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OPTIMIZING MARITIME PREPOSITIONING FORCE SELECTION OF SHIP CLASS TO RESPOND TO HUMANITARIAN ASSISTANCE AND DISASTER RELIEF OPERATIONS IN THE PACIFIC THEATER

by

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This project will focus on analyzing critical planning factors of the different ship classes within the Maritime Prepositioning Force (MPF) program for Humanitarian Assistance and Disaster Relief (HADR) operations in the Pacific theater. By optimizing how gear is transported, Marines can provide relief in an expedient manner and minimize cost (i.e., loss of life) in a HADR. We develop an initial response model, Joint Transportation Optimization Planner – Sealift (JTOP-S), to optimize the size and number of ships needed to conduct HADR effectively and efficiently based on the equipment utilized. The port functionality, capacity of the ships, and supply and demand requirements are some constraints that hinder the aid given and delay the process. JTOP-S is able to determine an optimal solution, given the different inputs and parameters. The scenarios we ran to test the model resulted in the following findings: (1) Capacity of the different ship classes is not a limiting factor, the speed is. (2) The model will first max out the available supplies from the closest Sea Port of Embarkation (SPOE) to the Sea Port of Debarkation (SPOD) via the fastest mode of transport. (3) The model will then select the ship class that has the lowest planning factor average from the same SPOE. (4) If the demand is not met from one SPOE, the model will source the remaining demand from the next closest SPOE via the fastest mode of transportation, and then from the planning factor average value.

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OPTIMIZING MARITIME PREPOSITIONING FORCE SELECTION OF SHIP CLASS TO RESPOND TO HUMANITARIAN ASSISTANCE AND DISASTER RELIEF OPERATIONS IN THE PACIFIC THEATER

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This project will focus on analyzing critical planning factors of the different ship classes within the Maritime Prepositioning Force (MPF) program for Humanitarian Assistance and Disaster Relief (HADR) operations in the Pacific theater. By optimizing how gear is transported, Marines can provide relief in an expedient manner and minimize cost (i.e., loss of life) in a HADR. We develop an initial response model, Joint Transportation Optimization Planner – Sealift (JTOP-S), to optimize the size and number of ships needed to conduct HADR effectively and efficiently based on the equipment utilized. The port functionality, capacity of the ships, and supply and demand requirements are some constraints that hinder the aid given and delay the process. JTOP-S is able to determine an optimal solution, given the different inputs and parameters. The scenarios we ran to test the model resulted in the following findings: (1) Capacity of the different ship classes is not a limiting factor, the speed is. (2) The model will first max out the available supplies from the closest Sea Port of Embarkation (SPOE) to the Sea Port of Debarkation (SPOD) via the fastest mode of transport. (3) The model will then select the ship class that has the lowest planning factor average from the same SPOE. (4) If the demand is not met from one SPOE, the model will source the remaining demand from the next closest SPOE via the fastest mode of transportation, and then from the planning factor average value.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAA	Arrival and Assembly Area
AAV	Assault Amphibious Vehicle
AO	Area of Operation
AOR	Area of Responsibility
ARG	Amphibious Ready Group
BLT	Battalion Landing Team
CLB	Combat Logistics Battalion
CLR	Combat Logistics Regiment
CRFP	Crisis Response Force Package
DoD	Department of Defense
EUCOM	European Command
FEMA	Federal Emergency Management Agency
FHA	Foreign Humanitarian Assistance
FIE	Fly-in-Echelon
FMF	Fleet Marine Force
GCC	Geographic Combatant Commander
HADR	Humanitarian Assistance and Disaster Relief
HA	Humanitarian Assistance
LARC	Light Amphibious Resupply Cargo
LCAC	Landing Craft Air Cushion
LCM	Landing Craft Mechanized
LCU	Landing Craft Utility
LHA	Amphibious Landing Helicopter Assault
LHD	Landing Helicopter Dock
LPD	Amphibious Transport Dock
LSD	Amphibious Dock Landing Ship
MAG	Marine Aircraft Group
MAGTF	Marine Air Ground Task Force
MARDIV	Marine Division
MAW	Marine Aircraft Wing

MCPP-N	Marine Corps Prepositioning Program - Norway
MEB	Marine Expeditionary Brigade
MEF	Marine Expeditionary Force
MEU	Marine Expeditionary Unit
MLG	Marine Logistics Group
MPF	Maritime Prepositioning Force
MPS	Maritime Prepositioning Ship
MPSRON	Maritime Prepositioning Ship Squadron
MSC	Maritime Sea Lift Command
MSE	Major Subordinate Element
NM	Nautical Miles
NSS	National Security Strategy
OPCON	Operational Control
RCT	Regimental Combat Team
ROMO	Range of Military Operations
RO/RO	Roll on, Roll off
SPMAGTF	Special Purpose Marine Air Ground Task Force
SPOD	Sea Port of Debarkation
SPOE	Sea Port of Embarkation
T-AK	Tactical Container Ship
T-AKE	Tactical Dry Cargo Ship
T-AKR	Tactical Vehicle Cargo Ship
TEU	Twenty-Foot Equivalent Unit
USAID	U.S. Agency of International Development
USMC	United States Marine Corps
USN	United States Navy
USPACOM	United States Pacific Command
VMM-rein	Marine Medium Tiltrotor Squadron Reinforced
WT	Warping Tug

EXECUTIVE SUMMARY

The Marine Corps can be a vital asset for the United States to provide humanitarian aid and disaster relief to countries in need around the world. III Marine Expeditionary Force (III MEF) presented an opportunity to develop a tool to be used in response to Humanitarian Assistance and Disaster Relief (HADR) operations. Due to the location of III MEF, the ability to respond to crises in a timely manner is of strategic importance. In large-scale HADR operations, a unified effort is required in order to provide timely support.

This project develops a model, the Joint Transportation Optimization Planner-Sealift (JTOP-S), to optimize the size and number of ships that are needed to effectively and efficiently conduct HADR operations based off the equipment utilized. We recognize that the initial military response to a natural disaster comes from the Marine Expeditionary Unit (MEU) assets but we focus our study on the Maritime Prepositioning Force (MPF) Fleet and evaluate how efficiently and effectively they can respond to a crisis in the Pacific theater. Specifically, we focus our research on the T-AK BOBO Class, T-AK SHUGHART Class, T-AKR WATSON Class, T-AKR BOB HOPE Class, and the T-AKE LEWIS & CLARK Class ships (*USMC Prepositioning Handbook*, 2015). The model from this study will be a tool to help Marine Air Ground Task Force (MAGTF) planners determine the most cost effective way to transport equipment throughout the Pacific theater.

The first research question we answer is what configuration of sealift assets minimizes response penalties by optimizing the efficacy of Department of Defense (DoD) responsiveness based on asset availability? The first step to answering this question is to determine an appropriate way to quantify response penalties. Three characteristics of response operations that we focused on were cost, speed of response, and amount of supply transported. From there we develop an optimization model that minimizes response penalties.

The second question that this project answers is whether the optimization model developed is employable in a HADR scenario. Given a past or fictional scenario, can the

model calculate and produce an optimal answer for the Navy and Marine Corps team to conduct HADR operations efficiently and effectively? We accomplished proof of concept for our optimization model by reviewing past HADR operations and developing fictitious scenarios to test and ensure ease of use and applicability of JTOP-S.

The data inputs for JTOP-S were obtained primarily from online research and previous research conducted at the Naval Postgraduate School. With the direction of our advisor and project partner, III MEF, we were able to determine Sea Ports of Debarkation/ Embarkation (SPOD/SPOE respectively) and the type of ships we wanted to include in our model. The SPOEs were determined by selecting those in close proximity to large, Marine Corps bases or established presences. SPODs were selected based off the operational area of III MEF, historical impacts of natural disasters, and relations with the U.S.

Our process starts with basic transportation model. Verification of transporting the supplies from SPOE to SPOD was simple to confirm. Next, we wanted the model to select different modes of transportation. We knew the different ship classes had different travel speeds so we had our model select the optimal mode of transportation based off distance divided by speed. The distances between each SPOE and SPOD were divided by the speed of each ship class so that each ship class would have a travel time associated with that specific route [(Distance from SPOE to SPOD/Average Cruise speed of Ship Class) = Travel Time in hours]. This travel time was the beginning to formulating our coefficient within our objective function. Since our model includes more than just travel time, we had to account for other factors via our planning factor average, which is an average of our observed factors.

The different aspects that factor into the cost of the model are speed, cost to run the ship per day, availability of the ship, and the capacity of the ship. The formulated coefficient is vital to the selection of ship class in our model. We calculated into our model this coefficient by multiplying it to travel time per ship class for each SPOE to SPOD route (Travel Time x Planning Factor Average= Operational Effectiveness (E)). Operational Effectiveness is the objective function coefficient in our model.

The next step in formulating our model was being able to recognize a ports availability. This means identifying whether the port was operable for use. The way we incorporated this factor into our model was by assigning a binary variable [0,1] to it. If a port becomes unavailable, whether it was destroyed in the natural disaster or for other reasons it is assigned a [0]. If the port is operable it is assigned a [1]. Assigning this binary variable to port availability allows us to turn it on or off within the model.

After the proof of JTOP-S concept was verified we expanded our model to more ports. With four SPOEs, 44 SPODs, and five ship classes our model has 880 decision variables to consider. This is above the capacity of what Excel solver can handle. Due to the large number of decision variables we downloaded the add-in called OpenSolver to solve our model ("OpenSolver for Excel – The Open Source Optimization Solver for Excel," n.d.).

In conclusion, JTOP-S is able to determine an optimal solution given different inputs and parameters. Capacity of the different ship classes did not seem to be the limiting factor. First, the model would max out available supplies from the closest SPOE to the SPOD via fastest mode of transportation. From there the second factor was not the speed with which supplies could be delivered, but instead the value of our planning factor average from the same SPOE. If the demand is not completely met from a SPOE, the model will source the remaining demand from the next closest SPOE via the fastest mode of transportation. Again, once that mode of transportation is exhausted the value of the planning factor average becomes the determining factor.

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I. INTRODUCTION

The United States Marine Corps is the world's most elite fighting force, capable of responding to any crisis around the world. The Navy and Marine Corps team is tasked with conducting numerous different types of missions across the range of military operations (ROMO), but in this study we focus on Humanitarian Assistance and Disaster Relief (HADR) operations. The goal of our study is to find the most cost effective and efficient way of responding to a natural disaster in the Pacific region with the available number of ships and equipment in the area. For this reason, we develop an optimization model. Our research analyzes the different Maritime Prepositioning Force (MPF) Fleet and the seaports available throughout the Asia-Pacific region of the world, and whether they are feasible to employ.

A. PURPOSE

This project develops a model, the Joint Transportation Optimization Planner – Sealift (JTOP-S), to optimize the size and number of ships are needed to effectively and efficiently conduct HADR operations based off the equipment utilized. We evaluate the capacity of ships available to the Maritime Sealift Command (MSC) within the Pacific Area of Responsibility (AOR). However, our focus is also on how many sea ports are available for use in HADR operations. The model will be able to help the mission commander select specific ports for embarkation and debarkation based on specific requirements and operational constraints. This research will assist III Marine Expeditionary Force (MEF) with meeting mission requirements set forth by U.S. Agency of International Development (USAID) in the event of a crisis. As pressure continues to build on the United States military to cut costs, the Marine Corps will set the example by utilizing innovative techniques and technologies. The model developed from this study will be a tool to help Marine Air Ground Task Force (MAGTF) planners determine the most cost effective way to transport equipment throughout the Pacific theater.

1. Research Questions and Activities

The first research question we answer is what configuration of sealift assets minimizes response penalties by optimizing the efficacy of DoD responsiveness based on asset availability? The first step to answering this question is to determine an appropriate way to quantify response penalties. Three characteristics of response operations we focus on were cost, speed of response, and amount of supply transported. Our model minimizes these response penalties.

The second question that this project answers is whether the optimization model is employable in a HADR scenario. Given a past or fictional scenario, can the model calculate and produce an optimal answer for the Navy and Marine Corps team to conduct HADR operations efficiently and effectively? We verify proof of concept for our optimization model through reviewing past HADR operations and developing fictitious scenarios to test ensure ease of use and applicability of our model.

