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Forging the Logistics Coalition: Enhancing U.S. Marine Corps Disaster Response in the Indo-Pacific

June 2025

Capt Rachel L. Murphy, USMC

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ABSTRACT

The U.S. Marine Corps must enhance its logistical capabilities to support both warfighting and humanitarian assistance/disaster relief (HA/DR) operations in the Indo-Pacific's distributed maritime environment. This research provides a paradigm for addressing HA/DR response in the strategically relevant and natural disaster-prone region. It introduces a "logistics coalition" as a strategic initiative to improve response effectiveness by leveraging prepositioning concepts.

This research centers around a network model focused on the distribution of five equipment types from eight supply nodes (Okinawa military base, Yokota air base, Guam military base, Philippines, Singapore, Diego Garcia, Darwin, and South Korea) to six demand nodes (Philippines, Indonesia, India, Taiwan, Thailand, and Japan). It develops six mathematical models, each aligned to a different demand node, to identify the most efficient prepositioning network for HA/DR response in the Indo-Pacific. The models are computed in Microsoft Excel using linear programming techniques to optimize the allocation of resources across the network. The results highlight key prepositioning sites and provide recommendations for resource allocation across Department of Defense (DoD) sites in the region. The research proposes a logistics coalition and offers decision-makers with a model framework to improve HA/DR readiness, ensuring timely and effective disaster response in the Indo-Pacific.

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ABOUT THE AUTHOR

Captain Rachel Murphy was commissioned after graduation from the U.S. Naval Academy on May 24, 2019. Upon completing the Basic School and the Logistics Officers Course, she received orders to Combat Logistics Battalion 13 in Camp Pendleton, CA. While at Combat Logistics Battalion 13 from July 2020-June 2023, she served in three different billets. First, she served as the landing support platoon commander, supporting Weapons Tactics Instructor course 2-20 and 2-21. During her time as landing support platoon commander, Captain Murphy also graduated from the Army Basic Airborne Course. Next, she rapidly deployed to Qatar in support of Operations Allies Refuge as the evacuation control center detachment commander alongside senior MARCENT leadership. Lastly, she deployed as the battalion future operations officer on the 13th Marine Expeditionary Unit in support of a WESTPAC 23.1 deployment.

In June 2023, Captain Murphy moved to Monterey, CA to attend the Naval Postgraduate School. She is currently completing her master's degree in defense logistics management, set to graduate in June 2025. While at Naval Postgraduate School Captain Murphy also graduated from non-resident Expeditionary Warfare School.

Captain Murphy's personal awards include the Navy and Marine Corps Commendation Medal. She is married to Captain Michael Murphy who will serve as an operations analyst at the Combat Development & Integration Operations Analysis Directorate upon graduation from the Naval Postgraduate School.

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Thank you to Commander Christopher O’Connor for your invaluable guidance on military operations, logistics, and DoD supporting commands. Your expertise and insight have greatly enhanced my understanding of the operating environment and the transformative potential of data-driven decision models across the joint force.

Lastly, I would like to thank my husband, Deke, who, despite managing his own course load and thesis in the Operations Research Department, supported me unconditionally throughout this academic journey at the Naval Postgraduate School. From the very beginning, you encouraged me to pursue a subject I am truly passionate about, and your unwavering support made this achievement possible. I could not have done it without

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LIST OF ACRONYMS AND ABBREVIATIONS

AB	air base
ARG	amphibious ready group
A2/AD	anti-access/ area denial
CARE	Cooperative for Assistance and Relief Everywhere
CJCS	Chairman of the Joint Chiefs of Staff
DART	disaster assistance response team
DLA	Defense Logistics Agency
DoD	Department of Defense
DOS	Department of State
EABO	expeditionary advanced base operations
EDCA	enhanced defense cooperation agreement
FHA	foreign humanitarian assistance
HA/DR	humanitarian assistance/disaster relief
HQMC	Headquarters Marine Corps
INDOPACOM	Indo-Pacific Command
IOM	International Organization for Migration
JTF	joint task force
MARFORPAC	Marine Corps Forces Pacific
MCPN	Marine Corps Prepositioning Network
MEB	Marine Expeditionary Brigade
MEU	Marine Expeditionary Unit
MHE	material handling equipment
MITAM	mission tasking matrix
MLF	Marine Littoral Regiment
MPF	Maritime Prepositioning Force
MPSRON	Maritime Prepositioning Ship Squadrons
MRF	Marine Rotational Force
MSC	Military Sealift Command
MTVR	medium tactical vehicle replacement
NEO	non-combatant evacuation operations

NGO	non-governmental organization
NM	nautical miles
PRC	People's Republic of China
R2P2	rapid response planning process
SIF	stand-in force
TRAM	tractor rubber-tired articulated steering multipurpose
UNHCR	United Nations High Commissioner for Refugees
USAID	United States Agency for International Development
USTRANSCOM	United States Transportation Command
WFP	World Food Program

EXECUTIVE SUMMARY

The Marine Corps serves a critical role in the country's foreign policy as the expeditionary force in readiness across the range of military operations. The service is expected to respond quickly and effectively, while being equipped with the least number of resources among all military services. With that, the efficient allocation of scarce resources must be considered in all facets of operations.

Among the many challenges faced by the Marine Corps, the adaptation to the new battlefield of the vast Indo-Pacific region ranks highly. The Indo-Pacific is marked by emerging security threats as the social and economic influence of the People's Republic of China (PRC) competes with the worldwide influence of the United States. The region is also marked by distributed island chains and nations that are extremely prone to natural disasters due to its tectonic plate composition and atmospheric weather patterns. For this reason, the Marine Corps' warfighting capability centric modernization efforts are concerning, as they fail to account for the modernization of critical crisis response efforts. The service's new doctrine and guidance do not account for the resources required for timely and effective humanitarian assistance/disaster relief (HA/DR) response efforts in the Indo-Pacific region. This oversight signals a gap in the Marine Corps' ability to respond to a highly vulnerable region of the world that is of strategic significance to the U.S., especially as the great power competition with the PRC continues. The Marine Corps must adapt its doctrine and strategic planning to ensure its ability to effectively counter the influence of adversaries such as the PRC on nations devastated by natural disasters in the region.

The thesis explores prepositioning strategies throughout the Indo-Pacific region, proposing a framework for a logistical network primed for HA/DR response operations. Data collection for the model is focused on identifying historical disaster trends and vulnerable locations in the region, mapping existing Department of Defense (DoD) infrastructure, and assessing critical HA/DR equipment requirements. This research centers around a network model focused on the distribution of five types of equipment (ground transportation assets, vertical lift assets, material handling equipment, generators,

and fuel storage containers) from eight supply nodes (Okinawa, Yokota Air Base, Philippines, Guam, Singapore, Diego Garcia, Darwin, and South Korea) to six demand nodes (Philippines, Indonesia, India, Taiwan, Thailand, and Japan). It uses six mathematical models, each aligned to a specified demand node, and constrained by equipment supply capacities, demand requirements, and loading configuration. The models examine the positioning of Marine Corps transportation, logistics and engineering assets throughout the Indo-Pacific. The objective function of the model framework is to minimize operational costs that are a function of transportation costs and distances between supply and demand nodes. In these models, cost represents more than just money though; it reflects logistical efficiency, effectiveness of resource management, and timeliness of response to natural disasters across the Indo-Pacific.

The approach used in this thesis leverages the hub-and-spoke logistics model, logistics network models, and the linear programming technique to optimize diverse logistical scenarios. The ultimate objective of the models and research is to provide decision-makers with a data-driven approach to HA/DR response planning enabled by prepositioning in the Indo-Pacific. This preposition-focused solution is tailored to be executed by a Marine Expeditionary Brigade (MEB) joint task force (JTF). The models used in this research have potential to serve as a foundation for a decision aid that could be used for wargaming, the rapid response planning process (R2P2), or deliberate planning throughout the force.

The analysis of the six hypothetical HA/DR scenarios revealed that certain DoD-affiliated supply nodes were more frequently utilized, suggesting that resource allocation across the Indo-Pacific is currently suboptimal. Within the findings, Okinawa, Singapore, and the Philippines emerged as the most frequently utilized supply nodes due to their geographic proximity and existing infrastructure. Guam was the least utilized supply node, suggesting inefficiencies in resource allocation. Diego Garcia, South Korea, Yokota Air Base, and Darwin played supporting roles, but their contributions varied based on disaster location and response needs. The outputs of the model suggested that a logistics coalition comprised of the optimal prepositioning sites and associated equipment sets could prove effective in reducing operational costs. Once the models were solved, a time-space analysis was conducted to determine whether critical supplies could make it from each supply node to each demand node in an acceptable amount of time. The U.S. Marine Corps standard for an HA/DR response is to have equipment at the demand site within 72 hours.

This thesis recommends the reallocation of logistics and engineering equipment resources throughout the DoD-affiliated supply nodes to establish a more efficient logistics coalition. Highly utilized supply nodes with lower supply capacities, such as Singapore and the Philippines, should increase their ground transportation, generator, vertical lift, material handling equipment (MHE), and fuel storage capacities. Concurrently, underutilized supply nodes such as Guam, Diego Garcia, and Darwin could effectively reallocate some of those needed resources without degrading their operational readiness. The implementation of these recommendations has potential to aid the Marine Corps in balancing modernization and crisis response capability. This thesis offers prepositioning as a potential solution to HA/DR response in the Indo-Pacific and encourages the use of data-driven decision models in decision-making. Lastly, it highlights the importance of the HA/DR mission set in the Marine Corps as a facet of U.S. foreign policy.

The models in this thesis allow adjustment of parameters like equipment type and node locations to support planning across a range of HA/DR scenarios. They can be tailored to specific units, expanded for broader Marine Corps operations such as campaigning, and adapted for joint operations.

During the writing of this thesis, United States Agency for International Development (USAID) was unfunded and closed by the administration of the 47th President of the United States. This action creates significant uncertainty in the DoD's mission and capability to conduct HA/DR response in the future. Solutions to HA/DR response in the Indo-Pacific, including the one offered in this thesis, will need to adapt to new strategic level guidance once it is released.

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I. INTRODUCTION

The Marine Corps' adaptation to its new battlefield in the Indo-Pacific and its subsequent new doctrine introduces considerable challenges. While many aspects of the service and how it operates require attention and modernization, this thesis focuses on the challenges of humanitarian assistance/disaster relief (HA/DR) response in the Indo-Pacific.

A. MARINE CORPS CRISIS RESPONSE MISSION

The Marine Corps serves as the nation's force in readiness for expeditionary operations across the range of military and non-military operations. This means that it must stand ready to respond to crisis marked by both manmade and natural disasters. The role is twofold in that the force must be capable of both warfighting and conducting crisis response. The Marine Corps' reputation as a force comprised of discipled riflemen who are notably first to fight sometimes overlooks the importance of its crisis response mission. For example, the *38th Commandant's Planning Guidance* only addresses the challenges and modernization efforts for the warfighting mission of the Marine Corps, failing to address its crisis response mission.

The Marine Corps' crisis response mission is composed of two non-military operations: non-combatant evacuation operations (NEO) and humanitarian assistance/ disaster relief (HA/DR). Briefly explained, NEO is the evacuation of non-combatants from life-threatening conditions created by hostile political unrest in a nation, while HA/ DR is conducted after natural disasters devastate a nation and its life-providing infrastructure. In both non-military operations, the U.S. Department of State (DOS) is head of the mission, while the Marine Corps, under direction of the Department of Defense (DoD), serves as a strategic enabler. From 1970–2007, the Marine Corps conducted 29 HA/DR responses, over half of which were in the Indo-Pacific region (United States Marine Corps History Division, 2007). The intricacies of the HA/DR mission set are discussed in Chapter II of this paper.

B. MARINE CORPS FORCE DESIGN

The progression of the People's Republic of China (PRC) as a peer competitor has caused the U.S. military to alter the way that is fights. The Marine Corps force design doctrine was published in 2020 and sent a cultural shock wave across the Corps. The doctrine called for a massive change to the structuring and mission focus of the Marine Corps by the year 2030. Amongst its primary imperatives was to restructure to be a lighter, more versatile force to adapt to the future battlefield of the Indo-Pacific. With that, the 38th commandant released the force design doctrine to rise to the occasion of the United States' new primary competitor, the PRC. Within this document, the 38th commandant tasked Headquarters Marine Corps (HQMC) to update the guidance for the Marine Corps Prepositioning Network (MCPN), tailoring it toward force design and the Indo-Pacific region (Berger, 2019). The research involved in this thesis is in alignment with the 38th commandant's requests to the force.

