } j \end{cases}$$

Decision Variables

$$Y_i = \begin{cases} 1 \text{ if ship } i \text{ is deployed or diverted} \\ 0 \text{ otherwise} \end{cases}$$

The Optimization Model

$$\text{minimize} \sum_{i \in I} \sum_{j \in J} c_{ij} Y_i \tag{1}$$

subject to

$$\sum_{i \in I} \eta_{ij} Y_i \geq D_j \quad \forall j \in J \tag{2}$$

$$Y_i \text{ integer} \quad \forall i \in I \tag{3}$$

Objective function (1) minimizes the cost of a ship *i* across all the capabilities $j \in J$ summed over all ships $i \in I$, thus yielding the total cost. Constraints (2) ensure that demand for capability $j \in J$ is met by the flotilla of the ships that are deployed and/or diverted to the AHC. Constraints (3) guarantee that fractional ships are not deployed or diverted.

The Results

We solved the optimization model using Microsoft Excel Solver. Results of the baseline model using plausible yet notional data based on previously collected information for the 2004 Indian Ocean tsunami, the 2005 Hurricane Katrina, the 2010 Haiti earthquake (Greenfield & Ingram, 2011; Ures, 2011), and the 2011 Tohoku earthquake in Japan (Kaczur et al., 2012; Herbert et al., 2012) are given in Table 7. Since the accessible data only gave the functional cost for all the ships together, c_{ij} the cost of functional capability $j \in J$ of ship $i \in I$ had to be assumed to be the same across the ships.

The baseline model offered one perspective—namely, which ships will be used if all costs were the same by focusing on capabilities alone as opposed to the cost of the capabilities. However, not all ships cost the same when deployed or diverted. The costs depend on many factors such as the ships' size , whether they are built to commercial standards, and whether they travel with support or sail alone.

Ship platforms	Nnumber of ships	Cost (in thousands)
Nuclear Carriers	0	2,021.00
Amphibious	**3**	2,021.00
CRUDES	0	2,021.00
LCS	0	2,021.00
PM-1	0	2,021.00
PM-2	**2**	2,021.00
PM-3	**4**	2,021.00
PM-5	0	2,021.00
RRF	0	2,021.00
Landing Craft	0	2,021.00
Total cost		18,189.00
Total ships	9	

Table 7. Results of the baseline model for deployment or diversion of ships to AHC

In order to incorporate this limitation of the baseline model, we conducted sensitivity analysis by exploring the model further and focusing on the relative ranking of the cost of the ship itself with everything else being equal. The motivation was the same as before −to discover which ships show up in the optimal mix. Assuming that all ships are ready to be deployed and are travelling from same point A to same point B, and maintaining the same demands, we ran the model with different rankings of the ship costs based on different subject matter experts. We gave higher rank to ships with higher cost. Thus the rank of the ship is the surrogate for its relative cost of deployment (and does not account for diverted ships). We understand that this is a limitation but it has its own advantage of evaluating ships based on deployment alone. We believe it adds to the set of data points for making an informed decision. The total cost is representative of the cost and not the actual cost. But it is descriptive of the cost incurred as the ranks are varied. The results of this computational experiment are given in Table 8.

Ship platforms	*Nuclear Carriers*	*Amphibious*	*CRUDES*	*LCS*	*PM-1*	*PM-2*	*PM-3*	*PM-5*	*RRF*	*Landing Craft*	*Total cost*	*Total ships*
Experiment 1.1												
Nnumber of ships		**3**				**2**			**4**			9
Rank of cost	10	9	8	7	5	5	5	5	2	1	45	
Experiment 1.2												
Nnumber of ships		**3**				**2**			**4**			9
Rank of cost	10	9	8	7	6	5	6	6	4	3	53	
Experiment 1.3												
Nnumber of ships		**3**				**2**	**4**					9
Rank of cost	10	9	8	5	5	5	5	5	5	5	57	
Experiment 1.4												
Nnumber of ships		**3**				**2**			**4**			9
Rank of cost	10	9	8	7	3	3	3	3	2	1	41	
Experiment 1.5												
Nnumber of ships		**3**				**2**			**4**			9
Rank of cost	10	8	7	9	6	5	3	3	2	1	42	

Table 8. Results with Different Rank of Costs

In order to explore how demands affect the optimal mix of the ships, in addition to the notional scenario, we also varied demands maintaining the same rank of cost to discover which ships show up in the optimal solution often. The demands were varied based on the past disaster characteristics and the affected area. The primary motivation for this sensitivity analysis was whether the demand or the costs dictate the mix of the supply. The impetus here was to see if costs or capabilities drove the model. Table 9 describes the results of the effect, if any, of varying the demand. The demands for the disasters were derived from extensive computation of the available data and discussions with subject matter experts. The demands for the computational experiments are given in Appendix B.