B. SCOPE AND METHODOLOGY

We obtain data inputs for our model primarily from online research and previous research conducted at the Naval Postgraduate School. With the direction of our advisor and project partner, III MEF, we determine Sea Ports of Debarkation/Embarkation (SPOD/SPOE, respectively) and the type of ships we include in our model. The SPOEs are in close proximity to large, USMC bases or established presences. SPODs were selected based off the operational area of III MEF, historical impacts of natural disasters, and relations with the U.S. The types of ships we select to evaluate in our model are specifically the ships within the Maritime Prepositioning Force (MPF). We recognize that the initial military response to a natural disaster typically comes from the Marine Expeditionary Unit (MEU) assets but we focus our study on the Maritime Prepositioning Ships (MPS) and evaluate how efficiently and effectively they can respond to a crisis in the Pacific theater.

Our model has constraints to account for the supply and demand requirements. The supply constraints do not allow for the flow of supplies from any SPOE to any SPOD to exceed the amount of supply at the point of origin. Without this constraint the model would continue to pull supplies that do not exist. The demand constraint tells the model that the flow of supplies from any SPOE to any SPOD must meet or exceed the demand at the destination point. This constraint forces the model to fulfill the supply demand. Without this constraint, no supplies would be sent. We also incorporate a port functionality constraints and a capacity constraint into our model. The port functionality constraint is built into our model in the event a port is destroyed due to a disaster and the ships cannot dock. Another constraint is to limit the number of ships sent to be equal to or less than the number of ships available. Without this constraint the model would send ships that are not available to transport supplies. Within the number of ships sent constraint, there is another constraint to ensure the flow of supplies on ships sent from a SPOE is less than the amount available at the SPOE. The capacity constraint is built to account for the amount of supplies moved by each type of transportation. This constraint determines the number of ships sent by ship type without overloading a specific ship class.

1. Limitation and Assumptions

There is input data that has to change format prior to being input into our model. The result is an average of planning factors. These factors include: Cost Comparison Ratio, Operational Control (OPCON), Number of Ships Available ratio, and the average of the above factors. Below is an explanation of the above factors; how they incorporate into our model will be explained further on:

Cost Comparison Ratio: The cost to run a ship per day is in the tens of thousands of dollars (Carmichael, 2018). In order to factor in the cost per day per ship class, the cost (in dollars per day), has to be converted into a number suitable for our model. The most effective way to integrate cost into our model is to create a comparison ratio amongst the ship classes rather than a ranking system. A ranking system is not applicable in our model because costs of the ships are not scalable; meaning one ship class is not two or three times costlier than another ship. To develop a comparison ratio, we incorporate cost in such a way that the model would weigh the less costly ships more than those that cost more per day. To do this we took the lowest cost per day ship class which was the (BOB HOPE Class) and use that as the denominator when comparing it to other ships. This results in the lowest cost per day ship class having a cost comparison ratio value of "1" and the other costlier ship classes having a cost comparison ratio value greater than one. For example, the T-AKR (BOB HOPE Class) ship is the lowest cost per day ship class at $45,078 (Carmichael, 2018) and has a cost comparison ratio of 1. This is calculated by taking [(Ship Class Type Cost per day/T-AKR (BOB HOPE Class) cost per day)] which for this example would be [(45,078) / (45,078)] = 1. The T-AKR (WATSON Class) ship has a cost per day of $73,751 (Carmichael, 2018) and has a cost comparison ratio of 1.636. This is calculated by taking [(Ship Class Type Cost per day/T-AKR (BOB HOPE Class) cost per day)] which for this example would be [(73,751) / (45,078)] = 1.636.

Operational Control: This is how much tasking control the USMC and III MEF have over the ships within our model. In our study we are making the assumption that the USMC and III MEF have no direct OPCON. OPCON remains with the Navy. This means that III MEF and the USMC cannot directly task the ships we analyzed but rather would have to request the support. For our model, all ships fall under Military Sealift Command (MSC) and therefore have the same tasking hierarchy. Since there is only one tasking hierarchy we assigned it a value of [1] within our model. This number would change if tasking authority of the ships were to change or if our model is expanded to include ships under other commands. This will result in a number ranking developed by the planning team under guidance of the tasking authority prior to implementation.

Number of ships available ratio: The number of ships available vary by class and location. Our model accounts for location of number of ships available via objective function; but to capture total capacity of a specific ship class in our model we develop a ratio which compares total ship class availability. The more available a ship is, i.e., the more of that class available, the lower we want the ratio. This is because our model minimizes our objective function and inputting the number of ships would penalize the ships with a higher availability. To create a ratio, we find the total number of ships available by class. The ship class with the greatest number of ships available is our numerator [(number of T-AK (BOBO Class)/ number of Ship Class Type available)]. This results in a ratio that would work with our model. For example, there are five total T-AK (BOBO Class) ships available, which is the ship class with the highest number available, resulting in a ship availability ratio of 1 [(5 of T-AK (BOBO Class)/ 5 of T-AK (BOBO Class)] = 1.

The T-AKE (LEWIS & CLARK Class) ship has two total ships available resulting in a ship availability ratio of 2.5: [(5 of T-AK (BOBO Class)/ 2 of T-AKE (LEWIS & CLARK Class) available)] = 2.5 (*USMC Prepositioning Handbook*, 2015).

Planning Factor Average: Originally, we multiply the above ratios to create a coefficient for our optimization model. We quickly saw that even with the ratios that certain factors would heavily outweigh others. For example, the differences in ship availability ratios among the different ship classes were greater than the difference in cost comparison ratios for the same ship classes. To alleviate these differences without completely negating the influence of the ratios, we take the average of the above factors and ratios. The result is a coefficient that did not heavily favor one factor over another. For example, the cost comparison ratio and the ship availability ratio weigh the same.

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II. BACKGROUND

The Asia-Pacific region of the world continues to be greatly affected by natural disasters. In recent years, this region has experienced multiple earthquakes, cyclones, hurricanes, typhoons, floods and tsunamis (Miles, 2012). As the nation's global response force, the Marine Corps must be prepared to react effectively and in a timely manner when called upon to support operations anywhere in the world. The organization should be able to provide swift, affordable relief to countries following a natural disaster no matter the climate or location at a moment's notice. In our research, we study the military's capability to transport equipment by sea vessels. While minimizing cost is important, we must remember that delays in transportation of emergency supplies may result in the critical cost of human life. This renders the speed of delivery equally as, if not more important.

A. III MEF'S ROLE IN USAID/ HADR OPERATIONS

Although similar to I MEF and II MEF mission, III MEF is the only expeditionary force that serves as a constant forward-deployed force in the Indo-Pacific Region. The strategic advantage of being present in the Pacific theater allows III MEF to respond to a crisis during the critical first moments. Under III MEF's command is the 31st MEU whose mission is to "provide a forward deployed, flexible sea-based Marine Air Ground Task Force capable of conducting amphibious operations, crisis response and limited contingency operations in the Asia-Pacific area" ("*31st MEU*," n.d.) This Area of Operations (AO) is arguably one of the most dynamic and crucial AO in which the Marine Corps maintains a presence. The strategic advantage of having III MEF positioned in Okinawa, Japan allows the Corps to have the capability to perform a wide ROMO to include HADR operations. Some notable HADR missions carried out by III MEF include:

> Super Typhoon Megi in the Philippines during 2010; earthquake-relief efforts in Japan during March 2011; Operation Tomodachi, a tsunami-relief effort in Japan during May of the same year; flood-relief efforts in Thailand during October-November 2011; typhoon-relief efforts in the Philippines during December 2012 and November 2013; earthquake-relief efforts in Nepal during 2015 and in Kumamoto, Japan, in 2016. (*III MEF*, n.d.)

All of these HADR operations have directly contributed to how III MEF and its subordinate commands train and plan to support and conduct future HADR operations in the Pacific theater.

B. MARINE AIR GROUND TASK FORCE

The Marine Air-Ground Task Force (MAGTF) is the principal organizational construct for Marine Corps missions across the ROMO (“*ARG/MEU Overview,”* n.d.). These MAGTFs provide the United States with a spectrum of timely response options from prepositioned forces around the globe. There are four different types of MAGTF’s, all task-organized by specific mission requirements. All four MAGTF consist of four elements; ground combat element, aviation combat element, logistics combat element, and the command element. From largest to smallest, the largest MAGTF is the MEF, consisting of a Marine Division (MARDIV), Marine Aircraft Wing (MAW), Marine Logistics Group (MLG), and the Command Element. Next is the Marine Expeditionary Brigade (MEB), consisting of a Regimental Combat Team (RCT), Marine Aircraft Group (MAG), a Combat Logistics Regiment (CLR), and the Command Element. The MEU is the smallest type of MAGTF in the Fleet Marine Force (FMF). The MEU typically consist of a Battalion Landing Team (BLT), a Marine Medium Tiltrotor Squadron reinforced (VMM-rein), a Combat Logistics Battalion (CLB), and a Command Element. The last type of MAGTF is the Special Purpose MAGTF (SPMAGTF) which is more mission-focused than the other three aforementioned MAGTF’s structures. A SPMAGTF can be of the same size of any of the other three MAGTF’s but generally equivalent to the size of a MEU with approximately 2,000 Marines, sailors, and support elements (“Types of MAGTFs,” n.d.). A SPMAGTF is comprised of “Marine Corps units with tailored capabilities required for accomplishing a specific mission, operation, or regionally focused exercise” (“Types of MAGTFs,” n.d.). A SPMAGTF is prepared to conduct a wide range of missions or operations to include Foreign Humanitarian Assistance (FHA) if called upon.

Marine Expeditionary Unit (MEU): The MEU provides the Marine Corps with substantial crisis response capability. There are a total of seven MEUs within the Marine Corps. Three of which, doctrinally, are concurrently deployed throughout the world ready to respond to any crisis that may arise. The MEU operates on an 18-month cycle. This cycle consists of six months of pre-deployment training and certification, six months of deployment as a crisis response force, and six months after a deployment of personnel changes, major subordinate element (MSE) changes, and planning for the next deployments. The 31st MEU, a subordinate command of III MEF located in Okinawa, Japan, is the only MEU that is permanently forward-deployed. The second deployed MEU, which could be the 22nd, 24th, or 26th, comes from II MEF located in Camp Lejeune, North Carolina (*Amphibious Ready Group and Marine Expeditionary Unit Overview Handbook*, n.d.). The third deployed MEU, which could be the 11th, 13th, or 15th, comes from I MEF located in Camp Pendleton, California (*Amphibious Ready Group and Marine Expeditionary Unit Overview Handbook*, n.d.). When the United States Marine Corps is tasked with conducting a HADR operation, the MEU is typically the unit chosen to respond to the crisis. Figure 1 depicts a typical MEU layout of all the organic equipment they bring to a crisis response.

Figure 1. Notional Laydown of a MEU. Source: "Types of MAGTFs," (n.d.).

While deployed into theater, the MEU is typically embarked on three different amphibious warfare ships. The amphibious landing helicopter assault (LHA) or landing helicopter dock (LHD) type of ship, the amphibious transport dock ship (LPD) and the amphibious dock landing ship (LSD). The Marine Corps personnel and organic equipment are distributed among all three ships allowing each ship the capability to perform specific ARG/MEU mission requirements. Additionally, when the Navy and Marine Corps team is tasked with conducting HADR operations they also utilize the available MPS under the Military Sealift Command (MSC).

C. MILITARY SEALIFT COMMAND (MSC)

The MSC is the primary ocean transportation network for all branches of service within the Department of Defense (DoD) (*Military Sealift Command*, n.d.). The MSC "safely operates, supplies, and maintains the ships that provide logistics support, conduct special missions, move military equipment, supply combat forces, provide humanitarian relief, and strategically position combat cargo around the world" (*Military Sealift Command*, n.d.). The MSC is organized into six operational functions; the Combat Logistics Force, the Service and Command Support, the Special Mission Program, the Prepositioning Program, the Sealift Program, and the Ready Reserve Force (*MSC Annual Report*, 2017). All six functions have a specific mission and capability set that, depending on the mission, can be activated to meet the needs of any GCC. However, for this study we are going to focus on the MPS availability within the MPF program. Specifically analyzing the utilization of the Tactical Container Ship (T-AK), the Tactical Dry Cargo/ Ammunition Ship (T-AKE), and the Roll-on/Roll-off (RO/RO) Tactical Vehicle Cargo Ship (T-AKR) during a HADR operation (*MSC Handbook*, 2018). We exclude the Tactical Expeditionary Transfer Dock (T-ESD) from this study because it does not have any capacity to carry cargo or rolling stock to the fight but we do acknowledge it as an asset needed to accomplish at-sea transfer operations. These MPS are an essential tool and tactical advantage to have readily available so that the Marine Corps can quickly deploy and employ forces in the event of a crisis.