1. A Shifting Battlefield

Marines spent 20 years fighting in the land-locked desert of the Middle East during the Global War on Terror. Since the last forces were extracted from Afghanistan in August 2021, the Marine Corps' focus has shifted. The force is now preparing to fight within the expansive, distributed maritime environment of the Indo-Pacific as the great power competition with the PRC continues.

The publication of the 38th and 39th commandant's planning guidance, as well as the force design doctrine starting in 2020, prompted multiple attempts for adaptation to the new battlefield of the Indo-Pacific. The establishment of the Marine Littoral Regiment (MLR) and the development of the concepts of the stand-in force (SIF) and expeditionary advanced base operations (EABO) stand at the top of the list for force modernization. EABO is tailored to the anti-access/area denial (A2/AD) mission, where Marines work to deny freedom to maneuver for all adversaries, while the SIF is designed to man these expeditionary advanced bases (U.S. Marine Corps, 2023). These concepts involve the procurement and use of smaller, more technical equipment sets and the concurrent divestment of larger, heavier equipment sets.

The Marine Corps is shifting to a leaner fighting force, the MLR, that does not necessarily support the Marine Corps' mission set of HA/DR, which typically requires large, heavy equipment and, in most cases, a large military response force. Additionally, the new concept of SIF, that changes both the Marine Corps' composition and concept of operations, is not conducive to supporting HA/DR missions. The SIF is characterized by being small, agile, and logistically self-sustaining to the highest degree possible. The projections of the new forces to be employed do not support the Marine Corps' role in the United States' mission as the global 911 force (Berger, 2019). The new force construct of MLRs that are to be stationed in the United States' forward bases in the Indo-Pacific region currently do not have HA/DR spelled out as one of their assigned mission sets.

2. Marine Corps Prepositioning Network

Operating in the dispersed island chain environment within the Indo-Pacific, centered around the South China sea, calls for a high operational tempo and a concurrent stress on the logistics network in the area of operations. To counter the stressed logistics system, the Marine Corps must establish a logistics network in the region (Smith, 2024).

Prepositioning and caching of materials historically has taken form as what has been colloquially called an *iron mountain*. In this logistical model, copious quantities of supplies are concentrated in a single location. It was used throughout the entire Global War on Terror; however, it is increasingly impractical in the Indo-Pacific due to its inability to support dispersed forces across vast areas.

Therefore, prepositioning in the Indo-Pacific, will take on a different form of logistical model, notionally deemed *iron hills* (Katzman, 2022). As seen in Figure 1, this model illustrates how smaller and more abundant stockpiles will be dispersed throughout the battlefield. This modernized, notional concept is in line with the Marine Corps concept of EABO, as it serves to ensure timely support to distributed forces. The *iron hill* method also reduces the risk of catastrophic losses, particularly in contested environments where logistics hubs are prime targets (Katzman, 2022).

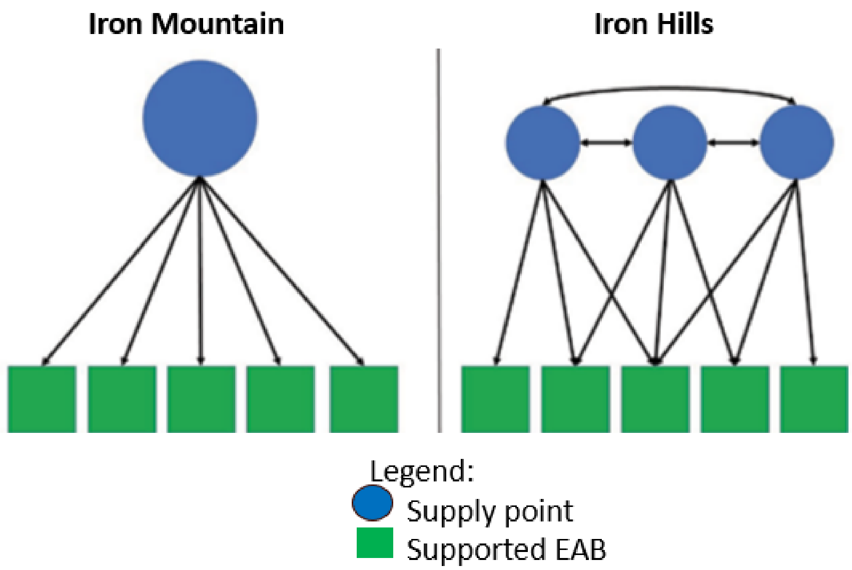

Figure 1. Notional supply and distribution networks. Source: Katzman (2022, p.16).

Although the force design doctrine does not explicitly address crisis response, it does contain some initiatives that have the potential to degrade the Marine Corps' crisis response mission set, such as the use of smaller equipment sets, and some initiatives that could mutually support crisis response missions, such as prepositioning (Berger, 2019). This research focuses on the use of prepositioning to further enhance the logistics coalition in the Indo-Pacific Command (INDOPACOM) region in support of the Marine Corps' role in HA/DR. It serves as another potential solution to solving the larger problem at hand of operating in the Indo-Pacific.

The Marine Corps is currently not equipped to both modernize and continue its robust crisis response mission set within the Indo-Pacific. It must ensure that its modernization effort has at least a subtle undertone of crisis response. Knowing that, this research consistently takes the force's modernization and the services' warfighting mission into effect. Warfighting and crisis response missions must be mutually supportive to yield success in the distributed maritime environment that characterizes the Indo-Pacific. Success in the Indo-Pacific hinges on leveraging capabilities dispersed throughout the joint force, inclusive of all military branches and various DoD-affiliated commercial organizations, such as the Defense Logistics Agency (DLA) and the Maritime Prepositioning Force (MPF).

3. Challenges in the Indo-Pacific

The vast distances and dispersed geography of the Indo-Pacific theater present unique challenges for transportation networks and supply chains. The make-up of the region threatens the HA/DR response capabilities of the DoD, specifically the Marine Corps. These challenges demand more resilient logistics solutions, such as prepositioning. This research recognizes that the DoD has conducted a multitude of HA/DR responses in the Indo-Pacific, however, it adds that a layer of complexity is added with the growing geopolitical tensions in the region and the force reconstruction. As seen in Figure 2, the geography of the Indo-Pacific is marked by distributed island chains alongside the coast of Asia, many of which border China.

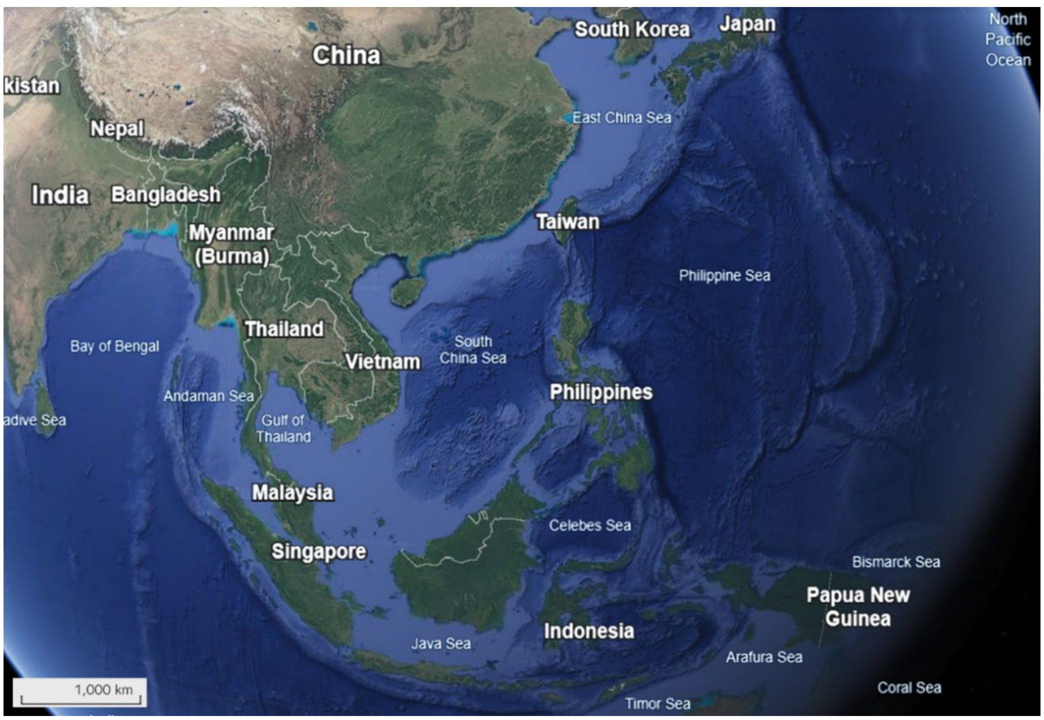

Figure 2. Map of the Indo-Pacific region. Source: Google Earth (2025).

This complex distributed maritime environment combined with rising geopolitical tensions introduces new challenges for logistical missions and reinforces the importance of a well-designed logistics coalition for rapid response.

a. Contested Logistics

As articulated by the 39th Commandant of the Marine Corps, the PRC employs tactics that challenge the international rules-based order. They aim to undermine the current world order, increasing their sphere of influence socially, economically, and politically (Economy, 2022). China's global infrastructure development strategy, deemed its belt and road initiative, drives the PRC's efforts to impart influence worldwide and to create a China dependent global supply chain (Economy, 2022). The PRC's actions and efforts foreshadow continued attempts to disrupt U.S. influence in the Indo-Pacific region.

The response required to effectively deter the PRC's influence includes enhancing expeditionary capabilities to support deterrence, crisis response, and joint operations within a whole-of-government framework (Smith, 2024). The concept of contested logistics is that transportation and resupply missions are both delayed and disrupted by enemy forces in the name of competition. Therefore, these missions cannot be treated as routine in any sense. Logistical missions must be conducted with the knowledge that they are being targeted by the enemy. The Marine Corps should also prepare for these same disruptions of logistical missions in non-military operations such as HA/DR.

The Indo-Pacific offers an abundance of complex challenges both geographically, geopolitically, and threat-wise. The Marine Corps and the United States have more work to do before considering themselves ready for the next fight or response in the region.

C. THESIS MOTIVATION

HA/DR operations are complex due to unpredictable demand for equipment, supplies, and personnel in combination with the need for rapid response. These complexities are exaggerated in the Indo-Pacific, considering the region's expansive maritime geography and rising geopolitical tensions. In this region, access to resources and transportation routes are often disrupted by adversaries, exemplifying the concept of contested logistics and further complicating the DoD's ability to operate. This research addresses the Marine Corps' critical role in HA/DR within the Indo-Pacific amidst contested logistics. The purpose is to address a critical gap in the Marine Corps' force restructuring as it shifts its primary focus onto operations in the Indo-Pacific by developing a framework to enhance disaster response. The research centers around a network model focused on the distribution of five types of equipment from eight supply nodes (Okinawa, Yokota AB, Philippines, Guam, Singapore, Diego Garcia, Darwin, and

South Korea) to six demand nodes (Philippines, Indonesia, India, Taiwan, Thailand, and Japan). The model builds on the current network that is in place while bringing attention to potential inefficiencies and oversights.

This thesis aims to address the following research question: How can the Marine Corps best posture itself for inevitable HA/DR response in the Indo-Pacific while taking the changing operational environment and contemporary force design doctrine into account?

Using the linear programming technique in Microsoft Excel, the models optimize resource allocation given the geographic location and capacities of designated supply nodes in relation to the needs and location of a specified demand nodes. The results and analysis of the six models aim to identify critical gaps in the current prepositioning network, proposing an optimized solution. The research integrates concepts from logistics and network models, hub-and-spoke models, and transshipment logistics to optimize the rapid deployment of equipment in the region. The models developed in this thesis are designed to serve as a framework for a future model that could be used for wargaming, the rapid response planning process (R2P2) and the deliberate planning process in the Marine Corps.

This thesis leverages prepositioning as a strategic enabler for HA/DR missions in the Indo-Pacific. The prepositioning-based course of action recommended throughout this thesis is designed to be used by a Marine Expeditionary Brigade (MEB) joint task force (JTF). It also serves as a potential solution to enhancing Marine Expeditionary Unit (MEU) operations as some of the service's larger equipment is phased out in accordance with force design doctrine.