Ship platforms	*Nuclear Carriers*	*Amphibious*	*CRUDES*	*LCS*	*PM-1*	*PM-2*	*PM-3*	*PM-5*	*RRF*	*Landing Craft*	*Total cost*	*Total ships*
2004 Indian Ocean Tsunami												
Nnumber of ships	0	**12**	0	0	0	**10**	0	0	**15**	0	196.6	37
2005 Hurricane Katrina												
Nnumber of ships	0	**1**	0	0	0	**1**	0	0	**2**	0	19.4	4
2010 Haiti Earthquake												
Nnumber of ships	0	**5**	0	0	0	**4**	0	0	**4**	0	74.4	13
2011 Japan Earthquake/Tsunami												
Nnumber of ships	0	**1**	0	0	0	**1**	0	0	**1**	0	16.4	3

Table 9. Results of the Model for the Past Disasters

Discussion

The developed optimization model was run for a notional scenario. The baseline results show that the optimal mix of vessels included amphibious ships, PM-2, and PM-3. The critical capabilities of these platforms together provide the necessary relief.

The sensitivity analysis of the model by first changing the relative cost of the ships and then, by changing the demands based on past disasters while keeping the costs constant, yielded a set of optimal solutions. The solutions are summarized in Table 10.

The pattern can be seen through the experiment. The ships that show up every time are amphibious ships, PM-2, and RRF. PM-1 and PM-3 show up a few times. But it is clear that the unique and critical capabilities of the amphibious ships in providing aircraft and landing craft support, search and rescue operations, berthing facilities, and transfer of personnel make them indispensable for HADR. That is most likely the reason why they show up in all the optimal solutions irrespective of relative cost or demand. Based on this result it is clear that capabilities of the ships for HADR is all that mattered in this experiment. The same can be said about PM-2 with its unique capability for salvage operations and RRF for its cargo space for dry and refrigerated goods, fresh water, and fuel.

Sensitivity Analysis I										
Fixed demand and vary relative cost										
Ship platforms	***Nuclear Carriers***	***Amphibious***	***CRUDES***	***LCS***	***PM-1***	***PM-2***	***PM-3***	***PM-5***	***RRF***	***Landing Craft***
Expriment 1.1		3				2			4	
Expriment 1.2		3				2			4	
Expriment 1.3		3				2	4			
Expriment 1.4		3				2			4	
Expriment 1.5		3				2			4	
Sensitivity Analysis II										
Fixed relative cost and vary demand based on disasters										
Ship platforms	***Nuclear Carriers***	***Amphibious***	***CRUDES***	***LCS***	***PM-1***	***PM-2***	***PM-3***	***PM-5***	***RRF***	***Landing Craft***
2004 Indian Ocean		12				10			15	
2005 Hurricane		1				1			2	
2010 Haiti		5				4			4	
2011 Japan Earthquake and Tsunami		1				1			1	

Table 10. Results of Sensitivity Analysis, Ships in the Optimal Solutions

What is also important to note is which ships did not show up even a single time in all these solutions. One has to keep in mind that we carried out the computational experiment for only the deployed ships. Of interest, the ships that never showed up were the nuclear carriers, crudes, and LCSs.

It should also be noted that in investigating the binding constraint of all the versions of the model, we uncovered that demands for aircraft support, roll on and roll off capability, and salvage operations were exactly satisfied, indicating that these demands were critically satisfied with no surplus, whereas demand for fresh water, fuel, and berthing capacity were overly satisfied. However, when it comes to HADR, this is a good thing.

Conclusion

We conducted a computational experiment by developing an optimization model to find out which USN platforms are critical and hence most effective and efficient for HADR. Our conclusions were that amphibious, PM-2, and RRF ships are the most capable ships for humanitarian operations. On the other hand, nuclear carriers, crudes, and LCSs are not. We have to point out that there were certain assumptions made to look at the bigger picture. Availability of data or lack thereof was also a limiting factor.

In the future research it would benefit the analysis further if the model is run with real, relevant, and appropriate data. We are currently exploring venues for this purpose.

The current model can be enhanced in the future to eliminate certain limitations. It could be modified to include proximity of the ship to replenishing ports or AHC. The model can also be expanded to incorporate availability of the ships.

It is also possible to use an entirely different optimization model such as a "set covering" model. Such a model would evaluate the minimum ships necessary to cover most relief requirements through their capabilities.

THIS PAGE INTENTIONALLY LEFT BLANK

References

Apte, A. (2009). Humanitarian logistics: A new field of research and action. *Foundations and Trends® in Technology, Information and OM, 3*(1), 1–100.