Maritime Prepositioning Force (MPF): The primary purpose of the MPF program is "to enable the rapid deployment and engagement of a MAGTF anywhere in the world in support of our National Defense Strategy" (*USMC Prepositioning Handbook*, 2015). The MPF program has strategically placed MPS with enough supplies and equipment to sustain a MEB-sized MAGTF for 30 days. Currently, the MPF is organized into two Maritime Prepositioning Ship Squadrons (MPSRON); MPSRON-2 is based out of Diego Garcia in the Indian Ocean, and MPSRON-3 is based out of Guam and Saipan in the Western Pacific Ocean (*Maritime Prepositioning Force*, n.d.). Each MPSRON is composed of seven ships, consisting of the T-AK type ships, T-AKE type ships, T-AKR type ships, and a T-ESD type ship. These four different type of ships are the ones available within the Marine Corps Prepositioning Program. However, there are two different classes of T-AK type ships, the BOBO Class and the modified SHUGHART Class (*USMC Prepositioning Handbook*, 2015). There are also two different classes of T-AKR type ships, the BOB HOPE Class and the WATSON Class (*USMC Prepositioning Handbook*, 2015). There is currently only one class of T-AKE type ships, the LEWIS & CLARK Class (*USMC Prepositioning Handbook*, 2015). Figure 2 provides the location and composition of MPSRON 2 and MPSRON 3. Figure 3 list the different type and class of ships within the MPSRONs.

Figure 2. MPSRONs Composition and Location. Source: *USMC Prepositioning Handbook* (2015).

MPF Ships	BOBO Class	Modified SHUGHART Class	LEWIS & CLARK Class
Type Number	T-AK 3008/09/10/11/12	T-AK 3017	T-AKE 1, 2
			
	Length Overall: 673 ft Beam: 105 ft 6 in Displ: 40,846 ltons	Length Overall: 849 ft Beam: 105 ft 7 in Displ: 59,468 ltons	Length Overall: 689 ft Beam: 105 ft 7 in Displ: 42,416 ltons
Ship Names	USNS's BOBO, BUT-TON, LOPEZ, LUM-MUS, WILLIAMS	USNS STOCKHAM	USNS LEWIS & CLARK USNS SACAGAWEA

MPF Ships	BOB HOPE Class	WATSON Class	Monford Point Class
Type Number	T-AKR 304, 302	T-AKR 311, 312	ESD 1,2
			
	Length Overall: 884 ft Beam: 105ft 10 in Displ: 62,833 lton	Length Overall: 905 ft Beam: 105 ft 9 in Displ: 61,790 ltons	Length Overall: 785 ft Beam: 164 ft in Displ: 98,320 ltons
Ship Names	USNS PILILAAU USNS SEAY	USNS SISLER USNS DAHL	USNS MONTFORD POINT USNS JOHN GLENN

Figure 3. MPF Program Ship Type and Class. Adapted from *USMC Prepositioning Handbook* (2015).

The Marine Corps Prepositioning Program consists of the MPF and the Marine Corps Prepositioning Program – Norway (MCPP-N). However, in our research to develop our optimization model, we focused on the different types of ships and ship capabilities, and the MPF portion of the MCPP. As mentioned above, each MPSRON has to support a MEB-sized MAGTF for up to 30 days when activated to provide support for an operation. In order to accomplish this, the MPF must combine with the supporting unit's Fly-in-Echelon (FIE) of organic supplies and equipment to ensure the rapid deployment of personnel, supplies, and equipment to the designated Arrival and Assembly Area (AAA)

(MCO 3000.17, 2013). Figure 4 depicts the MPF overall concept of operations when activated to provide support to a crisis response.

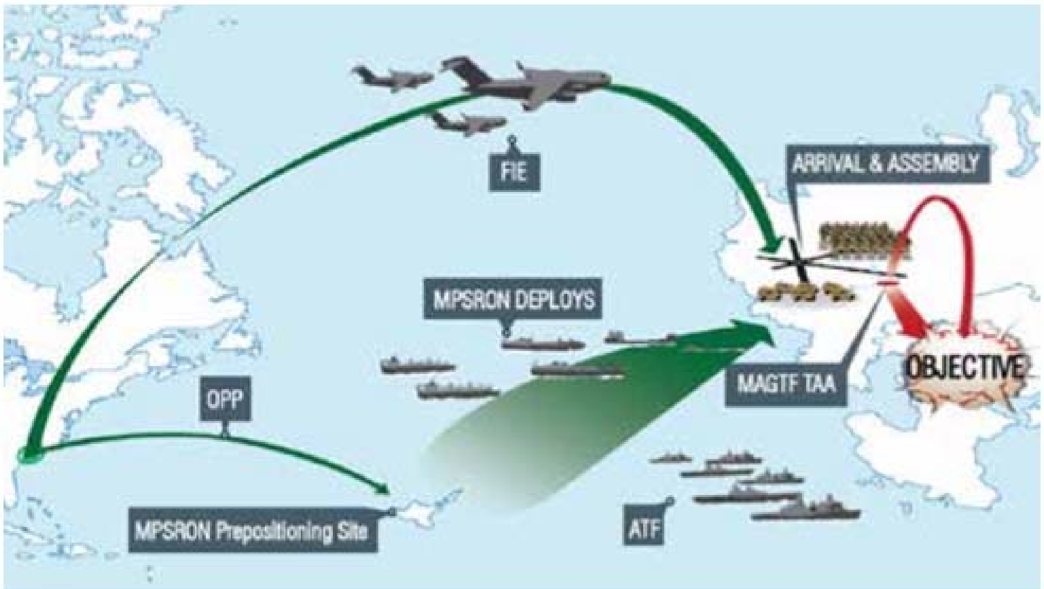

Figure 4. MPF Operation Overview. Source: *USMC Prepositioning Handbook* (2015).

From Figure 4 you can see that it takes a combined effort of air and sea assets to create the MEB Table of Equipment. As stated above a MPSRON has to support a MEB-sized MAGTF for up to 30 days. However, the Marine Corps also equips MPSRON 2 & 3 with Crisis Response Force Packages (CRFPs). These CRFPs contain a subset of equipment and supplies that are tailored towards supporting an operating force in a crisis response situation. Each MPSRON is capable of providing two different light CRFPs, as well as a medium CRFPs and a full MPSRON if required (*USMC Prepositioning Handbook*, 2015). Figure 5 depicts the different variations of light, medium, and full size CRFPs that a MPSRON can deliver during a crisis response.

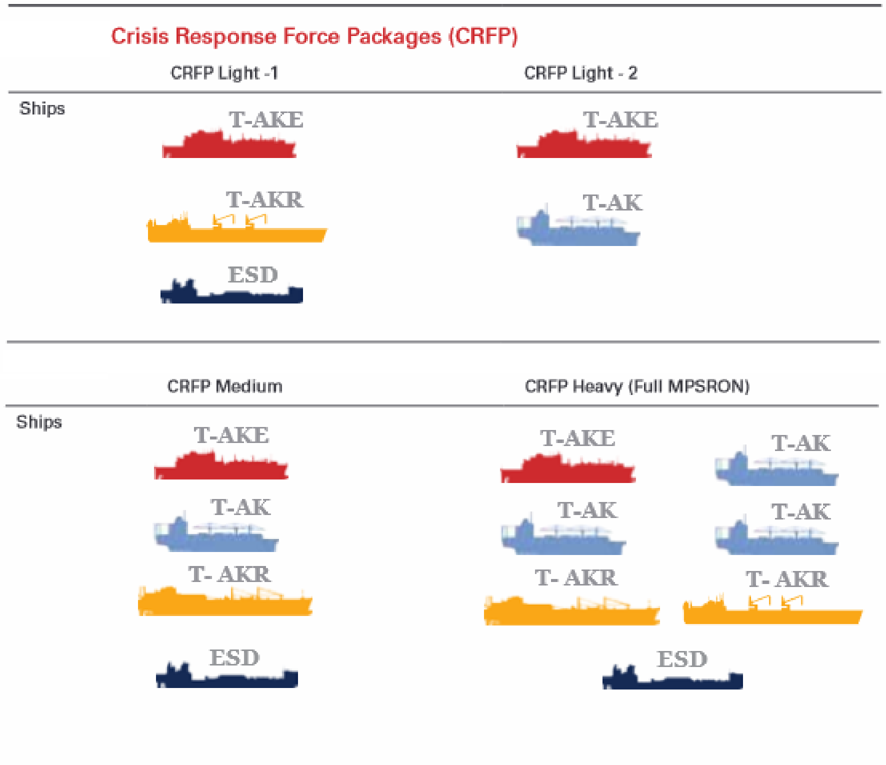

Figure 5. MPSRON Light, Medium, and Full-Size CRFPs. Adapted from *USMC Prepositioning Handbook* (2015).

With all the capabilities that the MPS offer within the MPF program it is evident how it can play a big role in HADR operations. These CRFPs are a critical component when tasking a MPSRON to assist in a HADR operation because it allows for an effective and efficient immediate response.

D. SUMMARY

Our research focuses on prepositioned ships and their ability to respond to HADR operations. III MEF has many different capabilities available to crises response missions. The pacific AOR is in vital need of a tool that assists in planning for HADR missions. Our MBA project incorporates the above knowledge and research into a model.

III. LITERATURE REVIEW

As the world becomes more connected through increases in technology, HADR missions are also becoming more and more essential to the U.S. National Security Strategy (NSS). How the U.S. responds to our allies and those in need says a great deal to the world about our ability to react to different situations. The purpose of this literature review is to identify existing issues with HADR responses, existing transportation models, cost benefit analysis of HADR mission, and to identify the gaps in existing research that pertains to our project.

A. SUPPLY CHAIN AND LOGISTICS

One of the more difficult aspects of HADR is the lack of preparation before a disaster hits (Greenfield & Ingram, 2011). Some disasters allow for more preparation than others but the uncertain nature creates issues for planners and those that execute: "Due to the inherent uncertainty involved in dealing with disaster response, all the standard problems facing commercial supply chains are amplified for HADR operations" (Greenfield & Ingram, 2011). One way to counter the uncertainty with HADR is through prepositioning supplies. However, HADR supplies often have a shelf life associated and cannot be stored for indefinite amounts of time. The military attempts to manage large stores of supplies, while also maintaining the necessary material handling equipment and operators needed to move the large stores of supplies (Apte & Yoho, 2012).

While having large stores of supplies is essential, maintaining the proper equipment, and being able to transport it is equally as important. HADR adds layers of complexity to the supply chain due to all of the unknown variables. The uncertainty creates stress on the transportation system of the supply chain. The time constraint bears more importance in a HADR response than in the private sector supply chain due to potential loss of life.

In an effort to identify the location of DoD prepositioning material and the ability to access those inventories of supplies to sustain HADR operations, research was conducted to see if there was a report that provide all the holding inventory of each branch of service (Cisek, J., Mitchell, G., & Reilly, B., 2011). They concluded that there is no report readily available or within each branch of service (Cisek, J., Mitchell, G., & Reilly, B., 2011). The prepositioning program is a great platform to use in order to plan for sustaining HADR operations for any branch of service. However, it needs to become more efficient in order to be rapidly employ in the event of a natural disaster.

B. TRANSPORTATION

Mogilevsky (2013) constructed a Disaster Relief Airlift Planner for the United States Pacific Command (USPACOM) AO. The model is specific for airlift and incorporates transportation nodes, commodity types, aircraft types, air routes, and other aspects. The purpose was to provide the Navy with a planning tool to assist in HADR responses. The model does not explore the possibility of utilizing different modes other than air for transportation.

Additionally, Dozier (2012) constructed an analytical model and it pointed out that "space-available transportation is insufficient to address EUCOM HA shipping requirements." Specifically, the model showed that it is difficult to provide all the support needed for a HADR operation in EUCOM due to the inefficient way the HA programs we have currently operate (i.e., Denton Program, Funded Transportation Program, and Project Handclasp). Compared to Mogilevsky (2013), this model does explore the different available channels of transportation via both sea and air routes to maximize flow of cargo from origins to destination. However, this model was not develop to maximize response time in the event of a disaster but rather to illustrate how we can strengthen and build strategic relationships within the EUCOM AOR through improved HA mechanism (Dozier, 2012).

C. GAPS IN CURRENT LITERATURE

While substantial research has been conducted on HADR operations factors, such as the cost to run a ship, effective response time, and most recently, Carmichael (2018) who combined all previous research into one model. His model included all ships in the Navy's arsenal. There is little research that analyzes the total capability available within the MPF program specifically. Our model is intended to fill that gap and serve as a tool in the planning process for III MEF to minimize response time to HADR missions. Furthermore, we understand our model is not a final product and can be constantly improved upon over time as will be discussed later.