The top five objectives for this thesis are as follows:

1. Conduct data collection and analysis to identify DoD logistics supply nodes in the Indo-Pacific as well as vulnerable demand nodes that are susceptible to catastrophic natural disasters in the Indo-Pacific region.
2. Create mathematical models designed to identify the optimal logistics coalition for specified HA/DR scenarios considering constraints. These models shall closely resemble hub-and-spoke models and will be computed using the linear programming technique in Microsoft Excel.

3. Optimize multiple logistical scenarios focused on HA/DR to provide useful conclusions for future prepositioning planning and assess the effects of having various prepositioning sites with various equipment sets.
4. Contribute to the enhancement of military supply chain resilience amid a contested logistics situation. Identify gaps in the logistics coalition to propose restructured prepositioning load outs to fill the gaps. Aid in the efficient allocation of resources within the DoD.
5. Develop a framework for a data-driven design-making model that can be altered and used by military leadership ashore or afloat for HA/DR planning and/or response.

The implementation of this research and its methods have the potential to enhance the Marine Corps' ability to conduct HA/DR missions in the Indo-Pacific region. By proactively addressing resource shortfalls, it works to enable more efficient responses to natural disasters in the region. The models created in this thesis prioritize the use of already existing DoD infrastructure and make recommendations for resource reallocation to optimize responses. Their findings have the potential to shape strategic decisions on prepositioning locations and equipment configurations, directly impacting the readiness of DoD supply nodes. This research aligns with the DoD's strategic objectives by strengthening the Marine Corps' presence and influence in the Indo-Pacific while fostering regional stability through enhanced disaster response capabilities.

D. THESIS ORGANIZATION

This thesis consists of six chapters: Introduction, Humanitarian Assistance/ Disaster Relief, Data Collection, Model Formulation, Analysis, and Conclusion and Future Work. Now that the background, motivation, and objectives have been discussed, this paper moves on to the intricacies and strategic importance of U.S. HA/DR efforts. Then, within the Data Collection Chapter, there is a discussion of historical natural disasters and the current DoD infrastructure in the Indo-Pacific region to determine the demand and supply nodes. There is also a discussion on critical DoD equipment that is used in HA/DR responses to determine the equipment to be used in the model. The chapter concludes with the selection of the supply and demand nodes to be used in the mathematical model.

From there, a discussion of hub-and-spoke logistics, network models, and linear programming lay the conceptual foundation for mathematical models. The models are formulated based on data collection from open-source documents and networks, and the use of mathematical calculations. Then this thesis discusses the results of the model outputs and offers an analysis. It recommends the optimal logistics coalition, then, finally, draws conclusions based on the analysis and discusses the potential future work to be done with this research topic.

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II. HUMANITARIAN ASSISTANCE/DISASTER RELIEF

Foreign humanitarian assistance (FHA) is defined in the Foreign Assistance Act of 1961 as "assistance to meet humanitarian needs, including needs for food, medicine, medical supplies and equipment, education, and clothing" (Committee on International Relations & Committee on Foreign Relations [CIR & CFR], 2003, p. 3). It serves to aid foreign countries that have been stricken by disaster and require outside assistance to restore their life-sustaining infrastructure and capabilities. FHA is designed to augment host nation efforts to achieve unity of effort (Chairman of the Joint Chiefs of Staff [CJCS], 2019). The HA/DR mission is multi-faceted and is not successful without the planning, coordination, and response of many different agencies throughout the United States and other partner nations. There are a multitude of agencies involved in the HA/DR response (CJCS, 2019). The Department of State (DOS) takes the lead on foreign crisis response missions, serving as the primary liaison between the U.S. government and the host nation requiring a response. The military's involvement in HA/DR responses is sometimes even funded by the DOS. The United States Agency for International Development (USAID) is a facet of the DOS and is designated specifically as the lead agency for coordinating foreign disaster relief (CJCS, 2019).

Common non-governmental organizations (NGOs) involved in foreign humanitarian assistance are the World Food Program (WFP), the International Red Cross, and the Cooperative for Assistance and Relief Everywhere (CARE). An NGO is a private, non-profit organization that is committed to alleviating human suffering (CJCS, 2019). Alongside NGOs, various multinational organizations play a vital role in HA/DR responses, notably the United Nations High Commissioner for Refugees (UNHCR) and International Organization for Migration (IOM). Together, NGOs and multinational organizations deliver critical aid to natural disaster-affected areas, providing essential commodities such as food, water, medical supplies, clothing, shelter, and sanitation services. The DoD, as directed by the secretary of defense, serves as an enabler to the government, NGOs, and multinational organizations. An HA/DR response cannot be initiated without a request from the host nation and approval of the host nation's ambassador. This authority flows through the DOS, who then requests support from the

DoD if required. U.S. military forces can only conduct FHA missions at the request of USAID, making the agency an essential partner in HA/DR response.

A. THE U.S. MILITARY IN HA/DR

The role of the DoD in disaster relief operations is defined in the Foreign Assistance Act of 1961 (CIR & CFR, 2003). Since a primary objective of U.S. foreign policy is to protect the security of American people, the DoD shall maintain a community of nations by “using wisely the world’s limited resources in an open and equitable international economic system” (CIR & CFR, 2003, p. 5). This means that it is in the interest of U.S. safety and security to ensure that the United States’ community of allies and partners is free from unnecessary suffering. The United States has an obligation to promote conditions in which its partners and allies can achieve self-sustaining economic growth (CIR & CFR, 2003).

The scope of this research focuses on military assistance in the mission of HA/DR response, which is only one of many actions that should be carried out to abide by this portion of U.S. foreign policy. With that, chapter two of the Foreign Assistance Act of 1961 states that the president authorizes military assistance on certain terms to aid any friendly country or international agency that will bolster national security and cultivate world peace (CIR & CFR, 2003). Within the range of options is to assign members of the U.S. military to “perform duties of non-combatant nature” (CIR & CFR, 2003, p. 6). Additionally, the United States military is mandated to support the efforts of the USAID (CIR & CFR, 2003). The military receives tasking for response support by the submission of a mission tasking matrix (MITAM) to the DoD by USAID and other civil-military planners. The DoD then plans and executes their tasks and report progress to the DOS head of mission (JTF 505, PowerPoint slides, June 2015). DoD agencies are typically augmented by disaster assistance response teams (DART) from USAID for the planning and execution of responses. An important distinction of the military’s role in HA/DR response is that it transitions relief efforts to the host nation government and NGOs when appropriate (JTF 505, PowerPoint slides, June 2015). The military is not a long-term response solution to natural disasters.

The MEU is a Marine Air Ground Task Force (MAGTF) that is deployed on an amphibious ready group (ARG) comprised of three naval amphibious vessels and serves as the premier crisis response unit in the Marine Corps. Prior to the release of the force design doctrine, it was implied that a MEU would carry the equipment needed for HA/DR response. However, with the force restructuring, the presence of large, heavy equipment such as medium tactical vehicle replacement (MTVR) 7-ton trucks and material handling equipment (MHE) is not a given. Additionally, with the recent amphibious warfare vessel readiness issues, there is no guarantee that a MEU is reliably capable of response (Maurer & Oakley, 2024). The proposed logistics coalition enabled by prepositioning serves as a supporting effort for the MEU.

Aside from the MEU, INDOPACOM has a JTF who stands ready to respond to humanitarian crises in the Indo-Pacific region. The Marine forces who stand to support this JTF originate from Marine Forces Pacific (MARFORPAC). When they receive formal tasking from the DOS, they develop a table of organization for personnel and a table of equipment to meet mission requirements (JTF 505, PowerPoint slides, June 2015). The prepositioning focused solution developed throughout this thesis is tailored to fulfill the equipment requirements of the HA/DR response by the JTF.

B. HUMANITARIAN LOGISTICS

Humanitarian logistics is defined as the logistical operations carried out in preparation for response to natural and manmade disasters. It is one of the facets of the HA/DR responses conducted by the DoD. The supply chains used for humanitarian logistics are some of the most involved in the world, driven by numerous uncertainties and the urgency of response (Apte, 2009, p. 9). Common unknown factors revolve around the amount of personnel affected and in what ways, the status of critical infrastructure, and the contributions from all responding government organizations and NGOs. Fundamentals to logistics planning for disasters that result in the need for humanitarian aid are knowing and having ready the necessary commodities required and understanding the planning priorities (Ozdamar & Ekinci, 2004). Necessary commodities in humanitarian logistics missions include but are not limited to medical supplies, specialized rescue equipment, vehicles, food, and water (Ozdamar & Ekinci, 2004).

Planning priorities include but are not limited to quantities of commodities required and quantities available, origins and destinations of the supplies to be transported, modes of transportation, and transportation timelines (Ozdamar & Ekinci, 2004). Common obstacles that arise within humanitarian logistics are limited supply, inability to accurately forecast demand, unpredictable vehicle routes, and damages to infrastructure required for transportation. (Ozdamar & Ekinci, 2004).

There is a multitude of coordination among many organizations that must occur to carry out humanitarian logistics missions successfully. The coordination and planning required is deliberated through logistics experts who face challenges with multimodal transportation and task prioritization (Ozdamar & Ekinci, 2004). Proactively prepositioning supplies in the most optimal locations is an effective method of decreasing the human suffering caused by natural disasters (Apte, 2009, p. 8). Studies in logistics show that locations of distribution centers for critical equipment and supplies are the most principal factor while providing services under uncertainty. Complexity and risk can be mitigated with the use of various models and real time information sharing (Ozdamar & Ekinci, 2004).

HA/DR response is an important non-military operation that enables the conduct of humanitarian logistics missions. It is vital to the safety and security of the United States. Humanitarian logistics is an important facet of the nation's operations in the Indo-Pacific region as it positively contributes to relationships with strategic allies. The PRC has threatened the relevancy of the U.S. in this critical mission, foreshadowing the stand up of bases in Cambodia, Myanmar, Thailand, Singapore, Indonesia, Pakistan, Sri Lanka, United Arab Emirates, Kenya, Seychelles, Tanzania, Angola, and Tajikistan. (DoD, 2021). If the PRC does this successfully, they could respond to disasters within the countries of U.S. partners and allies and indebt them into a willing or unwilling relationship with the PRC, further threatening U.S. strategic dominance.

III. DATA COLLECTION

Within this chapter, the foundation of the six mathematical models used in this thesis is laid by the selection of demand and supply nodes, as well as the selection of an HA/DR response focused equipment set. To keep this research unclassified, there were a multitude of assumptions and approximations made when collecting data; these are explained in Chapter IV.

A. DEMAND NODES

The demand nodes selected in this thesis are representative of Indo-Pacific locations requiring resources due to the impact of natural disasters. These locations are selected based on historical disaster patterns indicating vulnerability and the strategic relationships of their respective countries with the United States. Each of the six chosen demand nodes will have an individual model to optimize HA/DR response.

1. Disasters in the Indo-Pacific

The Indo-Pacific is inherently situated to generate natural disasters. The region is geologically characterized by active tectonic plates in both the Pacific and Indian Oceans, which have served as catalysts for tsunamis and earthquakes (Economic and Social Commission for Asia and the Pacific [ESCAP], 2015). Additionally, both oceans are renowned for the onset of tropical cyclones and typhoons due to their warm temperatures and strong prevailing winds. The weather systems in this subregion are also driven by monsoon variability, which leads to seasons of both flood and drought (ESCAP, 2015). Throughout history, there has been a plethora of natural disasters, inclusive of typhoons, tsunamis, floods, heatwaves, and earthquakes, in the Indo-Pacific. Over the years, these natural disasters have devastated the populations and infrastructure of U.S. partners and allies in the Southeast Asian region of the world. According to Asia-News (2023), in the last 50 years, disaster-related deaths have surpassed two million, primarily from typhoons, tsunamis and earthquakes.

As seen in Figure 3, Asia and the Pacific region experienced 2.04 million deaths from disaster-related causes from 1970–2022, while the rest of the world experienced

1.42 million disaster-related deaths. These numbers mean that approximately 59% of the world's disaster-related deaths occurred in the Asia Pacific region throughout this period. According to the United Nations' ESCAP, with over half of the world's disaster-related deaths, the Indo-Pacific region is considered the most vulnerable region of the world (Asia-News, 2023).