Apte, A. (in press). Strategic and operational pre-positioning in seasonal natural disasters: A perspective. In P. Keskinocak (Ed.), *Wiley encyclopedia of operations research and management science*, 2014. New York, NY: John Wiley & Sons.

Apte, A., & Yoho, K. (2011a). Capabilities and competencies in humanitarian operations. Paper presented at the18th EurOMA (European Operations Management Association) Conference, Cambridge, United Kingdom.

Apte, A., & Yoho, K. (2011b). Strategies for logistics in case of a natural disaster. Paper presented at the 40th Annual Meeting of Western Decision Sciences Institute, Portland, Oregon.

Apte, A., Yoho, K., Greenfield, C., & Ingram, C. (2013). Selecting maritime disaster response capabilities. *Journal of Supply Chain Management*, *6*(2), 40–58.

Congressional Research Service (CRS). (2005, September 19). *Hurricane Katrina: DoD disaster response (RL33095)*. Retrieved from http://fas.org/sgp/crs/natsec/RL33095.pdf

Greenfield, C., & Ingram, C. (2011). *An analysis of U.S. Navy humanitarian assistance and disaster relief operations* (MBA report). Monterey, CA: Naval Postgraduate School.

Jones, E. (2013). *Director of American Red Cross Regional Disaster Services Presentation*. Presentation made at the Second Mini-conference in Humanitarian Operations and Crisis Management, POMS College of Humanitarian Operations and Crisis Management, Denver, CO.

Herbert, D., Wharton, R., & Prosser, A. (2012). *A cost analysis of the U.S. Navy Humanitarian assistance and disaster response to the 2011 Tohoku earthquake and tsunami* (MBA report). Monterey, CA: Naval Postgraduate School.

Kaczur, A., Aurelio, J., & Joloya, E. (2012). *An analysis of United States Naval participation in Operation Tomodachi: Humanitarian and disaster relief in the tsunami stricken Japanese mainland* (MBA report). Monterey, CA: Naval Postgraduate School.

Kleindorfer, P. R., Singhal, K., & Wassenhove, L. N. (2005). Sustainable operations management. *Production and Operations Management, 14*(4), 482–492.

Lee, H. (2002). Aligning supply chain strategies with product uncertainties. *California Management Review*, Spring, 105–119.

Lee, H. (2004). The Triple-A Supply Chain. *Harvard Business Review*, *82*(10), 102–113.

Louisiana Department of Health and Hospitals (LDHH). (2006, August 2). Hurricane Katrina—Deceased reports. Retrieved from http://new.dhh.louisiana.gov/assets/docs/katrina/deceasedreports/KatrinaDeaths_082008.pdf

McKinnon, A., Browne, M., & Whiteing, A. (2012). *Green logistics: Improving the environmental sustainability of logistics*, Hamburg, Germany: Kogan Page.

National Geographic. (2005, January 7). The deadliest tsunami in history? [Press release]. Retrieved from Southeast_Asia-_Tsunami

National Geophysical Data Center (NGDC). (2011, April 2). Tsunami events search—Sorted by date, country. Retrieved from NOAA website: http://www.ngdc.noaa.gov

National Oceanic Atmospheric Administration (NOAA) Public Affairs. (2007, February 12). Hurricane Katrina. Retrieved from http://www.netadvisor.org/wp-content/uploads/2012/04/Hurricane-Katrina-costs-NOAA.pdf

Plyer, A. (2013, April 14). Facts for features: Hurricane Katrina impact. Retrieved from http://www.gnocdc.org/Factsforfeatures/HurricaneKatrinaImpact/index.html

Van Wassenhove, L. N. (2006). Humanitarian aid logistics: Supply chain management in high gear. *Journal of Operational Research Society*, *57*(5), 475–489.

VanRooyen, M., & Leaning, J. (2005). After the tsunami—Facing the public health challenges. *New England Journal of Medicine*, *352*, 435–438. Retrieved from http://www.nejm.org

Ures, S. (2011). *Paying for military support in humanitarian assistance & disaster response—A cost analysis and planning model* (MBA report). Monterey, CA: Naval Postgraduate School.