There is a gap of data available regarding MPS operations during HADR missions. Most of the data available is in aggregate form and there is little data available regarding how much equipment and supplies were delivered through MPS for any recent HADR operation. With that in mind, we look at the data available in recent research and apply what we can to develop our optimization model.

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IV. DATA AND METHODOLOGY

In order to answer the research questions, the model would have to optimize the transportation of cargo from one port to another. Due to the complexity of the problem it is best to start with a simple model that can be developed by further research. The model is a linear, deterministic, and static model, which may seem simple but as can be seen below can be complicated.

A. DATA SOURCES

Data is from past NPS theses and projects, Marine Corps publications, Transportation Engineering Agency surveys, and from our liaison with III MEF. Ship cost per day, capacity, ship type by location, and speed are all directly from the above sources. One piece of information we derive is the distances between the ports of origin and destination ports. This is accomplished using a distance calculator and inputting the latitude and longitude of both ports. This distance, in nautical miles, is input into our model and in our objective function coefficient.

B. MODEL

The beginning of every model starts with determining the algebraic model. Then it can be implemented into a platform to solve it.

1. Indices and Sets

i Sea Ports of Embarkation- SPOE (1, 2, 3, 4)

j Sea Ports of Debarkation- SPOD (1, 2, 3…44)

t Mode of Transportation (1:BOBO) (2:SHUGHART) (3:WATSON) (4:BOB HOPE) (5:LEWIS & CLARK)

2. Input Data

Y_{jt} Ship t Ability to port at $SPOD_j$; Y= (0, 1)

O_t Operational Control of Mode of Transport t

Z_j	Functionality of $SPOD_j$; Z= (0, 1)
K_t	Average Cruise Speed of Mode of Transportation t (Knots)
C_t	Capacity of Ship t (TEU)
N_{ij}	Distance from $SPOE_i$ to $SPOD_j$ (Nautical Miles)
S_i	Amount of Supply at $SPOE_i$ (TEU)
D_j	Amount of Demand at $SPOD_j$ (TEU)
A_{jt}	Number of available Ships of type t at $SPOE_i$
M_t	Cost per day to operate ship t (U.S. DOLLARS)
Q	Extremely large number to force model to accept flow of x at $SPOD_j$ unless $Z_j = 0$

3. Calculated Data

R_t

$$\frac{\text{Cost per day to run ship class type t}}{\text{Cost per day to run ship class type with lowest cost}} \quad (1)$$

A_t

$$\frac{\text{number of highest available ship class}}{\text{number of Ship Class t available}} \quad (2)$$

P_t

$$\frac{1}{3}(R_t + A_t + O_t) \quad (3)$$

E_{ijt}

$$P_t \times \frac{N_{ij}}{W_t} \quad (4)$$

4. Decision Variables

X_{ijt}	Flow of Supplies transported from $SPOE_i$ to $SPOD_j$ via transportation mode t [(i= 1, 2, 3, 4) (j= 1, 2, 3…44) (t= 1, 2, 3, 4, 5)]
T_{ijt}	Number of Ships sent by mode of transportation t from $SPOE_i$ [(i= 1, 2, 3, 4) (j= 1, 2, 3…44) (t= 1, 2, 3, 4, 5)]

5. Objective Function

Minimize $$\sum_{i=1}^{4} \sum_{j=1}^{44} \sum_{t=1}^{5} E_{ijt} X_{ijt} \tag{5}$$

6. Constraints

Supply Constraints:

$$\sum_{j=1}^{44} \sum_{t=1}^{5} X_{ijt} \leq S_i \qquad \forall\, i \tag{6}$$

Demand Constraints:

$$\sum_{i=1}^{4} \sum_{t=1}^{5} X_{ijt} \geq D_j \qquad \forall\, j \tag{7}$$

Additional Constraints:

$$\sum_{i=1}^{4} \sum_{t=1}^{5} X_{ijt} \leq Q\, Z_j \qquad \forall\, j \tag{8}$$

$$\sum_{i=1}^{4} \sum_{t=1}^{5} X_{ijt} \leq Q\, Y_{jt} \qquad \forall\, j, t \tag{9}$$

$$\sum_{j=1}^{44} T_{ijt} \leq A_{it} \qquad \forall\, i, t \tag{10}$$

$$\sum_{t=1}^{5} C_t\, T_{ijt} \leq S_i \qquad \forall\, i \tag{11}$$

$$\sum_{j=1}^{44} \sum_{t=1}^{5} C_t\, T_{ijt} \geq \sum_{j=1}^{44} \sum_{t=1}^{5} X_{ijt} \qquad \forall\, t \tag{12}$$

$$X_{ijt} \geq 0 \tag{13}$$

$$T_{ijt} \geq 0 \textit{ and integer} \tag{14}$$

7. Explanation of Objective Function and Constraints

Equation (5) is our objective function and seeks to minimize response penalties. Response penalties are captured through our Operational Efficiency coefficient (E). The model runs through the different combinations of SPOD, mode of transportation, and SPOE. The coefficient (X) is the amount of flow from SPOD i to SPOD j via mode of transportation t. There are 880 different decision variables that our model runs through and then selects the appropriate values for (X) thus finding the optimal solution. The constraints within the model are what ensures the model operates as intended.

Equation (6) is our supply constraint and prevents our model from sending excess supply from a SPOE to a SPOD. The constraint says that the flow of (X) from a SPOE to a SPOD must be less than the supple available at SPOE. Equation (7) is our demand constraint and ensures that demand at SPOD j is met. The additional constraints (8-12) control the ship class type selected and the ability to port at the different SPODs.

Equation (8) controls the ability to turn a port on or off captured through our Port Functionality coefficient (Z). The coefficient (Z) is a binary variable and has a value of [0] assigned to it when the port needs to be turned off. When the port is turned on (Z) is assigned a value of [1]. By multiplying (Z) to an extremely large number (Q), it allows the model to accept the flow of (X) (unless Z is 0). Equation (9) works in a similar manner to equation (8) but instead the coefficient (Y) is the ability of the mode of transportation to port into a specific SPOD. When a ship is unable to debark at a SPOD, the coefficient (Y) is assigned a value of [0] thus turning that SPOD off. When (Y) is [1] the ship class is able to debark at the SPOD.

Equations (10-12) deal with the selection of ship class and the number of ships sent. Equation (10) dictates that the capacity of ships sent has to be less than the capacity of ships available. This prevents the model from sending more ships than are available. Equation (11) says that the capacity of the ships sent must be less than then the available supply at the SPOE. Equation (12) states that the sum of the capacity of each mode of transportation multiplied by the actual number of ships sent must be greater than or equal to the flow of supplies (X) for all modes of transportation.

These constraints make the model more realistic. Without these constraints the model would not work or would select the same ship regardless of scenario due to the Planning Factor Average.

8. Model Diagram

The diagram in Figure 6 shows our supply sources and destinations with demand for resources. This diagram follows the traditional transportation model format and shows any route from SPOD to SPOE has the potential to be employed as long as the constraints allow.

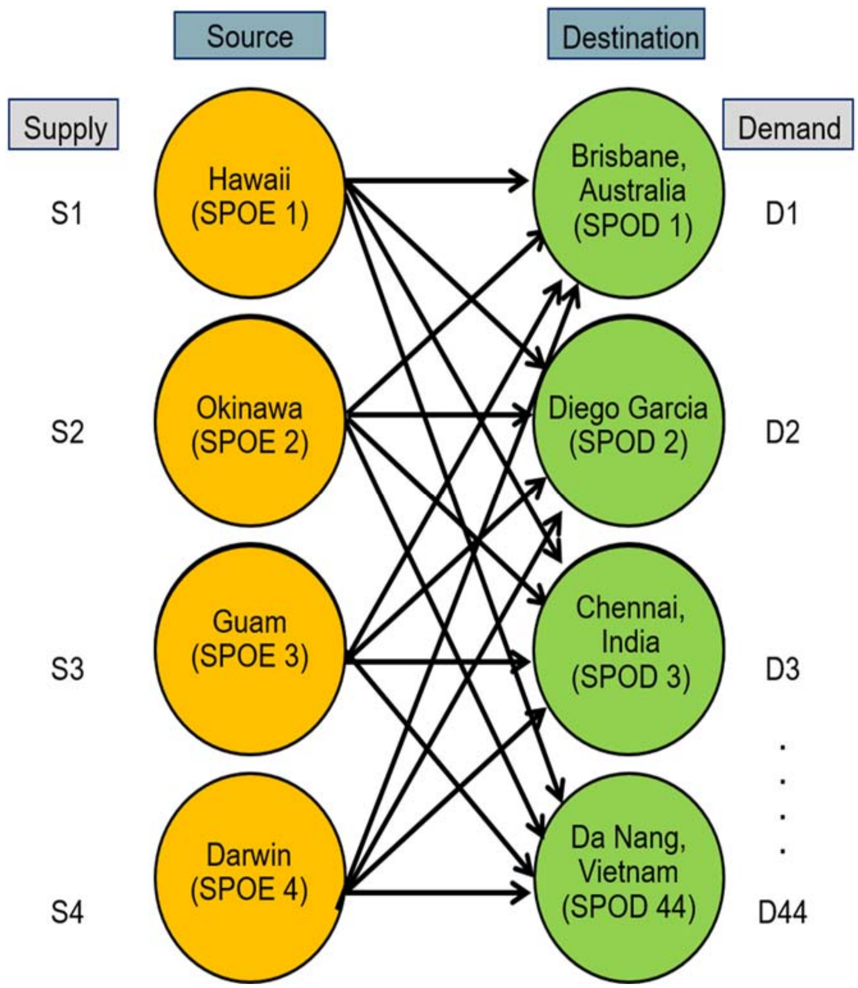

Figure 6. Transportation Diagram

C. MODEL FORMULATION

Our process starts with a basic transportation model to ensure confirmation of concept. Verification of transporting the supplies from SPOE to SPOD is simple to confirm. Next the model selects different modes of transportation. We know the different ship classes have different travel speeds so the model selects the optimal mode of transportation based on distance divided by speed. The distances between each SPOE and SPOD are divided by the speed of each ship class so that each ship class has a travel time associated with that specific route [(Distance from SPOE to SPOD/Average Cruise speed of Ship Class) = Travel Time in hours]. This travel time was the beginning to formulating our coefficient within our objective function. Since our model includes more than just travel time, we account for other factors via our planning factor average which is an average of our observed factors.

The different aspects that factor into the cost of the model are speed, cost to run the ship per day, availability of the ship, and the capacity of the ship. The coefficient is vital to the selection of ship class in our model. We calculate into our model this coefficient by multiplying it to travel time per ship class for each SPOE to SPOD route [Travel Time x Planning Factor Average= Operational Effectiveness (E)]. Operational Effectiveness is our objective function coefficient within our model. The next step in formulating our model is being able to recognize a ports availability. This means identifying whether the port is operable for use. The way we incorporate this factor into our model is by assigning a binary variable [0,1] to it. If a port becomes unavailable, whether it is destroyed in the natural disaster or for other reasons it is assigned a [0]. If the port is operable, it is assigned a [1]. Assigning this binary variable to port availability allows us to turn it on or off within the model.

Once our model is working on a small scale and selecting different ship types based on our coefficient, we expand our model to more ports. With four SPOE, 44 SPOD, and five ship types our model has 880 decision variables that the model must compare. This is above the capacity of what Excel solver can handle. Due to the large number of decision variables we download the add-in called OpenSolver to solve our model since it can process a larger number of variables than a standard Excel solver ("OpenSolver for Excel – The Open Source Optimization Solver for Excel,"n.d.).

A user interface was developed for easy input of parameters and understanding of the model outputs, Appendix A outlines how to properly operate the optimization model. Appendix B is our model input into Excel, the tool we used to solve our model.

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V. DATA ANALYSIS

In this section we discuss several hypothetical scenarios derived from past disasters. By varying the constraints, we will be able to identify any trends within the model. The intent is for this model to be an easy to use planning tool in future HADR operations.

A. ASSUMPTIONS

Data collected from past operations is primarily in tons of various supplies provided to the nation in need. Ship capacity is in twenty-foot equivalent units (TEU) so to put the supply into a common unit we assume the weight of twenty-foot containers to be fifteen tons (*USMC Prepositioning Handbook*, 2015). Additionally, we assume that the supplies will be maxed in each TEU whereas that may not happen in an actual case. For example, 30 tons will translate to two TEU in our model but in reality it may have been closer to five TEUs because space available in the TEU will be reached before the weight limits.