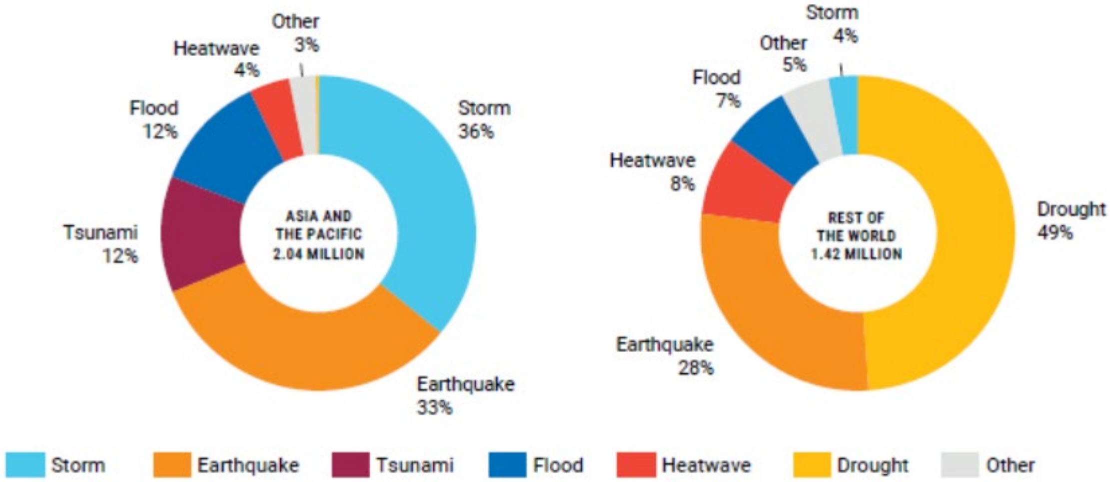

Figure 3. Number of fatalities from disasters in the Indo-Pacific region and the rest of the world from 1970–2022. Source: Emergency Events Database (2023).

As seen in Figure 4, between 1970 and 2014, over 5,000 natural disasters, inclusive of but not limited to, floods, earthquakes, tsunamis, and landslides, occurred in the Indo-Pacific region.

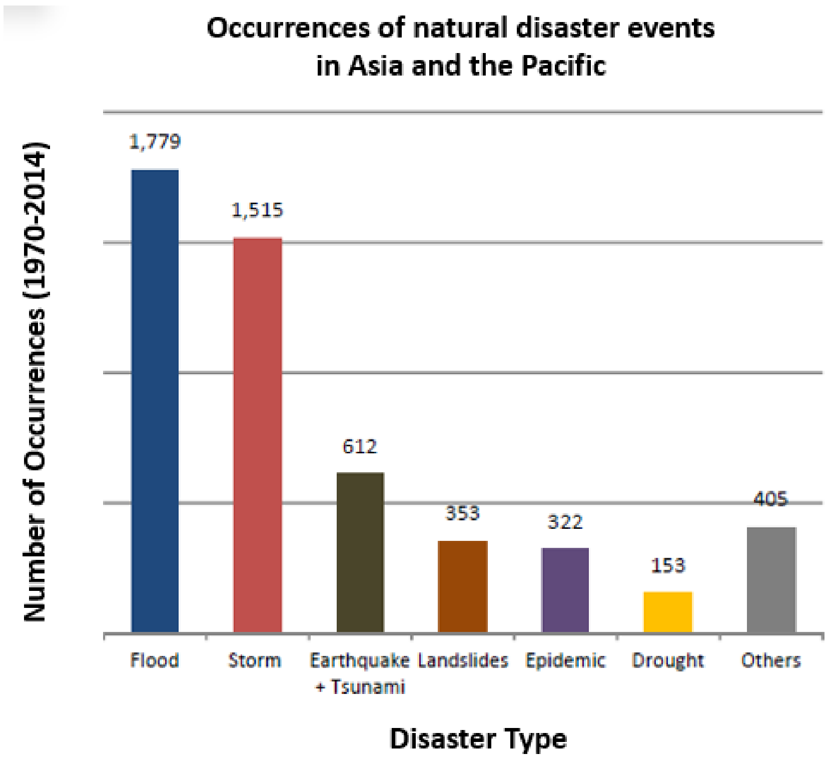

Figure 4. Occurrences of natural disaster events in Asia and the Pacific by type from 1970–2014. Source: Emergency Events Database (2015).

The impact of these disasters on people and economies was catastrophic, resulting in deaths in the hundreds of thousands and losses equivalent to millions of U.S. dollars for each occurrence. The effects led to a decline in the prosperity of the affected countries, leaving them extremely vulnerable. The disasters in the region are expected to increase in frequency as global temperatures continue to rise. Despite increased forecasting efforts since 2020, these regions are still expected to face peril from future disasters (Asia-News, 2023). Additionally, the increased forecasting efforts can only prevent so much in this densely populated region in which poverty forces many to settle in vulnerable areas like flood plains (ESCAP, 2015). Each natural disaster that strikes threatens to degrade these nations' abilities to recover, leaving them vulnerable to accepting assistance from U.S. adversaries such as the PRC, whose vows to aid the affected nations come at a significant cost.

2. Historical Disasters

The following list of historical natural disasters in the Indo-Pacific is not exhaustive and prioritizes U.S. allies and nations of strategic interest to the U.S. government.

- Taiwan's 1999 Chi Chi Earthquake caused the deaths of over 2,400 people and decimated infrastructure throughout the island (Wingfield-Hayes, 2024).
- The 2004 Indian Ocean tsunami affected Sumatra, Indonesia, Chennai, India, and the coast of Myeik in Thailand, killing over 220,000 people (ESCAP, 2015).
- The 2010 Pakistan and India flood was initiated by a severe monsoon season. The flood destroyed upwards of 1.8 million homes, leaving 11 million homeless (United Nations High Commissioner for Refugees, International Federation of Red Cross and Red Crescent Societies, & United Nations Settlements Programme, 2010).
- The Great Sendai (Tohoku) Earthquake, also known as the Great East Japan Earthquake, killed over 20,000 people, and displaced around 369,000 in 2011 (ESCAP, 2015). This magnitude-9.0 earthquake ruptured land and flooded parts of the city of Sendai in 2011 (Rafferty, 2016).
- The 2011 Thailand flood was caused by a combination of rainfall from monsoon season and rainfall from the remnants of nearby tropical storms (Gale & Saunders, 2013). Its flood magnitude was 7.5 and had effects that lasted 158 days.
- The super-typhoon Haiyan affected Manila, Philippines, and cities in India in November 2013, killing over 6,000 people and displacing close to four million people (ESCAP, 2015).
- The 7.4-magnitude Taiwan earthquake ruptured the city of Hualien in 2024 (Wingfield-Hayes, 2024).
- The magnitude 7.7 earthquake in Thailand and Myanmar that occurred in March of 2025, killing over 2,000 people (Lendon & Stambaugh, 2025).

Figure 5 shows the devastating effects of the Tohoku earthquake that struck Japan in 2011. The picture illustrates damage to roads, buildings and other critical infrastructure such as power lines.

Figure 5. Image showing the effects of the 2011 Tohoku earthquake on a metropolitan area of Japan. Source: Carbutt (2011).

There is no way to truly portray the devasting effects of a natural disaster on a nation through a photograph, however it does give a general framework to understand the scope of catastrophe for a nation. A large-scale natural disaster destroys buildings, roads, homes, taints water systems, and kills, displaces, and injures the population. Nations are often left in dire need of medical, logistical, and engineering support.

3. Demand Node Selection

The demand nodes were selected based on a cross-reference of vulnerable countries, as determined by the location of historical disasters in the Indo-Pacific and the Indo-Pacific Economic Framework. The Indo-Pacific Economic Framework brings together nations dedicated to promoting growth, peace, and prosperity (The White House, 2022). Member countries include the United States, India, Indonesia, Japan, the Philippines, Vietnam, Thailand, the Republic of Korea, Malaysia, Australia, Singapore, New Zealand, and Brunei Darussalam (The White House, 2022). With that, the chosen demand nodes are as follows:

- Philippines
- Indonesia
- India
- Thailand
- Japan
- Taiwan

The only country that was designated as a demand node that is not a part of the framework is Taiwan. This exception was made due to its strategic relevance in the great power competition.

As seen in Table 1, the demand nodes are categorized as countries and the associated grid coordinates used in the model are representative of specific locations in that country that were subject to natural disasters throughout history.

Table 1. Demand node locations, grid coordinates used in the research, and the actual location of the grid coordinate within the demand node location

Demand Node	Grid Coordinates	Actual Location Used
Philippines	14.599, 120.985	Manilla
Indonesia	-1.604, 103.973	Sumatra
India	13.087, 80.268	Chennai
Thailand	12.524, 98.794	Coast of Myeik
Japan	38.259, 140.886	Sendai
Taiwan	24.060, 121.325	Hualien

B. SUPPLY NODES

The supply nodes in this model are representative of Marine Corps bases, Marine Rotational Force (MRF) locations, Defense Logistics Agency (DLA) disposition centers, and Maritime Prepositioning Force (MPF) assets across the Indo-Pacific.

1. Marine Corps Infrastructure and Presence in the Indo-Pacific

The Marine Corps maintains several bases and strategic presences across the Indo-Pacific region. Currently, the primary base in the region is located on the island of Okinawa, Japan, serving as home to the 31st MEU and the 3rd MLR. Additionally, Guam hosts a Marine Corps base that supports elements of the 3rd MLR alongside a naval base.

This base, named Camp Blaz, is undergoing development as personnel and equipment transition from Okinawa to Guam (Yamaguchi, 2024).

The Marine Corps also deploys MRFs to strategic locations within the Indo-Pacific to train alongside partners and stand ready for response. These forces, such as the MRF Darwin (MRF-D) in Australia and the newly established MRF Southeast Asia (MRF-SEA) in Singapore, conduct regular 6-month rotations (Boyd, 2023). These deployments enhance interoperability through joint exercises and ensure the forces are ready to respond to crises and contingencies. There is a constant presence of both personnel and equipment in these locations.

2. Supporting Commands in the Indo-Pacific

The Indo-Pacific region hosts multiple DoD commands crucial to supporting U.S. armed forces operations overseas. This research focuses on two key organizations in the development of a logistics coalition for HA/DR response: DLA and the MPF.

According to the DLA, it manages the global defense supply chain, supporting all military branches, combatant commands, and allied nations. It operates disposition centers in Okinawa, Japan; Guam; Diego Garcia; Yokota, Japan; and Camp Henry in Daegu, South Korea in the Indo-Pacific region (Defense Logistics Agency [DLA], 2025).

The MPF is a part of the U.S. Navy's Military Sealift Command (MSC) that is subordinate to the U.S. Transportation Command (USTRANSCOM) (Military Sealift Command [MSC], n.d.). The MSC has a prepositioning program, titled, PM3, that strategically stores military supplies aboard ships "in key ocean areas to ensure rapid availability during a major theater war, a humanitarian operation or other contingency" (MSC, n.d.). The MPF consists of two Maritime Prepositioning Ship Squadrons (MPSRONs) strategically stationed in Guam and Diego Garcia. These squadrons maintain essential supplies onboard commercial ships with roll-on, roll-off capability, supporting the Army, Navy, Air Force, Marine Corps, and DLA (MSC, n.d.). The roll-on, roll-off capability is crucial for rapid equipment deployment during military and non-military operations.

Lastly, according to the enhanced defense cooperation agreement (EDCA), HA/DR-focused warehouses are strategically positioned throughout the Philippines to store DoD equipment for crisis response within the region (U.S. Embassy in the Philippines, 2023). The HA/DR focused warehouses are located on Basa Air Base (AB), Pampanga in Luzon and on Lumbia Air AB, Cagayan De Oro in Mindanao (U.S. Embassy in the Philippines, 2023).

