UTILIZATION OF UNITED STATES NAVY ASSETS FOR HUMANITARIAN OPERATIONS

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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 and this research advances that aim.

INTRODUCTION

The US Navy's willingness to provide assets in support of disaster relief efforts is well established [7] [12]. However, there has always been a need to perform humanitarian assistance and disaster response (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 utilizes its resources wisely. In other words, are the right ships deployed for HADR? The experience off the coast of Bangladesh suggests that sometimes, ships are diverted or deployed in a suboptimal way, perhaps due to lack of proper decision making due to time or process constraints [1]. This research develops a mathematical model to optimize the deployment of USN assets during HADR operations [1].

The vessels that the USN deployed for the 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 Destroyers (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 [1], 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. [1] 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. [1] studied the 2004 Indian Ocean tsunami, the 2005 Hurricane Katrina, and the 2010 Haiti earthquake [8] [9] [14] [2] [6] [10] [11] [15]. In addition, the 2011 earthquake and tsunami in Japan also prompted significant support from the USN [5].

Table 1: Response from USN [3] [5]

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	48	32

Table 1 describes the response from the USN in certain disasters. 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.

Table 2: Categories of the Ships in USN Response [3] [5]

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

We developed an optimization model based on the parameterized rating system [1] 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 PROBLEM

Our problem posits a potential disaster in 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 [13] [4] 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 [1], we developed the optimization model to decide what optimal mix of ships should be deployed to respond to this disaster.

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 3 describes a plausible set of demands for capabilities that are needed in the AHC. 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 4.

Table 3: Demands for the baseline model

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

Table 4: Capabilities for relief requirements

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 describes the type of ships and their corresponding capabilities. For a given type of demand, 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.

Table 5: Ship platforms and capabilities

Capability	Platforms									
	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

We use the following notation:

I = set of resources (ships), for $i \in I$; J = set of capabilities, for $j \in J$

D_j = demand for capability; $\{\eta_{ij}\}_{IxJ}$ = capability of ship;

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

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

The Optimization Model

$$\text{minimize} \quad \sum_{i \in I} \sum_{j \in J} c_{ij} Y_i \qquad (1)$$

$$\text{subject to} \quad \sum_{i \in I} \eta_{ij} Y_i \geq D_j \quad \forall j \in J \qquad (2)$$

$$Y_i \text{ integer} \quad \forall i \in I \qquad (3)$$

Objective function (1) minimizes the cost of a ship *i* across all the capabilities summed over all ships, thus yielding the total cost. Constraints (2) ensure that demand for capability is met by the flotilla of the ships that are deployed and/or diverted to the affected host country. 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 [3] [13], and the 2011 Tohoku earthquake in Japan [4] [5] are given in Table 6. Since the accessible data only gave the functional cost for all the ships together, the cost of functional capability of a ship 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.

Table 6: Results of the baseline model for deployment or diversion of ships

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	

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 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 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 7.

Table 7: Results with Different Rank of Costs

Ship platforms	Nuclear Carriers	Amphibious	CRUDES	LCS	PM-1	PM-2	PM-3	PM-5	RRF	Landing Craft	Total cost	Total ships
Number of ships		3				2			4			9
Rank of cost	10	9	8	7	5	5	5	5	2	1	45	
Number of ships		3				2			4			9
Rank of cost	10	9	8	7	6	5	6	6	4	3	53	
Number of ships		3				2	4					9
Rank of cost	10	9	8	5	5	5	5	5	5	5	57	
Number of ships		3				2			4			9
Rank of cost	10	9	8	7	3	3	3	3	2	1	41	
Number of ships		3				2			4			9
Rank of cost	10	8	7	9	6	5	3	3	2	1	42	

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 changing the relative cost of the ships yielded a set of optimal solutions. The solutions are summarized in Table 8.

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 are 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.

Table 8: Results of Sensitivity Analysis, Ships in the Optimal Solutions

Ship platforms	***Nuclear Carriers***	***Amphibious***	***CRUDES***	***LCS***	***PM-1***	***PM-2***	***PM-3***	***PM-5***	***RRF***	***Landing Craft***
Experiment 1.1		3				2			4	
Experiment 1.2		3				2			4	
Experiment 1.3		3				2	4			
Experiment 1.4		3				2			4	
Experiment 1.5		3				2			4	

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.

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.

The future research 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 "set covering" model. Such a model would evaluate the minimum ships necessary to cover most relief requirements through their capabilities.

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