The second assumption is about the composition and availability of the ships and ship class. The MSC fleet is much larger than what the USMC utilizes so the assumption is that the ships utilized in the model are from MPSRON-2 and MPSRON-3. These include five T-AK (BOBO Class) ships, one T-AK (SHUGHART Class) ship, two T-AKR (BOB HOPE Class) ships, two T-AKR (WATSON Class) ships, and two T-AKE (LEWIS & CLARK Class) ships (*USMC Prepositioning Handbook*, 2015).

The third assumption is SPOEs selected in our model and the variation of ships and number available by class at each SPOE. The MPSRONs are prepositioned ships that are constantly afloat in two different areas of the world. The SPOEs given to us by III MEF are Pearl Harbor, Naha in Okinawa, Guam, and Darwin in Australia. In our model, the SPOEs were selected by being closest to where the MPSRON is floating. We are assuming that although primarily afloat, the ships selected would travel to one of the four SPOEs for offloading of supplies not needed and loading of additional supplies prior to traveling to the affected area.

The fourth assumption is the amount of supply available to each MPSRON. Since the ships are preloaded with capability sets the amount of supply is finite (*USMC Prepositioning Handbook*, 2015). Appendix B and C break down the capability sets by TEUs for MPSRON 2 and 3 respectively. We assume that the preloaded capability sets will be initial supply available.

The fifth assumption is the compatibility of ships and ports at SPOEs and SPODs. We are assuming that all the ships within the MPSRONs are able to dock at all four SPOEs and the 44 SPODs. A second aspect of this assumption is that the ports also have the necessary infrastructure to support loading/offloading of MPF ships.

B. 2011 TOHOKU EARTHQUAKE AND TSUNAMI IN JAPAN, OPERATION TOMADACHI

In March of 2011 Japan was hit by one of the worst earthquakes in its history with a magnitude of 9.0. The earthquake triggered tsunamis and the two disasters resulted in over 12,000 people killed, 164,000 displaced, and more than 15,000 missing (Baxter, 2011). In an effort to assist Japan with relief efforts, the U.S. launched Operation Tomadachi. Throughout the operation a chartered High-Speed Vessel was used to transport 450 tons of cargo, primarily vehicles, between Okinawa and mainland Japan (Baxter, 2011). Additionally, throughout Operation Tomadachi, U.S. 7th Fleet Forces provided over 260 tons of HA/DR supplies throughout Honshu (*The Chronology of Operation Tomodachi*, n.d.). From our assumptions above 450 tons of cargo is converted into 30 TEUs and the 260 tons is converted 17.3 TEUs for a total of 47.3 TEUs. Additionally, the area most affected by the earthquake and tsunamis was Fukushima. The closest naval port to the affected area is Yokohama just to the south so that will be the SPOD.

The above tons provided are estimates of what was moved. The operation was so large and widespread that it is difficult to ascertain an exact number, in tons or TEUs, of what was provided. Information that was not captured is fresh water delivered, fuel dispersed and other miscellaneous items such as medical kits ("*The Chronology of Operation Tomodachi*," n.d.).

1. Results

The model was able to solve this scenario in under a minute and Figure 7 shows the results. The model selected the T-AKR (BOB HOPE Class) from Naval Base, Guam to send to the selected SPOD. Since our demand was not greater than the capacity of the T-AKR, it was able to fulfill the need with one ship taking up about 8% of the ship's capacity. While the (BOB HOPE Class) does not have the lowest Planning Factor Average, it is one of the fastest ships within the MPF fleet. The cruising speed in addition to a low cost to operate is why our model selected it as the ship class to send. Additionally, the model selected to send the (BOB HOPE Class) from Guam and not Australia. This decision makes sense as the Naval Base in Guam is much closer to the SPOD than Australia.

The intent behind our model is now that results have been generated, planners would be able to utilize this as a beginning step. We understand that more ships may have to be sent due to different capabilities such as refueling. Since only 8% of the ship's capacity is used a more cost effective mode of transportation may be used. It is important to keep in mind that with ships, the space occupied by supplies is usually maxed out before weight limitations. This means that transporting heavier equipment via ship would be more cost efficient than other modes such as air.

Supply/Demand

Port of Embarkation (Supply)	
Pearl Harbor, Hawaii	
Naha, Okinawa, Japan	
Naval Base, Guam	1,300
Darwin, Australia	1,100
Total Supply	2,400
Total Demand	47

Port of Disembarkation (Demand)	
Brisbane, Australia	
Diego Garcia	
Chennai, India	
Cochin, India	
Mormugao, India	
Hachinohe, Japan	
Hakata, Japan	
Iwakuni, Japan	
Nakagusuku, Japan	
Sasebo, Japan	
Yokohama, Japan	47
Kure, Japan	
Haeju, DPRK	
Chongjin, DPRK	
Hungnam, DPRK	
Kimchaek, DPRK	
Busan, S. Korea	
Masan, S. Korea	
Daesan, S. Korea	
Gunsan, S. Korea	

Ship Availability	# of Ships by Destination and Type
T-AK (Bobo) Pearl Harbor	
T-AK (Shughart) Pearl Harbor	
T-AK (Bobo) Naha. Okinawa, Japan	
T-AK (Shughart) Naha. Okinawa, Japan	
T-AK (Bobo)Naval Base, Guam	3
T-AK (Shughart)Naval Base, Guam	
T-AK (Bobo) Darwin, Australia	2
T-AK (Shughart) Darwin, Australia	1
T-AKR (Bob Hope) Pearl Harbor	
T-AKR (Watson) Pearl Harbor	
T-AKR (Bob Hope) Naha. Okinawa, Japan	
T-AKR (Watson) Naha. Okinawa, Japan	
T-AKR (Bob Hope) Naval Base, Guam	1
T-AKR (Watson) Naval Base, Guam	1
T-AKR (Bob Hope) Darwin, Australia	1
T-AKR (Watson) Darwin, Australia	1
T-AKE (Lewis & Clark/Sacagawea) Pearl Harbor	
T-AKE (Lewis & Clark/Sacagawea) Naha. Okinawa, Japan	
T-AKE (Lewis & Clark/Sacagawea) Naval Base, Guam	1
T-AKE (Lewis & Clark/Sacagawea) Darwin, Australia	1

Model Output	% of Ship Load Sent by Destination and Type
T-AK (Bobo) Pearl Harbor	0
T-AK (Shughart) Pearl Harbor	0
T-AK (Bobo) Naha. Okinawa, Japan	0
T-AK (Shughart) Naha. Okinawa, Japan	0
T-AK (Bobo)Naval Base, Guam	0
T-AK (Shughart)Naval Base, Guam	0
T-AK (Bobo) Darwin, Australia	0
T-AK (Shughart) Darwin, Australia	0
T-AKR (Bob Hope) Pearl Harbor	0
T-AKR (Watson) Pearl Harbor	0
T-AKR (Bob Hope) Naha. Okinawa, Japan	0
T-AKR (Watson) Naha. Okinawa, Japan	0
T-AKR (Bob Hope) Naval Base, Guam	0.078595318
T-AKR (Watson) Naval Base, Guam	0
T-AKR (Bob Hope) Darwin, Australia	0
T-AKR (Watson) Darwin, Australia	0
T-AKE (Lewis & Clark/Sacagawea) Pearl Harbor	0
T-AKE (Lewis & Clark/Sacagawea) Naha. Okinawa, Japan	0
T-AKE (Lewis & Clark/Sacagawea) Naval Base, Guam	0
T-AKE (Lewis & Clark/Sacagawea) Darwin, Australia	0

Model Output	# of Ships Sent by Destination and Type
T-AK (Bobo) Pearl Harbor	0
T-AK (Shughart) Pearl Harbor	0
T-AK (Bobo) Naha. Okinawa, Japan	0
T-AK (Shughart) Naha. Okinawa, Japan	0
T-AK (Bobo)Naval Base, Guam	0
T-AK (Shughart)Naval Base, Guam	0
T-AK (Bobo) Darwin, Australia	0
T-AK (Shughart) Darwin, Australia	0
T-AKR (Bob Hope) Pearl Harbor	0
T-AKR (Watson) Pearl Harbor	0
T-AKR (Bob Hope) Naha. Okinawa, Japan	0
T-AKR (Watson) Naha. Okinawa, Japan	0
T-AKR (Bob Hope) Naval Base, Guam	1

Figure 7. Model Results from Scenario 1

C. 2013 TYPHOON HAIYAN IN PHILIPPINES

In November 2018, Typhoon Haiyan struck the Philippines. The typhoon was one of the worst in the country’s history and killed over 6,000 people, displaced 4.1 million, and left 1,800 missing (Reid, 2018). The U.S. received notification shortly before the storm hit land, and therefore the U.S. was able to start preparing for relief efforts in advance. The U.S relief effort provided over 430 tons of critical supplies and equipment to the affected areas ("Office of the Press Secretary," 2013). The figures above translate into 28.6 TEU. It was difficult finding exact quantities of aid was provided in a format that did not need to be converted. The SPOD selected is Subic Bay because it is closer to the path of the typhoon.

Results

Figure 8 shows the results of our model, which was able to solve this scenario in under a minute. The model selected the T-AKR (BOB HOPE Class) from Naval Base, Guam to send to the selected SPOD. Our demand was not greater than the capacity of the T-AKR, as about 5% of the ship's capacity was occupied. While the (BOB HOPE Class) does not have the lowest Planning Factor Average, it is one of the faster ships available. The high cruising speed and low cost to operate is why our model selected it as the ship class to send. The model selected to send the (BOB HOPE Class) from Guam and not Australia due to its closer proximity to the SPOD. With the model selecting the (BOB HOPE Class) as the preferred mode of transportation.

Port of Embarkation (Supply)	
Pearl Harbor, Hawaii	
Naha, Okinawa, Japan	
Naval Base, Guam	1,300
Darwin, Australia	1,100
Total Supply	2,400
Total Demand	29

Port of Disembarkation (Demand)	
Brisbane, Australia	
Diego Garcia	
Chennai, India	
Cochin, India	
Mormugao, India	
Hachinohe, Japan	
Hakata, Japan	
Iwakuni, Japan	
Nakagusuku, Japan	
Sasebo, Japan	
Yokohama, Japan	
Kure, Japan	
Haeju, DPRK	
Chongjin, DPRK	
Hungnam, DPRK	
Kimchaek, DPRK	
Busan, S. Korea	
Masan, S. Korea	
Daesan, S. Korea	
Gunsan, S. Korea	
Gwangyang, S. Korea	
Incheon, S. Korea	
Jinhae, S. Korea	
Mokpo, S. Korea	
Mukho, S. Korea	
Okgye, S. Korea	
Okpo, S. Korea	
Ulsan, S. Korea	
Yeosu, S. Korea	
San Fernando, Philippines	
Subic Bay, Philippines	29

Ship Availability	# of Ships by Destination and Type
T-AK (Bobo) Pearl Harbor	
T-AK (Shughart) Pearl Harbor	
T-AK (Bobo) Naha. Okinawa, Japan	
T-AK (Shughart) Naha. Okinawa, Japan	
T-AK (Bobo)Naval Base, Guam	3
T-AK (Shughart)Naval Base, Guam	
T-AK (Bobo) Darwin, Australia	2
T-AK (Shughart) Darwin, Australia	1
T-AKR (Bob Hope) Pearl Harbor	
T-AKR (Watson) Pearl Harbor	
T-AKR (Bob Hope) Naha. Okinawa, Japan	
T-AKR (Watson) Naha. Okinawa, Japan	
T-AKR (Bob Hope) Naval Base, Guam	1
T-AKR (Watson) Naval Base, Guam	1
T-AKR (Bob Hope) Darwin, Australia	1
T-AKR (Watson) Darwin, Australia	1
T-AKE (Lewis & Clark/Sacagawea) Pearl Harbor	
T-AKE (Lewis & Clark/Sacagawea) Naha. Okinawa, Japan	
T-AKE (Lewis & Clark/Sacagawea) Naval Base, Guam	1
T-AKE (Lewis & Clark/Sacagawea) Darwin, Australia	1