3. Supply Node Selection

The selection of supply nodes was based on a comprehensive evaluation of existing and planned DoD infrastructure in the Indo-Pacific, including Marine Corps bases, DLA disposition centers, MPF assets, and specialized HA/DR warehouses. These nodes fulfill multiple critical roles:

- hosting U.S. DoD infrastructure
- existing in proximity to areas vulnerable to natural disasters
- possessing the necessary infrastructure to store critical goods and equipment
- demonstrating U.S. presence through military bases or bilateral/multinational exercises

While HA/DR may not be a primary mission for some units and DoD commands outlined in this section, Joint Publication 3-29 emphasizes the importance of considering all potential supply sources, including affected countries, commercial entities, multinational partners, and pre-positioned supplies (CJCS, 2019). This research aims to showcase the capability of these units to play a pivotal role in a logistics coalition for HA/DR response, thereby positioning this role as a contingency responsibility. The supply nodes chosen are as follows:

- Okinawa, Japan
- Guam
- Singapore
- Diego Garcia
- Yokota Air Base, Japan
- Darwin, Australia
- Camp Henry, South Korea
- Mindanao, Philippines

As shown in Table 2, the supply nodes are defined as specific locations within various countries. The associated grid coordinates used in the model represent selected sites within those countries that host U.S. forces and equipment.

Table 2. Supply node locations, grid coordinates used in the research, and the actual location of the grid coordinate within the supply node

Supply Node	Grid Coordinates	Location Used for Coordinates
Okinawa, Japan	26.277, 127.766	Marine Corps Air Station Futenma
Guam	13.423, 144.657	DLA Disposition Center Guam
Singapore	1.328, 104.017	Changi Naval Base
Diego Garcia	-7.310, 72.465	Point Marianne
Yokota Air Base, Japan	35.743, 139.341	Yokota AB DLA Disposition Center
Darwin	-12.447, 130.981	MRF Campground
Camp Henry, South Korea	35.853, 128.601	Camp Henry
Mindanao, Philippines	8.411, 124.611	Cagayan De Oro Airport

C. CRITICAL DOD EQUIPMENT IN HA/DR RESPONSE

HA/DR is a multi-dimensional operation with support from the DOS, specifically USAID, and various other NGOs. The DoD serves to enhance the response but is not the lead responder by any means. With that, there is a typical capability, and associated equipment set the DoD is called on to provide. The selected DoD organization typically provides support and combat service support forces inclusive of engineers, military police/security forces, logistics, transportation, legal services, chaplain services, civil affairs, public affairs, and medical services (CJCS, 2019). With a focus on the equipment sets rather than the personnel, requested equipment falls into the categories of engineering, transportation, and medical services. Among the typically requested equipment set is 5+ ton trucks (transportation/ logistics), vertical lift (transportation/ logistics), forklifts (engineering), bulldozers (engineering), fuel storage (engineering/ logistics), generators (engineering/logistics), and medical infrastructure (medical services); (McCall, 2006). This research focuses only on engineering and transportation/ logistics–focused equipment, making the bold assumption that medical equipment will be provided by another DoD source or by an NGO.

From the discussion regarding critical DoD equipment used in HA/DR response, five key equipment categories were selected, all within the Marine Corps' inventory to align with the project's scope. Each category features a single type and variant of equipment, chosen to simplify considerations like weight and transport costs. These categories encompass vital capabilities such as ground and air transportation for personnel and equipment, equipment handling and debris management, as well as power generation and refueling. The equipment to be used in the model is as follows:

- ground transportation assets, represented by the MTVR 7-ton MK23 variant
- vertical lift assets, represented by an empty MV-22B Osprey helicopter
- MHE, represented by a tractor rubber-tired articulated steering multipurpose (TRAM) with forklift attachment
- generators, represented by the MEP-802A (dry) with MEPDIS power distribution box
- fuel storage, represented by the fuel sixcon tank module (full) with its pump set

The weights of the equipment variants in Table 3 were taken from the associated technical manuals. The equipment weights are involved in the calculations used to estimate the transportation cost of each type of equipment between supply and demand nodes. With that, the values in Table 3 will be used in Chapter IV to calculate the objective function of each model.

Table 3. Summary of weights used for equipment transportation cost estimates in the model

	Ground transportation assets	**Vertical lift assets**	**MHE**	**Generators**	**Fuel storage**
Equipment used to estimate	MTVR 7-ton, MK23 Variant	empty MV-22B	TRAM with forklift attachment	MEP-802A (dry) with MEPDIS power distribution box	fuel sixcon tank module (full) + pump set
Weight (lbs)	62200	33140	40709	840	9770

D. SUPPLY CAPACITIES AND DEMAND REQUIREMENTS

The mathematical models in this thesis are designed for optimal resource allocation, emphasizing the supply capacity of supply nodes and the demand requirements of demand nodes. The supply capacities are simply the amount of each type of equipment available at each supply node. Similarly, the demand requirements are the amount of each type of equipment that is required for a proper HA/DR response at each of the demand nodes.

1. Supply Node Capacities

The amount of each type of equipment present at each supply node represents an estimate of deployable resources available for a HA/DR response scenario. The supply capacity of each node serves as a constraint in the models, ensuring that no node exceeds its supply capabilities.

The numbers in Table 4 denote the number of each specific type of equipment theoretically available at each of the eight supply nodes for the purpose of this thesis. These numbers were approximated based on the tables of equipment of various units that have been stationed or deployed to these bases/ regions between 2021–2024.

Table 4. Summary of equipment supply capacities for each supply node by equipment type

	Supply Capacities (# of pieces of equipment)				
	Ground transportation assets	Vertical lift assets	MHE	Generators	Fuel storage
Okinawa	65	24	65	130	30
Yokota AB	10	100	10	20	25
Philippines	5	0	5	10	3
Guam	15	24	15	30	10
Singapore	7	12	7	14	5
Diego Garcia (MPF)	150	0	150	300	100
Darwin	15	12	15	30	5
Korea	15	6	15	30	5

2. Demand Node Requirements

The equipment demanded by each of the demand nodes in the model was derived from information discovered in the assessment of responses to various historical natural disasters. For this research, demand is predicted by a large natural disaster that affects upwards of 60,000 people, kills 7,500, injures 22,000 people, destroys 700,000 structures and damages 200,000 structures. The disaster is assumed to render host nation power infrastructure ineffective for providing necessary life services. The DoD response to this disaster is assumed to last 14 days. Demand for all six demand nodes is assumed to be identical due to the similarities in geography, natural disaster vulnerability, and population density of each of the demand nodes. This thesis assumes that a natural disaster at any of the six demand nodes will result in a large equipment demand requirement.

Table 5 shows the approximated demand requirements for each of the demand nodes in the model. The demand requirements of a demand node are highly variable dependent on the operational scenario. However, the models used in this thesis will all use the same demand requirements for the sake of simplification and comparison for analysis.

Table 5. Summary of equipment demand estimates for demand nodes by equipment type

Demand Requirements (# of pieces of equipment)				
Ground transportation assets	Vertical lift assets	MHE	Generators	Fuel storage
50	20	25	150	20

E. TRANSPORTATION COSTS

Transportation cost is represented as the cost per pound per mile. This estimate is based on open-source data, with sea freight costs set at $0.02 per pound per mile—within the broader range of $0.01 to $0.10 per pound per mile. The lower-end estimate was intentionally chosen to avoid skewing the model with higher costs typically associated with transporting large commercial goods. The chosen constant of $0.02 per pound per mile is first multiplied by the weights of each equipment type shown in Table 3, producing the cost of transporting a single piece of equipment. Next, the cost of transporting a single piece of equipment is multiplied by the distance between nodes in nautical miles (nm).

The distances between nodes were calculated using the great circle method, based on grid coordinates obtained from Google Earth. The Haversine formula was applied using the latitude and longitude of each location to approximate these distances (Upadhyay, 2019). However, these calculations do not account for navigational obstacles and may not reflect the actual routes naval vessels would take in a crisis response scenario. The transportation costs of these six models are therefore positively correlated with the distance traveled between supply and demand nodes.

A summary of calculated distances, in nm, between each supply and demand node is depicted in Table 6. The equipment weights, sea freight transportation unit cost constant, and distances between supply and demand nodes were combined to produce the costs of transporting a single piece of equipment from supply nodes to the specified demand node.

Table 6. Summary of great circle distances between supply and demand nodes as nautical miles

		Supply Nodes							
		Okinawa	Yokota AB	Philippines	Guam	Singapore	Diego Garcia	Darwin	Korea
Demand Nodes	Philippines	797	1,608	428	1,380	1,283	3,173	1,728	1340
	Indonesia	2168	2990	1,042	2584	175	1916	1733	2637
	India	2782	3447	2,627	3751	1578	1309	3386	2936
	Taiwan	374	1284	958	1469	2189	3377	2317	802
	Thailand	1830	3014	1,547	2851	740	1989	2715	2124
	Japan	978	167	2,000	1504	3072	3643	3126	605

Table 7 depicts the cumulative unit transportation costs for the Indonesia response model. Each of the six demand nodes have their own model, each warranting a cost table that mirrors Table 7. The costs within the matrix were calculated using the following formula: miles from node to node * (equipment weight * sea transportation price per pound per mile) = price to transport a single piece of equipment from supply node to demand node. These numbers are used to compute the models' objective functions that will be explained in Chapter IV. The data collected throughout this chapter is now used in the formulation of the network models and mathematical models.

Table 7. Cost of transporting a single piece of equipment (by type) by sea from each supply node to Indonesia

Cost of transporting a single piece of equipment by sea to Indonesia								
Equipment Type	Supply Nodes							
	Okinawa	Yokota AB	Philippines	Guam	Singapore	Diego Gracia	Darwin	South Korea
Ground Transportation	$2,696,992	$3,719,560	$1,296,248	$3,214,496	$217,700	$2,383,504	$2,155,852	$3,280,428
Vertical Lift	$1,436,950	$1,981,772	$690,638	$1,712,675	$115,990	$1,269,925	$1,148,632	$1,747,804
MHE	$1,765,142	$2,434,398	$848,376	$2,103,841	$142,482	$1,559,969	$1,410,974	$2,146,993
Generator	$36,422	$50,232	$17,506	$43,411	$2,940	$32,189	$29,114	$44,302
Fuel Storage	$423,627	$584,246	$203,607	$504,914	$34,195	$374,386	$338,628	$515,270

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IV. MODEL FORMULATION

In accordance with the 39th Commandant's Planning Guidance, that prioritizes "balancing crisis response with modernization," this thesis uses a series of network and mathematical models to address the complex logistical challenges inherent to HA/DR response scenarios (Smith, 2024). The creation of six different models was necessary in this thesis as opposed to a single model due to Microsoft Excel's limitation of computing 200 decision variables. The scope of this model, that includes eight supply nodes, six demand nodes, and five equipment types, would necessitate 240 decision variables. The mathematical model framework used throughout each of the six models is used to optimize strategic decision-making processes about prepositioning in the Indo-Pacific. The research leverages logistical network frameworks and linear programming techniques tailored to resource management and optimization.

A. TECHNICAL APPROACH

The models all originate as conceptual network models with the specified demand node, the eight supply nodes, demand requirements, supply capacities, and arcs. Next, they are translated into mathematical models. The basis of the mathematical models are the logistics focused network models. Finally, they are computed with Microsoft Excel using the linear programming technique. The 'analytic solver' Microsoft Excel macro add-in is required to create and run the model used in this thesis, as it enables the solver function.

1. Hub and Spoke Model

The hub and spoke model is a logistics concept that specifically targets the transportation of goods. The model encourages efficient and cost-effective solutions for the distribution of goods across a network (UNISCO, 2025). Central supply locations serve multiple demand locations via multiple spokes or routes. It is a common method of solving complex logistics networks (UNISCO, 2025). This concept is used throughout the development of a logistics coalition in the Indo-Pacific, as it aims to find the optimal central locations, also known as hubs, to serve as prepositioned logistics nodes for response to the selected demand nodes. The series of optimally prepositioned logistics nodes also creates redundancy in the case of contested logistics, too.

2. Logistics Network Models

Logistics and network models serve to optimize the resource allocation and distribution networks of a supply chain. These models help logistics managers make decisions about where to produce or store a product and where it should be shipped to (E. Dahel, PowerPoint slides, August 1, 2024). Specifically, the transportation problem is a network model that addresses the distribution of goods from several supply nodes to a select number of demand nodes. Within this type of model, the supply capacity of the supply nodes is known and the demand requirement for each demand node is known (E. Dahel, PowerPoint slides, August 1, 2024). The objective of this type of model is typically to minimize the transportation costs.