Wooldridge, M. (2010, February 12). Haiti will not die, President Rene Preval insists. Retrieved from http://news.bbc.co.uk/2/hi/americas/8511997.stm

World Meteorological Organization (WMO). (2010). *Fact sheet: Climate information for reducing disaster risk*. Retrieved from http://www.wmo.int/wcc3/documents/WCC3_factsheet1_disaster_EN.pdf

THIS PAGE INTENTIONALLY LEFT BLANK

Appendix A. United States Navy Ship Platforms

U.S. Navy	Nuclear Carrier	CVN (Nimitz)	An aircraft carrier is a warship with a full-length flight deck and facilities for carrying, arming, deploying, and recovering aircraft, that serves as a seagoing airbase. A nuclear carrier is powered by nuclear power.
		CVN (Enterprise)	
	Amphibious Ships	LHD	The Amphibious ships have the ability to move swiftly through water and over land. They operate year-round, handling power projection and beach assault, as well as assisting in crisis response, humanitarian operations and disaster relief.
		LHA	
		LCC	
		LPD (San Antonio)	
		LPD (Austin)	
		LSD (Harpers Ferry)	
		LSD (Whidby Island)	
	CRUDES	CG	Navy cruisers, destroyers and frigates make certain no carrier, cargo/supply ship or oil tanker proceeds into an area where enemy action is possible. With lightning-quick communications, space-based radar systems, precision weapons and advanced engineering systems, these agile surface warfare ships provide anti-aircraft, anti-submarine and anti-ship protective measures.
		DDG (FLT I & II)	
		DDG (FLT IIA)	
		Frigates	
	Other	LCS (Freedom)	Littoral combat ships, patrol craft, and mine countermeasures ships.
		LCS (Independence)	
		PC	
		MCM	

Military Sealift Command Ship Platforms

Command	Program	Ship Type	Description
Military Sealift Command (MSC)	PM - 1	T-AOE	Naval Fleet Auxiliary Force (NFAF) are the supply lines to USN ships at sea. These ships provide virtually everything that navy ships need, including fuel, food, ordnance, spare parts, mail and other supplies.
		T-AO	
		T-AE	
		T-AKE	
		T-ARS	
		T-ATF	
		T-AH	
	PM - 2	LCC	Special Mission Program ships provide operating platforms and services for a wide variety of U.S. military and other U.S. Government missions. Most special mission ships are Government-owned and operated by civilian mariners who work for private companies under contract to MSC.
		AS	
		T-AGOS	
		T-AGS (Survey)	
		T-AGS (Nav)	
		T-AGM	
		T-ARC	
	PM - 3	LMSR	MSC's prepositioning ships are able to discharge cargo pierside or while anchored offshore by using shallow-draft barges, called lighterage, that are carried aboard. This allows cargo to be ferried to shore in areas where ports are to operate in both developed and undeveloped areas of the world.
		MPS	
		MPF Container	
		T-AOT	
		T-AK (USAF)	
		T-AK (USA)	
		T-AVB	
		OPDS	
		Break-Bulk	
		HSV	
	PM - 5	LMSR	MSC's Sealift ships provides high-quality, efficient and cost-effective ocean transportation for DOD and other federal agencies during peacetime and war.
		T-5	
		Common Use Tanker	
		Dry Cargo	
	Ready Reserve Force	Fast Sealift Ship	The Department of Transportation's Maritime Administration (MARAD) maintains cargo ships in the Ready Reserve Force (RRF) to provide prompt sealift support in the event they are needed for the rapid deployment of military forces. The RRF includes RO/RO cargo ships, breakbulk ships, barge carriers, Auxiliary Crane Ships (ACSs), tankers, and two troop ships for surge sealift requirement which are capable of handling bulky, oversized military equipment.
		RO/RO ships	
		Crane Ships	
		Lighterage-aboard ships	
		OPDT	
		Break-Bulk Ships	
		Avaition Logistics Support	

Military Sealift Command Ship Platforms (Continued)

Landing Craft	LCAC	Landing craft are used by amphibious forces to transport equipment and troops to the shore. Landing craft are also used to support civilian humanitarian/maritime operations. Landing craft are capable of transporting cargo, tracked and/or wheeled vehicles and troops from amphibious assault ships to beachheads or piers.
	LCU	
	LCM	
	LCM	

THIS PAGE INTENTIONALLY LEFT BLANK

Appendix B. Demands for Past Disasters

	2004 Indian Ocean Tsunami	2005 Hurricane Katrina	2010 Haiti Earthquake	2011 Japan Earthquake andTsunami
Aircraft support	17	3	9	1.0
Landing craft support	24	2	9	0.9
Search and rescue	6	0	0	0.0
Dry goods	12	2	7	0.7
Refrigerated goods	3	1	2	0.2
Fresh water	7	1	2	0.2
Roll On Roll Off	15	1	4	0.4
Fuel	15	1	4	0.4
Personnel transfer	3	1	2	0.2
Freshwater production	4	0	1	0.1
Personnel support	17	0	6	0.4
Berthing capability	3	1	2	0.2
Medical support	3	0	1	0.0
Salvage ops	10	1	3	0.4

THIS PAGE INTENTIONALLY LEFT BLANK

ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL
555 DYER ROAD, INGERSOLL HALL
MONTEREY, CA 93943

www.acquisitionresearch.net