Model Output	% of Ship Load Sent by Destination and Type
T-AK (Bobo) Pearl Harbor	0
T-AK (Shughart) Pearl Harbor	0
T-AK (Bobo) Naha. Okinawa, Japan	0
T-AK (Shughart) Naha. Okinawa, Japan	0
T-AK (Bobo)Naval Base, Guam	0
T-AK (Shughart)Naval Base, Guam	0
T-AK (Bobo) Darwin, Australia	0
T-AK (Shughart) Darwin, Australia	0
T-AKR (Bob Hope) Pearl Harbor	0
T-AKR (Watson) Pearl Harbor	0
T-AKR (Bob Hope) Naha. Okinawa, Japan	0
T-AKR (Watson) Naha. Okinawa, Japan	0
T-AKR (Bob Hope) Naval Base, Guam	0.047826087
T-AKR (Watson) Naval Base, Guam	0
T-AKR (Bob Hope) Darwin, Australia	0
T-AKR (Watson) Darwin, Australia	0
T-AKE (Lewis & Clark/Sacagawea) Pearl Harbor	0
T-AKE (Lewis & Clark/Sacagawea) Naha. Okinawa, Japan	0
T-AKE (Lewis & Clark/Sacagawea) Naval Base, Guam	0
T-AKE (Lewis & Clark/Sacagawea) Darwin, Australia	0

Model Output	# of Ships Sent by Destination and Type
T-AK (Bobo) Pearl Harbor	0
T-AK (Shughart) Pearl Harbor	0
T-AK (Bobo) Naha. Okinawa, Japan	0
T-AK (Shughart) Naha. Okinawa, Japan	0
T-AK (Bobo)Naval Base, Guam	0
T-AK (Shughart)Naval Base, Guam	0
T-AK (Bobo) Darwin, Australia	0
T-AK (Shughart) Darwin, Australia	0
T-AKR (Bob Hope) Pearl Harbor	0
T-AKR (Watson) Pearl Harbor	0
T-AKR (Bob Hope) Naha. Okinawa, Japan	0
T-AKR (Watson) Naha. Okinawa, Japan	0
T-AKR (Bob Hope) Naval Base, Guam	1
T-AKR (Watson) Naval Base, Guam	0
T-AKR (Bob Hope) Darwin, Australia	0

Figure 8. Model Results from Scenario 2

D. HYPOTHETICAL EARTHQUAKE IN SOUTH KOREA, VARYING DEMAND SCENARIOS

Due to the difficulty in obtaining input data for our model, we decided to do a large-scale relief effort which would take multiple ships. We will run different scenarios with different demand to be delivered to ports in close proximity to each other. It is with this scenario that we will truly test the limits of our model. Our first varying input will be demand and will involve 650 and 800 TEUs to explore the ship class and number sent. The second input will be two different ports in South Korea, Busan and Incheon. The first combination will involve 650 demand at Busan and 800 demand at Incheon. The second combination will be 800 demand and Busan and 650 demand at Incheon.

Results

In the first scenario the model selected to send three T-AK (BOBO Class) from Guam and one T-AKR (BOB HOPE Class) from both Guam and Darwin, Australia as seen in Figure 9. Korea is far from both Guam and Australia but we can assume that Guam is slightly closer due to four different ships being sent from that SPOE. Demand was just slightly over the supply available in Guam which is why the model selected the (BOB HOPE Class) ship from Australia. Three (BOBO Class) ships being sent from Guam to fulfill the demand in two different locations is interesting because it proves that our model will not send ships that are no longer available from a SPOE. The (BOBO Class) is almost half the daily cost of the (LEWIS & CLARK Class) which outweighed the superior capacity and speed of the latter class.

Port of Embarkation (Supply)			Port of Disembarkation (Demand)			Ship Availability	# of Ships by Destination and Type
Pearl Harbor, Hawaii			Brisbane, Australia			T-AK (Bobo) Pearl Harbor	
Naha, Okinawa, Japan			Diego Garcia			T-AK (Shughart) Pearl Harbor	
Naval Base, Guam	1,300		Chennai, India			T-AK (Bobo) Naha. Okinawa, Japan	
Darwin, Australia	1,100		Cochin, India			T-AK (Shughart) Naha. Okinawa, Japan	
			Mormugao, India			T-AK (Bobo)Naval Base, Guam	3
Total Supply	2,400		Hachinohe, Japan			T-AK (Shughart)Naval Base, Guam	
Total Demand	1,450		Hakata, Japan			T-AK (Bobo) Darwin, Australia	2
			Iwakuni, Japan			T-AK (Shughart) Darwin, Australia	1
			Nakagusuku, Japan			T-AKR (Bob Hope) Pearl Harbor	
			Sasebo, Japan			T-AKR (Watson) Pearl Harbor	
			Yokohama, Japan			T-AKR (Bob Hope) Naha. Okinawa, Japan	
			Kure, Japan			T-AKR (Watson) Naha. Okinawa, Japan	
			Haeju, DPRK			T-AKR (Bob Hope) Naval Base, Guam	1
			Chongjin, DPRK			T-AKR (Watson) Naval Base, Guam	1
			Hungnam, DPRK			T-AKR (Bob Hope) Darwin, Australia	1
			Kimchaek, DPRK			T-AKR (Watson) Darwin, Australia	1
			Busan, S. Korea	650		T-AKE (Lewis & Clark/Sacagawea) Pearl Harbor	
			Masan, S. Korea			T-AKE (Lewis & Clark/Sacagawea) Naha. Okinawa, Japan	
			Daesan, S. Korea			T-AKE (Lewis & Clark/Sacagawea) Naval Base, Guam	1
			Gunsan, S. Korea			T-AKE (Lewis & Clark/Sacagawea) Darwin, Australia	1
			Gwangyang, S. Korea				
			Incheon, S. Korea	800			
			Jinhae, S. Korea				

Model Output	% of Ship Load Sent by Destination and Type
T-AK (Bobo) Pearl Harbor	0
T-AK (Shughart) Pearl Harbor	0
T-AK (Bobo) Naha. Okinawa, Japan	0
T-AK (Shughart) Naha. Okinawa, Japan	0
T-AK (Bobo)Naval Base, Guam	1.253571443
T-AK (Shughart)Naval Base, Guam	0
T-AK (Bobo) Darwin, Australia	0
T-AK (Shughart) Darwin, Australia	0
T-AKR (Bob Hope) Pearl Harbor	0
T-AKR (Watson) Pearl Harbor	0
T-AKR (Bob Hope) Naha. Okinawa, Japan	0
T-AKR (Watson) Naha. Okinawa, Japan	0
T-AKR (Bob Hope) Naval Base, Guam	1
T-AKR (Watson) Naval Base, Guam	0
T-AKR (Bob Hope) Darwin, Australia	0.25083612
T-AKR (Watson) Darwin, Australia	0
T-AKE (Lewis & Clark/Sacagawea) Pearl Harbor	0
T-AKE (Lewis & Clark/Sacagawea) Naha. Okinawa, Japan	0
T-AKE (Lewis & Clark/Sacagawea) Naval Base, Guam	0
T-AKE (Lewis & Clark/Sacagawea) Darwin, Australia	0

Model Output	# of Ships Sent by Destination and Type
T-AK (Bobo) Pearl Harbor	0
T-AK (Shughart) Pearl Harbor	0
T-AK (Bobo) Naha. Okinawa, Japan	0
T-AK (Shughart) Naha. Okinawa, Japan	0
T-AK (Bobo)Naval Base, Guam	3
T-AK (Shughart)Naval Base, Guam	0
T-AK (Bobo) Darwin, Australia	0
T-AK (Shughart) Darwin, Australia	0
T-AKR (Bob Hope) Pearl Harbor	0
T-AKR (Watson) Pearl Harbor	0
T-AKR (Bob Hope) Naha. Okinawa, Japan	0
T-AKR (Watson) Naha. Okinawa, Japan	0
T-AKR (Bob Hope) Naval Base, Guam	1
T-AKR (Watson) Naval Base, Guam	0
T-AKR (Bob Hope) Darwin, Australia	1
T-AKR (Watson) Darwin, Australia	0
T-AKE (Lewis & Clark/Sacagawea) Pearl Harbor	0
T-AKE (Lewis & Clark/Sacagawea) Naha. Okinawa, Japan	0
T-AKE (Lewis & Clark/Sacagawea) Naval Base, Guam	0
T-AKE (Lewis & Clark/Sacagawea) Darwin, Australia	0

Figure 9. Korea Scenario 1 Results

Figure 10 shows the model selected to send two T-AK (BOBO Class) from Guam, one T-AKR (BOB HOPE Class) from Guam, and one T-AKR (BOB HOPE Class) from Darwin, Australia in the second scenario. The different composition of ship classes and their respective SPOEs is due to the locations of the demand changing from scenario 1 above. The model was able to satisfy demand with fewer ships as compared to scenario 1.

Port of Embarkation (Supply)			Port of Disembarkation (Demand)			Ship Availability	# of Ships by Destination and Type
Pearl Harbor, Hawaii			Brisbane, Australia			T-AK (Bobo) Pearl Harbor	
Naha, Okinawa, Japan			Diego Garcia			T-AK (Shughart) Pearl Harbor	
Naval Base, Guam	1,300		Chennai, India			T-AK (Bobo) Naha. Okinawa, Japan	
Darwin, Australia	1,100		Cochin, India			T-AK (Shughart) Naha. Okinawa, Japan	
			Mormugao, India			T-AK (Bobo)Naval Base, Guam	3
Total Supply	2,400		Hachinohe, Japan			T-AK (Shughart)Naval Base, Guam	
Total Demand	1,450		Hakata, Japan			T-AK (Bobo) Darwin, Australia	2
			Iwakuni, Japan			T-AK (Shughart) Darwin, Australia	1
			Nakagusuku, Japan			T-AKR (Bob Hope) Pearl Harbor	
			Sasebo, Japan			T-AKR (Watson) Pearl Harbor	
			Yokohama, Japan			T-AKR (Bob Hope) Naha. Okinawa, Japan	
			Kure, Japan			T-AKR (Watson) Naha. Okinawa, Japan	
			Haeju, DPRK			T-AKR (Bob Hope) Naval Base, Guam	1
			Chongjin, DPRK			T-AKR (Watson) Naval Base, Guam	1
			Hungnam, DPRK			T-AKR (Bob Hope) Darwin, Australia	1
			Kimchaek, DPRK			T-AKR (Watson) Darwin, Australia	1
			Busan, S. Korea	800		T-AKE (Lewis & Clark/Sacagawea) Pearl Harbor	
			Masan, S. Korea			T-AKE (Lewis & Clark/Sacagawea) Naha. Okinawa, Japan	
			Daesan, S. Korea			T-AKE (Lewis & Clark/Sacagawea) Naval Base, Guam	1
			Gunsan, S. Korea			T-AKE (Lewis & Clark/Sacagawea) Darwin, Australia	1
			Gwangyang, S. Korea				
			Incheon, S. Korea	650			
			Jinhae, S. Korea				

Model Output	% of Ship Load Sent by Destination and Type
T-AK (Bobo) Pearl Harbor	0
T-AK (Shughart) Pearl Harbor	0
T-AK (Bobo) Naha. Okinawa, Japan	0
T-AK (Shughart) Naha. Okinawa, Japan	0
T-AK (Bobo)Naval Base, Guam	1.2535714
T-AK (Shughart)Naval Base, Guam	0
T-AK (Bobo) Darwin, Australia	0
T-AK (Shughart) Darwin, Australia	0
T-AKR (Bob Hope) Pearl Harbor	0
T-AKR (Watson) Pearl Harbor	0
T-AKR (Bob Hope) Naha. Okinawa, Japan	0
T-AKR (Watson) Naha. Okinawa, Japan	0
T-AKR (Bob Hope) Naval Base, Guam	1
T-AKR (Watson) Naval Base, Guam	0
T-AKR (Bob Hope) Darwin, Australia	0.25083612
T-AKR (Watson) Darwin, Australia	0
T-AKE (Lewis & Clark/Sacagawea) Pearl Harbor	0
T-AKE (Lewis & Clark/Sacagawea) Naha. Okinawa, Japan	0
T-AKE (Lewis & Clark/Sacagawea) Naval Base, Guam	0
T-AKE (Lewis & Clark/Sacagawea) Darwin, Australia	0

Model Output	# of Ships Sent by Destination and Type
T-AK (Bobo) Pearl Harbor	0
T-AK (Shughart) Pearl Harbor	0
T-AK (Bobo) Naha. Okinawa, Japan	0
T-AK (Shughart) Naha. Okinawa, Japan	0
T-AK (Bobo)Naval Base, Guam	2
T-AK (Shughart)Naval Base, Guam	0
T-AK (Bobo) Darwin, Australia	0
T-AK (Shughart) Darwin, Australia	0
T-AKR (Bob Hope) Pearl Harbor	0
T-AKR (Watson) Pearl Harbor	0
T-AKR (Bob Hope) Naha. Okinawa, Japan	0
T-AKR (Watson) Naha. Okinawa, Japan	0
T-AKR (Bob Hope) Naval Base, Guam	1
T-AKR (Watson) Naval Base, Guam	0
T-AKR (Bob Hope) Darwin, Australia	1
T-AKR (Watson) Darwin, Australia	0

Figure 10. Korea Scenario 2 Results

VI. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSIONS

In conclusion, our model was able to determine an optimal solution given different inputs and parameters. Capacity of the different ship classes is not the limiting factor but instead is speed. First the model would max out available supplies from the closest SPOE to the SPOD via fastest mode of transportation. From there the second factor was not the speed with which supplies could be delivered, but instead the value of our planning factor average from the same SPOE. If the demand is not met from one SPOE, the model will source the remaining demand from the next closest SPOE via the fastest mode of transportation and then from the value of the planning factor average.