A network model is created from this transportation problem, which includes the set of supply nodes, set of demand nodes, associated supply capacities and demand requirements, and the length of the arc between the various supply and demand nodes. The length of the arc is the distance between the two nodes as a function of cost. Figure 6 is an example of a logistics network model to solve a transportation problem involving the distribution of kitchen tables for a fictional furniture store. The nodes are represented as circles, while the arcs are represented as the lines that connect the nodes (E. Dahel, PowerPoint slides, August 1, 2024). These models are always bound by a list of constraints.

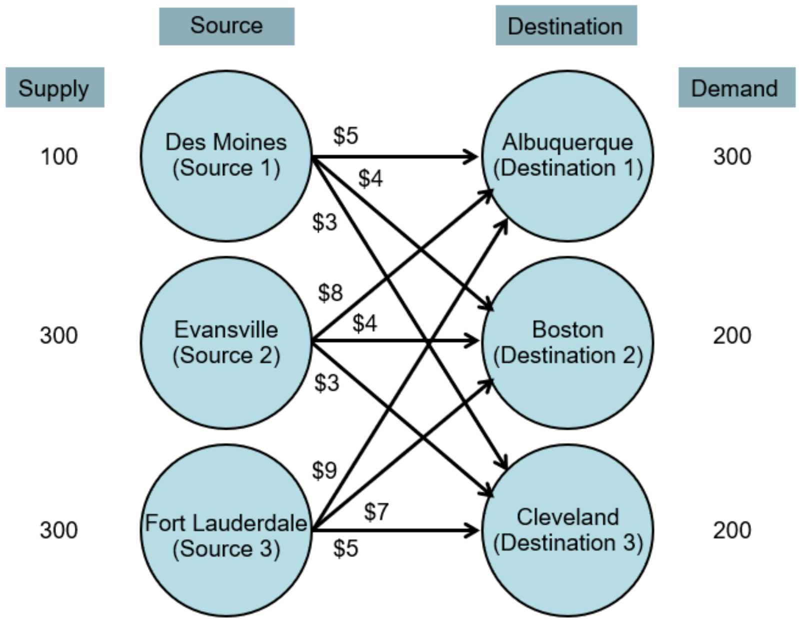


Figure 6. Example of a network model using a fictional furniture company distribution system. Source: E. Dahel, PowerPoint slides (August 1, 2024).

3. Linear Programming

Linear programming is a popular mathematical modeling technique that contributes to the planning and decision-making involved in resource allocation (E. Dahel, PowerPoint slides, July 15, 2024). In this case, programming means using a mathematical model to find an optimal solution to a problem. There are four properties common in a linear programming problem:

1. It seeks to maximize or minimize some quantity (objective function),
2. There are restrictions or constraints present,
3. Alternative courses of action are present, and
4. There are linear equations or inequalities involved. (E. Dahel, PowerPoint slides, July 15, 2024)

Linear programming is an example of an optimization problem that is used to find the best alternative under a set of constraints. It is a powerful tool for resource allocation and route optimization.

Network models are typically solved using linear programming in the military logistics field. This thesis formulates and solves a linear programming problem as it pertains to the distribution of military equipment throughout the Indo-Pacific for an HA/DR response.

B. SCOPE

The scope of the models condenses the logistical operations in the Indo-Pacific and simplifies the DoD's role in HA/DR responses significantly. This is done intentionally to keep the models simple and focused on big picture concepts. First, only Marine Corps bases, DLA disposition centers, MPF assets, and specified HA/DR warehouses are used as supply nodes. Other joint force infrastructures such as Army bases and Air Force bases are not considered in this research. Secondly, the equipment set used is scoped to only five of the primary pieces of equipment that the Marine Corps uses in HA/DR response. These models assume the humanitarian aid of NGOs and multinational organizations in disaster response and therefore do not include the prepositioning of any commodities such as food, water, medical supplies, etcetera. This is reasonable on account of the historical reliability of the life-saving aid provided by non-DoD organizations. The geographic scope of this logistics network model is Southeast Asia/Indo-Pacific region due to its strategic relevance to the Marine Corps and the region's vulnerability to natural disasters.

Importantly, the models do not account for the transportation assets required to transport the scoped equipment set from supply nodes to demand nodes, such as naval vessels. They do not address how the equipment is transported from supply node to demand node. The readiness of the naval fleet and the status of the nation's shipbuilding capability are two particularly important factors to consider in the conduct of logistics operations in the Indo-Pacific. These models also do not consider the degree of logistical capabilities and support available at each supply node such as ports, airfields, and specialized workforce. The degree of accuracy of the models is bound by a list of assumptions that are discussed in Section E of this chapter.

C. MODEL FORMULATION

The logistics network models focus on optimizing the Marine Corps' HA/DR response in the Indo-Pacific through prepositioning strategies. Six different models are established based on the six strategically significant demand nodes that were chosen.

Each of the models incorporate the eight DoD centric supply nodes and focus on the allocation of an equipment set that is both unique to the DoD and comprised of items that are typically requested during an HA/DR response. Each of the eight chosen supply nodes have a unique equipment set available dictated by the supply capacity of each of the five individual pieces of equipment in that location.

For the sake of this thesis, the Indonesia HA/DR response model will be used to showcase the model depiction throughout the remainder of this chapter. That is, the formulation of the mathematical model in Microsoft Excel will be specific to the Indonesia response. Each of the five other demand nodes warrant the same models specific to their location. The mathematical model depicted in this chapter represents the model framework used for all six demand nodes.

1. Network Model

The models were first created as logistics network models inclusive of eight supply nodes and a single demand node. The arcs within the network models are representative of the total transportation cost to transport all needed equipment between the supply nodes to the demand node. The costs vary throughout all six of the models based on the quantity of each of the five equipment types that are needed to move from each supply node to the specified demand node. In these models, distance between the supply and demand node and transportation cost is linear. The models computed in this thesis are based on HA/DR response to a single demand node.

A network model is shown in Figure 7 and depicts all supply nodes and a single demand node, as well as every arc that could enable the flow of equipment. Supply capacities and demand requirements are also illustrated in Figure 7. The network model is the basis for the formulation of the mathematical model.

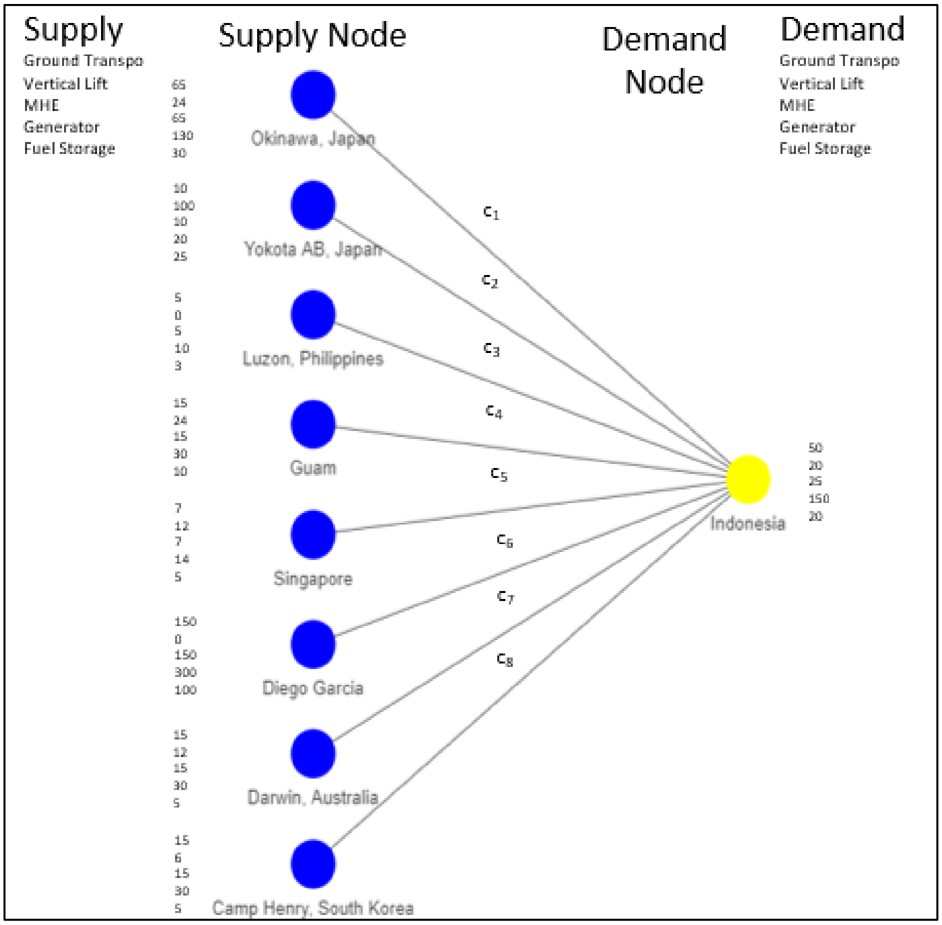


Figure 7. Network model for Indonesia HA/DR response

A simplified version of the combination of all six network models, including only supply and demand nodes, can be visualized on a map. Figure 8 depicts said geographical visual of the simplified network models used in this thesis. The figure provides a general visualization for the complexity of logistical operations in the Indo-Pacific region, due to the presence of the supply nodes and demand nodes scattered throughout the region.

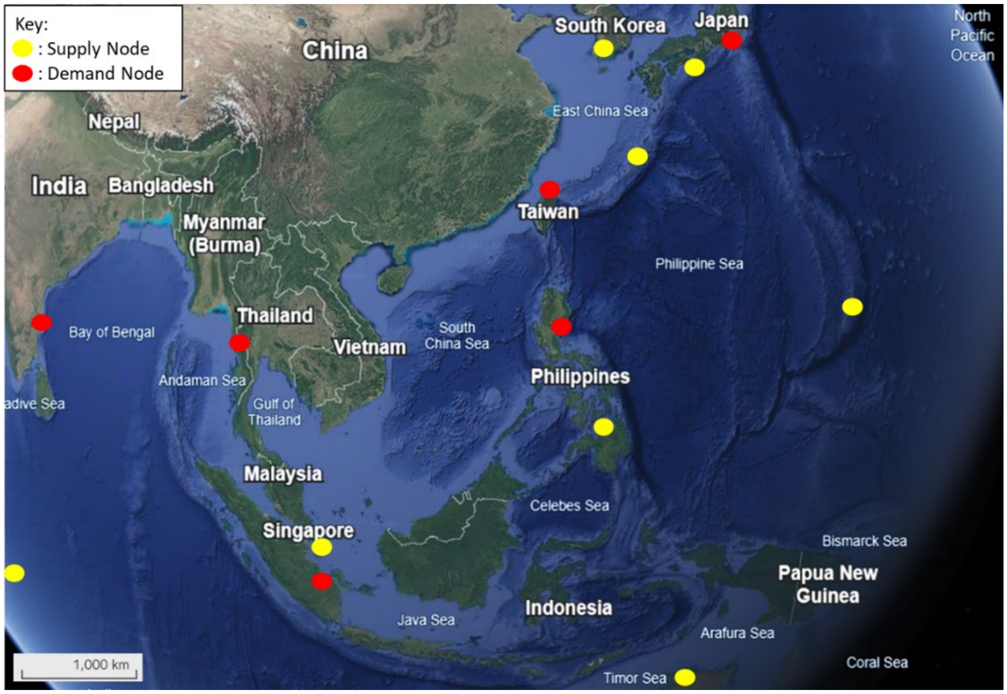


Figure 8. Map denoting the eight supply nodes (yellow) and six demand nodes (red) used in the network model. Source: Google Earth (2025).

2. Mathematical Model

The network models were translated into mathematical models to allow its implementation for computation. For this thesis, the mathematical model is in the form of a linear program that is comprised of decision variables, an objective function, and is subject to constraints. Figure 9 depicts the mathematical model framework that comprises the foundation for the computations conducted in this research. Each of the six demand nodes uses the mathematical model framework with their individual cost and demand matrices tailored to an HA/DR response at its respective location. The mathematical model framework depicted in Figure 9 is further explained throughout this subsection, starting with a breakdown of the decision variables.