B. RECOMMENDATIONS FOR FUTURE STUDY

1. Expanding the Model

As mentioned previously in this study, the model is not a final product. It can be improved upon, especially with the emergence of any new data, mission criteria, or for training evolutions. This model is a tool to help MAGTF planners determine the most cost effective way to transport equipment throughout the Pacific theater. It was developed with the goal of providing planners with the optimal solution to an immediate response. However, it does not take into account multiple days of operations. An expansion of this model would be to incorporate some new constraints and decision variables so that it can produce an optimal solution for an HADR operation that can account for multiple days. Additionally, this model could be combined with an air model to compare the effectiveness of either mode of transportation (See Scott and Watson, 2018).

2. MPS Connectors (Ship-to-Shore)

The optimization model only accounts for available ports in the Asia-Pacific region. It does not account for a scenario in which zero ports are available to provide immediate response. If such a scenario was to occur, the HADR mission will have to be carried out via a sea-basing operation. The model will then have to be modified to encompass ship-to-shore connectors in order to be able to deliver aid. This will require that data analysis be done on the capabilities, capacity, size, speed, availability, and cost per day to operate these ship-to-shore connectors. These ship-to-shore connectors will consist of the Warping Tug (WT), Landing Craft Mechanized (LCM), Landing Craft Utility (LCU), Lighter Amphibious Resupply Cargo (LARC), Assault Amphibious Vehicle (AAV), and the Landing Craft Air Cushion (LCAC) (*USMC Prepositioning Handbook*, 2015). By modifying the model to account for ship-to-shore connectors it will have to take into account the various air assets available as well that contribute to the ship-to-shore movement of supplies and equipment.

3. Capability Set Considerations

Capability sets preloaded on MPSRONs would be the primary reason to utilize those assets in a HADR operation. The ships would be able to meet personnel at the disaster area, similar to responding to a deployment for military operations. In our project we were unable to capture the value these sets would provide in HADR operations. Appendix C has the capability sets available in MPSRONs 2 and 3. We recommend that another project attempt to evaluate the importance of these capability sets, assign a ranking or value system to the sets, and implement the ranking system into the model. Once the sets have been captured in the model, it would enable leaders to make the decision between packing gear and sending it or utilizing the prepositioned equipment.

4. Planning Factor Average Development

The Planning Factor Average is vital to JTOP-S and the outputs it provides. Further development of the Planning Factor Average is essential to maintain the model and keeping it relevant to the global situation. Further development could include adjusting the capacity of ships to convert supplies from TEU into pounds, the number of personnel a ship can carry, the ability to refuel other ships, the ability to incorporate vertical lift assets, and many more.

This concludes our research and recommendations for future studies.

APPENDIX A. HOW TO USE JTOP-S

1. Select “Sea User Interface” worksheet.

2. Input Supply in TEUs available at SPOEs in “Port of Embarkation” table.

3. Input Demand in TEUs at affected SPOD in “Port of Debarkation” table.

4. Input available ships by location in “Ship Availability” table.

5. Select “Sea Model” worksheet.

6. Highlight cells C80 through AGD81 and clear contents.

7. Select “Data” tab.

8. Select “solve” under the OpenSolver add-in.

9. Select “Sea User Interface” worksheet. Results will be populated in both “Model Output” tables.

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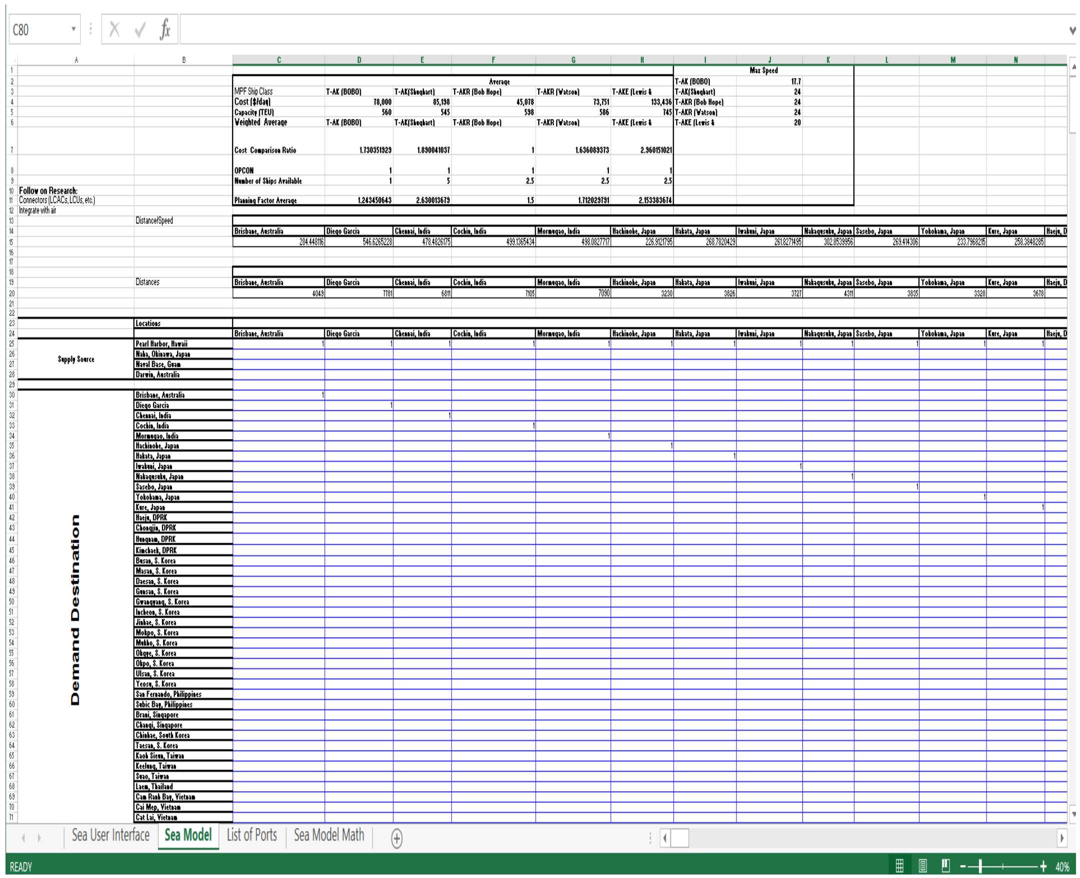
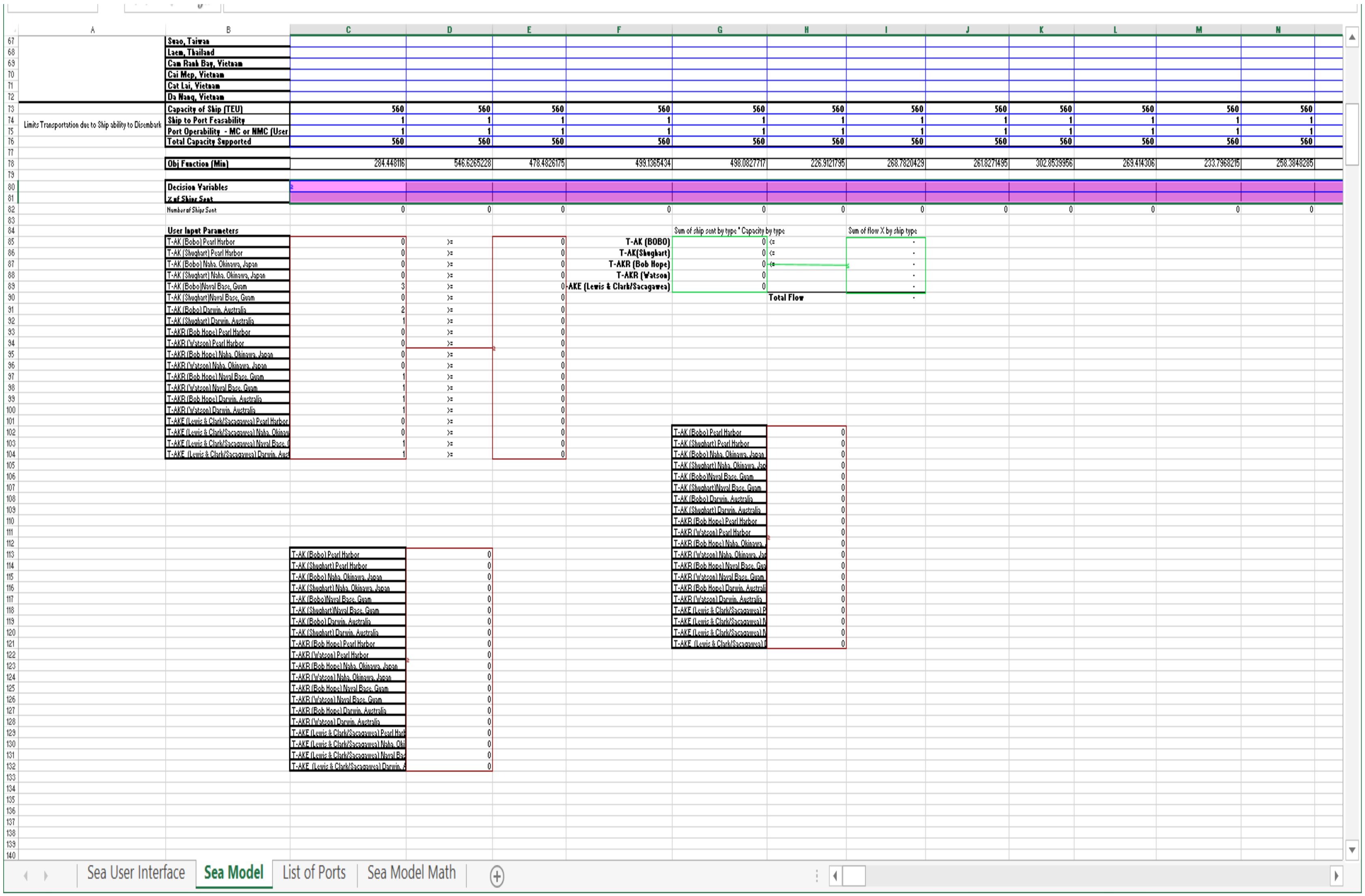
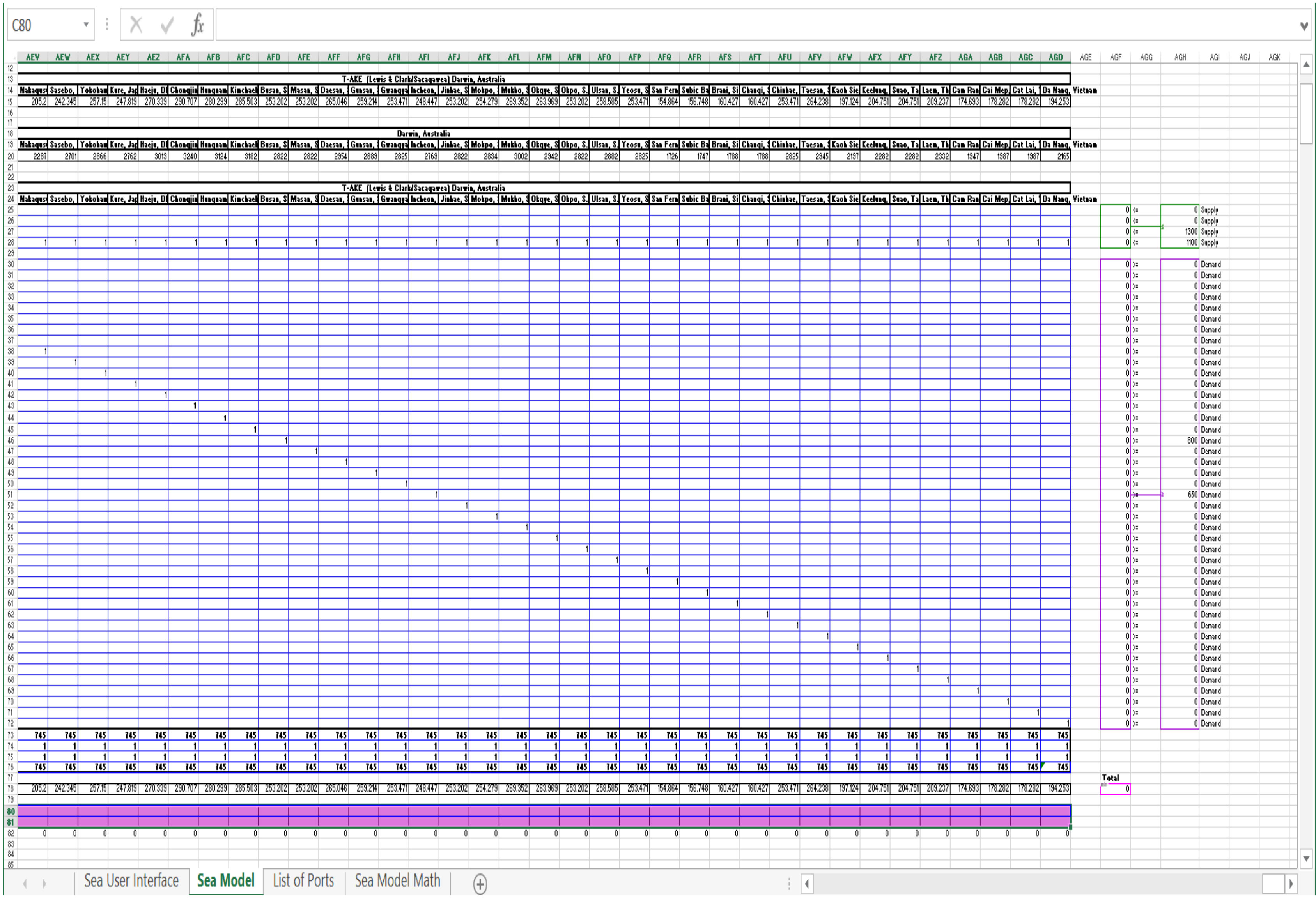
APPENDIX B. JTOP-S INPUT INTO EXCEL




Suao, Taiwan
Laem, Thailand
Cam Ranh Bay, Vietnam
Cai Mep, Vietnam
Cat Lai, Vietnam
Da Nang, Vietnam
Capacity of Ship (TEU)
Ship to Port Feasability
Port Operability - MC or NMC (User
Total Capacity Supported
Obj Function (Min)
Decision Variables
# of Ships Sent
User Input Parameters
T-AK (BOBO)
T-AK(Shughart)
T-AKR (Bob Hope)
T-AKR (Watson)
Total Flow
Sea User Interface
Sea Model
List of Ports
Sea Model Math


C80
T-AKE (Lewis & Clark/Sacagawea) Darwin, Australia
Darwin, Australia
T-AKE (Lewis & Clark/Sacagawea) Darwin, Australia
Total
Sea User Interface
Sea Model
List of Ports
Sea Model Math

Port of Embarkation (Supply)	
Pearl Harbor, Hawaii	
Naha, Okinawa, Japan	
Naval Base, Guam	1,300
Darwin, Australia	1,100
Total Supply	2,400
Total Demand	1,450

Port of Disembarkation (Demand)	
Brisbane, Australia	
Diego Garcia	
Chennai, India	
Cochin, India	
Mormugao, India	
Hachinohe, Japan	
Hakata, Japan	
Iwakuni, Japan	
Nakagusuku, Japan	
Sasebo, Japan	
Yokohama, Japan	
Kure, Japan	
Haeju, DPRK	
Chongjin, DPRK	
Hungnam, DPRK	
Kimchaek, DPRK	
Busan, S. Korea	800
Masan, S. Korea	
Daesan, S. Korea	
Gunsan, S. Korea	
Gwangyang, S. Korea	
Incheon, S. Korea	650
Jinhae, S. Korea	
Mokpo, S. Korea	
Mukho, S. Korea	
Okgye, S. Korea	
Okpo, S. Korea	
Ulsan, S. Korea	
Yeosu, S. Korea	
San Fernando, Philippines	
Subic Bay, Philippines	
Brani, Singapore	
Changi, Singapore	
Chinhae, South Korea	
Taesan, S. Korea	
Kaoh Sieun, Taiwan	
Keelung, Taiwan	
Suao, Taiwan	
Laem, Thailand	
Cam Ranh Bay, Vietnam	

Ship Availability	# of Ships by Destination and Type
T-AK (Bobo) Pearl Harbor	
T-AK (Shughart) Pearl Harbor	
T-AK (Bobo) Naha. Okinawa, Japan	
T-AK (Shughart) Naha. Okinawa, Japan	
T-AK (Bobo)Naval Base, Guam	3
T-AK (Shughart)Naval Base, Guam	
T-AK (Bobo) Darwin, Australia	2
T-AK (Shughart) Darwin, Australia	1
T-AKR (Bob Hope) Pearl Harbor	
T-AKR (Watson) Pearl Harbor	
T-AKR (Bob Hope) Naha. Okinawa, Japan	
T-AKR (Watson) Naha. Okinawa, Japan	
T-AKR (Bob Hope) Naval Base, Guam	1
T-AKR (Watson) Naval Base, Guam	1
T-AKR (Bob Hope) Darwin, Australia	1
T-AKR (Watson) Darwin, Australia	1
T-AKE (Lewis & Clark/Sacagawea) Pearl Harbor	
T-AKE (Lewis & Clark/Sacagawea) Naha. Okinawa, Japan	
T-AKE (Lewis & Clark/Sacagawea) Naval Base, Guam	1
T-AKE (Lewis & Clark/Sacagawea) Darwin, Australia	1

Model Output	% of Ship Load Sent by Destination and Type
T-AK (Bobo) Pearl Harbor	0
T-AK (Shughart) Pearl Harbor	0
T-AK (Bobo) Naha. Okinawa, Japan	0
T-AK (Shughart) Naha. Okinawa, Japan	0
T-AK (Bobo)Naval Base, Guam	0
T-AK (Shughart)Naval Base, Guam	0
T-AK (Bobo) Darwin, Australia	0
T-AK (Shughart) Darwin, Australia	0
T-AKR (Bob Hope) Pearl Harbor	0
T-AKR (Watson) Pearl Harbor	0
T-AKR (Bob Hope) Naha. Okinawa, Japan	0
T-AKR (Watson) Naha. Okinawa, Japan	0
T-AKR (Bob Hope) Naval Base, Guam	0
T-AKR (Watson) Naval Base, Guam	0
T-AKR (Bob Hope) Darwin, Australia	0
T-AKR (Watson) Darwin, Australia	0
T-AKE (Lewis & Clark/Sacagawea) Pearl Harbor	0
T-AKE (Lewis & Clark/Sacagawea) Naha. Okinawa, Japan	0
T-AKE (Lewis & Clark/Sacagawea) Naval Base, Guam	0
T-AKE (Lewis & Clark/Sacagawea) Darwin, Australia	0

Model Output	# of Ships Sent by Destination and Type
T-AK (Bobo) Pearl Harbor	0
T-AK (Shughart) Pearl Harbor	0
T-AK (Bobo) Naha. Okinawa, Japan	0
T-AK (Shughart) Naha. Okinawa, Japan	0
T-AK (Bobo)Naval Base, Guam	0
T-AK (Shughart)Naval Base, Guam	0
T-AK (Bobo) Darwin, Australia	0
T-AK (Shughart) Darwin, Australia	0
T-AKR (Bob Hope) Pearl Harbor	0
T-AKR (Watson) Pearl Harbor	0
T-AKR (Bob Hope) Naha. Okinawa, Japan	0
T-AKR (Watson) Naha. Okinawa, Japan	0
T-AKR (Bob Hope) Naval Base, Guam	0
T-AKR (Watson) Naval Base, Guam	0
T-AKR (Bob Hope) Darwin, Australia	0
T-AKR (Watson) Darwin, Australia	0
T-AKE (Lewis & Clark/Sacagawea) Pearl Harbor	0
T-AKE (Lewis & Clark/Sacagawea) Naha. Okinawa, Japan	0

Sea User Interface | Sea Model

READY

APPENDIX C. CAPABILITY SETS ABOARD MPSRON-2 AND MPSRON-3

CAPABILITY SETS
QUICK ACCESS/SPECIAL STOWAGE

MPSRON 2

	BUTTON	LOPEZ	STOCKHAM	SISLER	SEAY	LEWIS & CLARK*
Capability Sets	NUMBER OF TEUS OR PALLETS					
FUEL DISTRIBUTION SYSTEM						
Amphibious Assault Fuel System (AAFS)	37	34	54			
Tactical Airfield Fuel Dispensing System (TAFDS)	13	13	26		13	
Helicopter Expedient Refueling System (HERS)	2	4		2	2	6
Ground Expedient Refueling System (GERS)	2	2		2	2	7
WATER	5				5	
FOOD (MREs)	4				5	
HABITABILITY	13					208
MEDICAL	3					48
SECURITY	2					32
Quick Access / Special Stowage						
CHEMICAL BIOLOGICAL RADIOLOGICAL NUCLEAR (CBRN)	6	6	6			11
WASH RACK SYSTEM	4	4	4	4	4	
ARMORING ASSEMBLY SET	2	1	2			
COMMUNICATIONS (COMM VANS)	6	7	2	6	2	
AIRCRAFT RESCUE AND FIRE FIGHTING (ARFF)	1					
EXPEDITIONARY MEDICAL FACILITY (EMF)				168		
NSE (NSE HQ, BCM, BPM, ABLTS, RRDF, CSM)	2	2	3	3	3	2
SEABEE CONSTRUCTION MODULE (SCM)			11	11	11	
SEABEE SUSTAINMENT MODULE (SSM)					10	
SEABEE EQUIPMENT MAINTENANCE MODULE (EMM)				10		
SEABEE COMMAND AND CONTROL MODULE (CCM)			8			
SEABEE NMCB P29, NAVAL CONSTRUCTION REGIMENTS (NCR)		4				
SEABEE NMCB P32, CONSTRUCTION CAPABILITY AUGMENT (CCA)			2			
EXPEDITIONARY AIRFIELD (EAF) (FLAT RACKS)	85	80	125			

*Numbers reflect pallet quantities.

Source: *USMC Prepositioning Handbook*, (2015)

CAPABILITY SETS QUICK ACCESS/SPECIAL STOWAGE	MPSRON 3 LUMMUS	BOBO	WILLIAMS	PILILAAU	DAHL	SACAGAWEA*
Capability Sets	**NUMBER OF TEUS OR PALLETS**					
FUEL DISTRIBUTION SYSTEM						
Amphibious Assault Fuel System (AAFS)	37	37	71			
Tactical Airfield Fuel Dispensing System (TAFDS)	13	13	14	13	13	
Helicopter Exp Refueling System (HERS)	2	2	2			6
Ground Expedient Refueling System (GERS)	2	2		2	2	7
WATER		5		5		
FOOD (MREs)		4		4		68
HABITABILITY		13				416
MEDICAL		3				21
SECURITY		2				32
Quick Access / Special Stowage						
CHEMICAL BIOLOGICAL RADIOLOGICAL NUCLEAR (CBRN)	9	9	6			11
WASH RACK SYSTEM	4	4	4	4	2	
ARMORING ASSEMBLY SET	1	1	1			
COMMUNICATIONS (COMM VANS)					8	
AIRCRAFT RESCUE AND FIRE FIGHTING (ARFF)				1	1	
EXPEDITIONARY MEDICAL FACILITY (EMF)					168	
NSE (NSE HQ, BCM, BPM, ABLTS, RRDF, CSM)	2	2	2	3	3	2
SEABEE CONSTRUCTION MODULE (SCM)			11	11	11	
SEABEE SUSTAINMENT MODULE (SSM)				10		
SEABEE EQUIPMENT MAINTENANCE MODULE (EMM)					10	
SEABEE COMMAND AND CONTROL MODULE (CCM)			8			
SEABEE NMCB P29, NAVAL CONSTRUCTION REGIMENTS (NCR)	4					
SEABEE NMCB P32, CONSTRUCTION CAPABILITY AUGMENT (CCA)			2			
EXPEDITIONARY AIRFIELD (EAF) (FLAT RACKS)	85	85	125			

**Numbers reflect pallet quantities.*

Source: *USMC Prepositioning Handbook*, (2015)

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