Indices

I = set of supply nodes [Okinawa, Yokota AB, Philippines, Guam, Singapore, Diego Garcia, Darwin, South Korea]

J = set of equipment types [ground transportation, vertical lift, MHE, generator, fuel storage]

Decision variables

X_{ij} = number of units of equipment j shipped from supply node i

Parameters

c_{ij} = cost to ship a piece of equipment j from supply node i
S_{ij} = supply at node i of equipment j
D_j = demand for equipment j

Objective Function

$$\underset{X}{\text{Minimize}} \sum_i \sum_j c_{ij} X_{ij}$$

Subject to

$X_{ij} <= S_{ij}$	(1)
$\sum X_{ij} >= D_j$	(2)
$(X_{i4}/6) - X_{i1} <= 0$	(3)
$(X_{i6}/2) - X_{i1} <= 0$	(4)
$X_{ij} >= 0$ for all i in I and all j in J	(5)
X_{ij} is integer for all i in I and all j in J	(6)

Figure 9. Mathematical model framework

a. Decision Variables

There is a single decision variable for each of the six-demand node specific linear programs: X_{ij} = number of units of equipment j shipped from supply node i. The indices used in the mathematical model framework are uniform across all individual models:

I = set of supply nodes indexed by i:

[1 = Okinawa, Japan (Base),
2 = Yokota AB, Japan (DLA),
3 = Philippines (Warehouse),
4 = Guam (Base & DLA),
5 = Singapore (MRF),
6 = Diego Garcia (MPF),
7 = Darwin, Australia (MRF),
8 = Camp Henry, South Korea (DLA)]

J = set of equipment types indexed by j:

[1 = ground transportation asset,

2 = vertical lift asset,
3 = MHE asset,
4 = generator,
5 = fuel storage]

The parameters used in the mathematical model framework are dependent on their specified demand node. The model parameters are as follows:

c_{ij} = cost to ship a piece of equipment j from supply node i
S_{ij} = supply at node i of equipment j
D_j = demand for equipment j

Further explained, the cost to ship a piece of equipment j from supply node i, is dependent on the distance between the supply node and the demand node to which it is being shipped.

b. Objective Function

The objective of the models is to minimize the operational cost of an HA/DR response for its specified demand node as a function of equipment weight and miles traveled between demand and supply node. The function considers the distance between the demand node and the supply nodes, amount of equipment used from each supply node, equipment weight and the standardized cost per pound of transporting DoD equipment by the sea. Due to its array of considerations, this objective function also ensures that the supply nodes that offer the shortest distance to the various demand nodes are considered first, implying that timeliness of response is considered. The combination of variables considered further enables the minimization of operational costs to represent the logistical efficiency and effectiveness of resource management of the response. The objective function is represented as

$$\underset{X}{\text{Minimize}} \sum_{i} \sum_{j} c_{ij} X_{ij}$$

c. Constraints

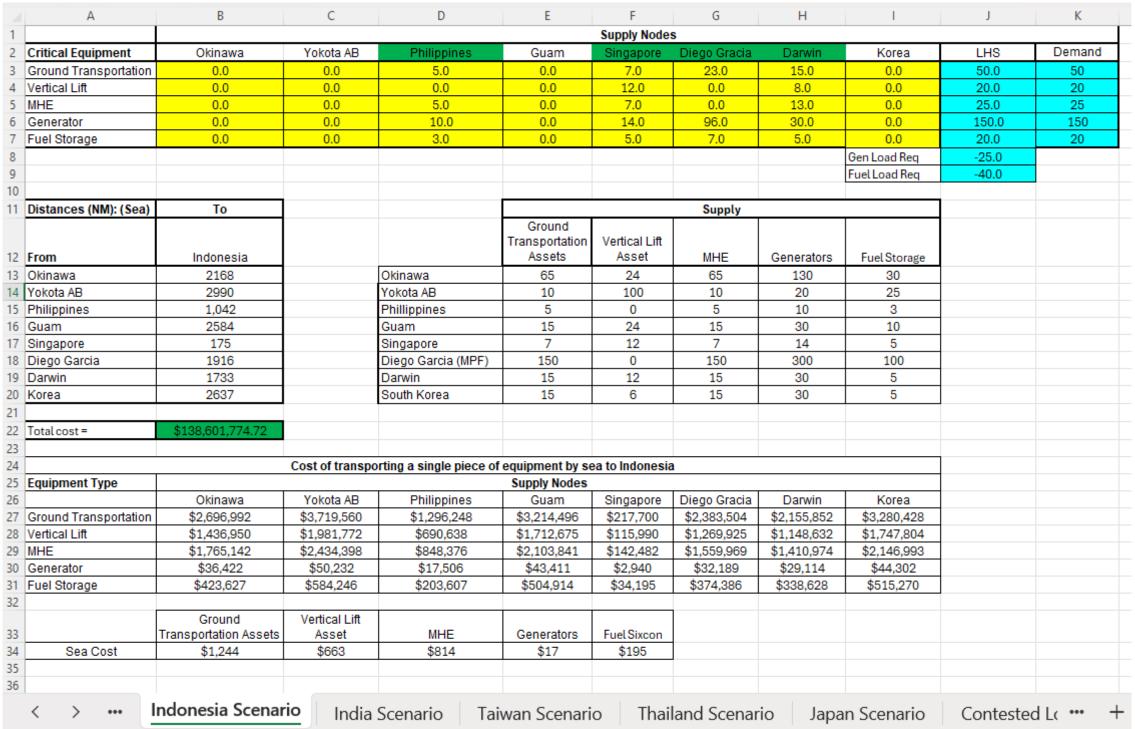
The objective function is subject to six constraints, categorized as supply constraints, demand constraints, loading constraints, the non-negativity constraint, and the integer constraint. The constraints will be listed in an abbreviated form for ease of reading. The constraints are specific to each of the six demand node responses.

- Supply Capacity Constraint: $X_{ij} <= S_{ij}$
- Demand Requirements Constraint: $\sum X_{ij} >= D_j$
- Generator Loading Constraint: $(X_{i4} /6) – X_{i1} <= 0$
  This constraint represents that for every six generators, there must be one ground transportation asset to enable proper mobility of the assets.
- Fuel Storage Loading Constraint: $(X_{i6} /2) – X_{i1} <= 0$
  This constraint represents that for every two fuel storage containers, there must be one ground transportation asset to enable proper mobility of the assets.
- Non-negativity Constraint: $X_{ij} >= 0$ for all i in I and all j in J
- Integer Constraint: X_{ij} is integer for all i in I and all j in J

For this research, time is considered outside the scope of the linear programming model. This is because the current network model would result in infeasible solutions given the chosen time constraint of three days. The response time constraint of three days from supply node to demand node, represents the Marine Corps' expeditionary standard to respond in 72 hours or less. A time-space analysis is instead conducted in Chapter V to determine whether critical supplies can make it from each supply node to each demand node in an acceptable amount of time. Time is calculated by multiplying the distances between nodes and the chosen average speed of 15 nm/hour, which is based on subject matter expert input. All model outputs are evaluated on time after the models are computed.

3. Computing the Model

Finally, the mathematical models are translated to and computed using Microsoft Excel. The equations are translated into functions with Microsoft Excel and are then input as solver parameters. Figure 10 and Figure 11 depict the model for the Indonesia HA/DR response in Microsoft Excel.



Critical Equipment	Okinawa	Yokota AB	Philippines	Guam	Singapore	Diego Gracia	Darwin	Korea	LHS	Demand
	Supply Nodes									
Ground Transportation	0.0	0.0	5.0	0.0	7.0	23.0	15.0	0.0	50.0	50
Vertical Lift	0.0	0.0	0.0	0.0	12.0	0.0	8.0	0.0	20.0	20
MHE	0.0	0.0	5.0	0.0	7.0	0.0	13.0	0.0	25.0	25
Generator	0.0	0.0	10.0	0.0	14.0	96.0	30.0	0.0	150.0	150
Fuel Storage	0.0	0.0	3.0	0.0	5.0	7.0	5.0	0.0	20.0	20
								Gen Load Req	-25.0	
								Fuel Load Req	-40.0	

Distances (NM): (Sea)	To
From	Indonesia
Okinawa	2168
Yokota AB	2990
Philippines	1,042
Guam	2584
Singapore	175
Diego Garcia	1916
Darwin	1733
Korea	2637

	Supply				
	Ground Transportation Assets	Vertical Lift Asset	MHE	Generators	Fuel Storage
Okinawa	65	24	65	130	30
Yokota AB	10	100	10	20	25
Phillippines	5	0	5	10	3
Guam	15	24	15	30	10
Singapore	7	12	7	14	5
Diego Garcia (MPF)	150	0	150	300	100
Darwin	15	12	15	30	5
South Korea	15	6	15	30	5

Total cost =	$138,601,774.72

Cost of transporting a single piece of equipment by sea to Indonesia								
Equipment Type	Supply Nodes							
	Okinawa	Yokota AB	Philippines	Guam	Singapore	Diego Gracia	Darwin	Korea
Ground Transportation	$2,696,992	$3,719,560	$1,296,248	$3,214,496	$217,700	$2,383,504	$2,155,852	$3,280,428
Vertical Lift	$1,436,950	$1,981,772	$690,638	$1,712,675	$115,990	$1,269,925	$1,148,632	$1,747,804
MHE	$1,765,142	$2,434,398	$848,376	$2,103,841	$142,482	$1,559,969	$1,410,974	$2,146,993
Generator	$36,422	$50,232	$17,506	$43,411	$2,940	$32,189	$29,114	$44,302
Fuel Storage	$423,627	$584,246	$203,607	$504,914	$34,195	$374,386	$338,628	$515,270

	Ground Transportation Assets	Vertical Lift Asset	MHE	Generators	Fuel Sixcon
Sea Cost	$1,244	$663	$814	$17	$195

Figure 10. Model view in Microsoft Excel for Indonesia response

As seen in Figure 10, the model in Microsoft Excel combines the use of all the data tables from the Data Collection Chapter. Each demand node has a separate model that mirrors the one depicted in Figure 10. Figure 11 is a view of the Microsoft Excel solver, denoting the cell used for the objective function and the list of constraints. The solver box collects all required information from the necessary cells depicted in Figure 10 and translates it to the solver parameters required to compute the model and output a solution.

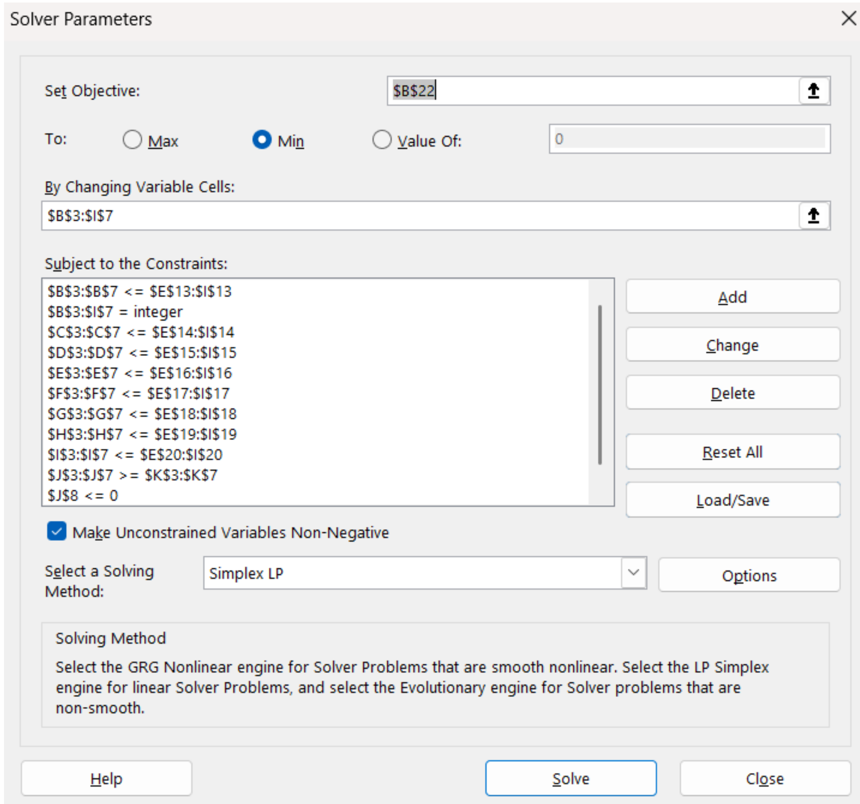


Figure 11. Microsoft Excel solver function box used for the model

4. Decisions

The decisions addressed by these models are as follows: How much of each type of equipment should be transported from what supply node(s) to what demand node? What equipment should be stored at what preposition locations? How much of each commodity should be stored at each location?

This model framework serves to contribute to the military's scientific approach to decision-making. The goal is to demonstrate the impacts of maintaining, establishing, and/or further equipping various preposition sites in the Indo-Pacific using data-driven models. The model framework has potential to be used in decision-making exercises, such as wargaming, or in actual response planning, such as R2P2.

D. OPERATIONAL SCENARIO

Each of the six models is computed to represent an operational scenario specified to each of the demand node locations. The models operate off the same scenario with identical demand requirements for each of the demand nodes. Use of identical demand requirements for each response is for simplification purposes. The operational scenario created for the six model computations is as follows:

> In September 2025, a powerful Category 5 tropical cyclone, named Typhoon Ravana, strikes [insert demand node], causing widespread devastation across the country. The [insert demand node] government requests international assistance to provide immediate humanitarian aid, disaster relief, and logistical support. MARFORPAC, as part of the INDOPACOM crisis response force, is tasked with leading the JTF to conduct HA/DR response operations in the affected areas to alleviate human suffering. No later than 14 days after the arrival of the first forces, the JTF must transition relief efforts to the host nation government and NGOs.

Assumed population requiring relief and assistance: 60,000
Estimated fatalities: 7,500
Estimated injuries: 22,000
Assumed response effort by U.S. Military: 14 days
Assumed number of destroyed structures: 700,000
Assumed number of damaged structures: 200,000
Assumed damaged power and transportation infrastructure

The purpose of the operational scenario is to provide practical application of mathematical models in optimizing resource allocation across the demand nodes.

E. ASSUMPTIONS

There was a plethora of assumptions that were used in the model framework to keep it both simple and unclassified. Throughout the remainder of this paper, please keep in mind that a model is only as realistic as its data and assumptions. The outputs of a model are only as accurate as the data inputted into the model. In any model, the data must be updated, or the outputs will be distorted.

1. Model Formulation Assumptions

- Supply nodes are inclusive of Marine and Naval bases as well as DLA disposition centers. The nodes do not include other joint force bases that are owned by the Army, Air Force, or Space Force.
- There are some locations that serve as both supply and demand nodes. It is assumed that if a disaster occurs in a location, making it a demand node, the supplies stored in the location will be able to be used in the response based on strategic positioning.

- Distances from supply to demand nodes are approximated using Google Earth tools.
- The model is limited to the distribution of the following equipment types: vertical lift assets, ground transportation assets, material handling equipment assets, generators, and fuel storage containers.
- NGOs have sufficient supply and capabilities to provide necessary food, water, medical supplies, temporary shelter, and sanitation services to fulfill the needs required to achieve the general well-being of a population.
- Demand node demand requirements are estimated based on reports and data on historic disasters.
- Equipment sets available at each of the supply node locations are approximations based on various unit tables of equipment throughout the Marine Corps and on subject matter expert input.
- Variables are continuous.
- The weight of each piece of equipment is represented by a single type and model of the equipment type in accordance with Marine Corps technical manuals.
- Cost is directly proportional to the number of miles traveled, related by the value function: Per Unit Cost = weight of a single piece of equipment (lbs.) * price per pound per mile by sea * distance between nodes.
- Models consider only pre-determined node locations.

2. Operational Context Assumptions

- The equipment located at the supply nodes will be operationally available when needed, assuming that it is not being used for any other mission sets.
- The equipment at the supply node locations is maintained and fully operationally capable.
- The Indo-Pacific area of operations falls between uncertain and hostile on the operational environment scale.
- The Marine Corps has the appropriate manpower to respond (logistics, engineering, medical services, chaplain services, legal services, civil affairs).
- Funding to bolster and establish prepositioning sites is available.
- U.S. partners and allies, with whom the nation seeks to strengthen or establish prepositioning sites, are in agreement.

3. Disaster Scenario Assumptions

- The demand for each of the demand nodes in the operational scenarios is known.
- These models assume localized disasters that result in HA/DR response to a single demand node.

- The response is conducted as a stand-alone response.

It should also be noted that all models should be both validated and verified before being used to aid decision-making. Validation evaluates whether the target is represented accurately in the model while verification tests whether the model was built correctly (Rowan, PowerPoint slides, July 2024).

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V. ANALYSIS

The analysis of the outputs of the model is focused on the establishment of the most efficient logistics coalition as a function of transportation cost while considering response time. Cost is computed within the models while time is analyzed outside of the models. Time was not used as a constraint on the model as the constrained period of three days would have resulted in infeasible solutions for four of the six demand nodes. The purpose of the time-space analysis after the computation of the models is to determine whether critical equipment could make it from each supply node to each demand node in an acceptable amount of time. The transportation cost in this model is representative of the operational cost that considers both logistical efficiency and proper resource allocation.

The analysis primarily focuses on the most heavily utilized and the most underutilized supply nodes to later offer insight into recommendations for resource re-allocation. It should be noted that the impact and recommendations made in this chapter are to be heavily scrutinized with further data analytics before being used to make operational or financial decisions.

A. SUMMARY OF RESULTS

The outputs of the models revealed patterns of what supply nodes were most heavily utilized and most underutilized within the network. Based on distances between supply and demand nodes, coupled with supply capacities, the linear program output the optimal supply nodes to be used for the HA/DR responses to each of the six demand nodes.

Table 8 depicts the supply node(s) used to optimally respond to each of the HA/DR scenarios at each of the demand nodes. The green boxes within Table 8 represent that a supply node's response was required at the associated demand node to meet requirements of the demand node.

Table 8. Supply nodes HA/DR response matrix

		Supply Nodes							
		Okinawa	Yokota AB	Philippines	Guam	Singapore	Diego Garcia	Darwin	South Korea
Demand Nodes	Philippines								
	Indonesia								
	India								
	Taiwan								
	Thailand								
	Japan								

Based on the solutions of each of the six models within the linear program, all supply nodes besides Guam were used in at least one hypothetical HA/DR response. As seen in Table 8, the various HA/DR responses were conducted by the following supply nodes:

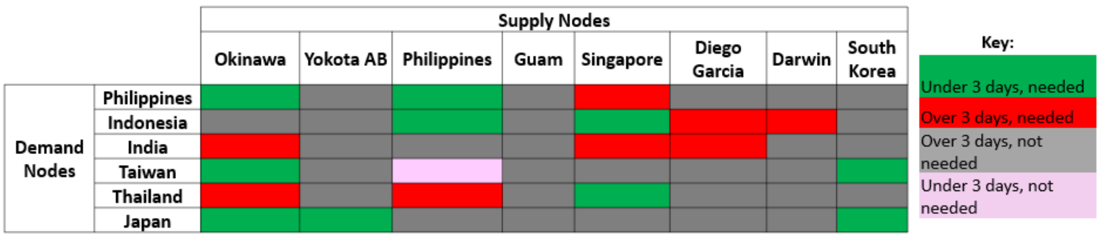
- Philippines Response: Okinawa, Philippines, Singapore
- Indonesia Response: Philippines, Singapore, Diego Gracia, Dawin
- India Response: Okinawa, Singapore, Diego Garcia
- Taiwan Response: Okinawa, Korea
- Thailand Response: Okinawa, Philippines, Singapore
- Japan Response: Okinawa, Yokota AB, Korea

In all cases, the use of equipment from more than one supply node was necessary to meet demand requirements due to the supply capacity constraints. Table 8 can also be interpreted as what supply nodes provided equipment to what demand nodes across the six logistical scenarios:

- Okinawa supplied: Philippines, India, Taiwan, Thailand, Japan
- Yokota AB supplied: Japan
- Philippines supplied: Philippines, Indonesia, Thailand
- Guam supplied: No demand node
- Singapore supplied: Philippines, Indonesia, India, Thailand
- Diego Garcia supplied: Indonesia, India
- Darwin supplied: Indonesia
- South Korea supplied: Taiwan, Japan

Table 9 combines the model outputs of what supply nodes responded to what demand nodes to meet requirements, coupled with the results of a time-space analysis. In conjunction with Table 8, Table 9 denotes the response time considerations for the equipment distribution from each supply node required to meet the demand of each of the six demand nodes. Table 9 signals whether a supply node was required for response to a specific demand node across the six logistical scenarios, coupled with whether the response took less than or more than three days. The metric of responding in three days or less is directly correlated with the HA/DR response's effectiveness.

Table 9. HA/DR response time matrix representing response times from supply nodes to demand nodes



As seen in Table 9, South Korea and Yokota AB were the only supply nodes that were able to respond to all their associated demand nodes within the time constraint of three days. In contrast, the Diego Garcia and Darwin supply nodes were unable to respond to any of their associated demand nodes with the time constraint. The supply nodes at Okinawa, Philippines, and Singapore were able to respond to approximately half of their required demand nodes within the time constraint of three days. Of note, the Philippines was the only supply node that was able to respond to a demand node that did not need its support, within the time constraint.

B. ANALYSIS AND IMPACT

The outputs of the models warrant a proper analysis to be of value. As seen in Figure 12, Okinawa played a role in the most hypothetical HA/DR responses, providing equipment to five of the six demand nodes throughout the six scenarios. Next was Singapore, providing equipment for four of the six demand nodes. In third place was the Philippines HA/DR warehouse providing equipment for three of the six demand nodes. Diego Garcia and South Korea were tied for fourth place, each providing equipment for two demand nodes across the six operational scenarios. Yokota AB, Japan, and Darwin were tied for second to last, each providing equipment for one of the six responses. Lastly, Guam provided no equipment to any of the six demand nodes through the model output.

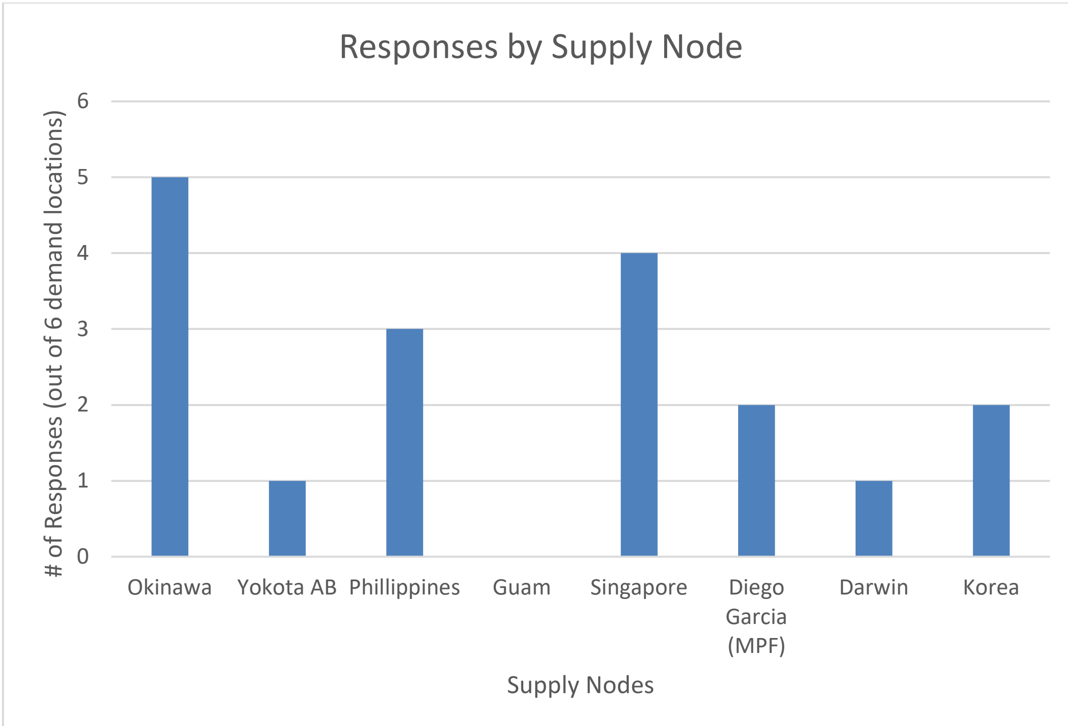


Figure 12. Responses by supply node as a histogram

Figure 13 depicts the same results as Figure 12, but as a pie chart with the percent response by supply node. By the solutions of the models, the Okinawa, Singapore, Philippines supply nodes are used most abundantly. Guam, Darwin, and Yokota AB supply nodes are used the least abundantly. While Diego Garcia and Korea lay somewhere in the middle. These results do not account from the benefits of established infrastructure, manned by Marines constantly for maintenance considerations in the underutilized locations.

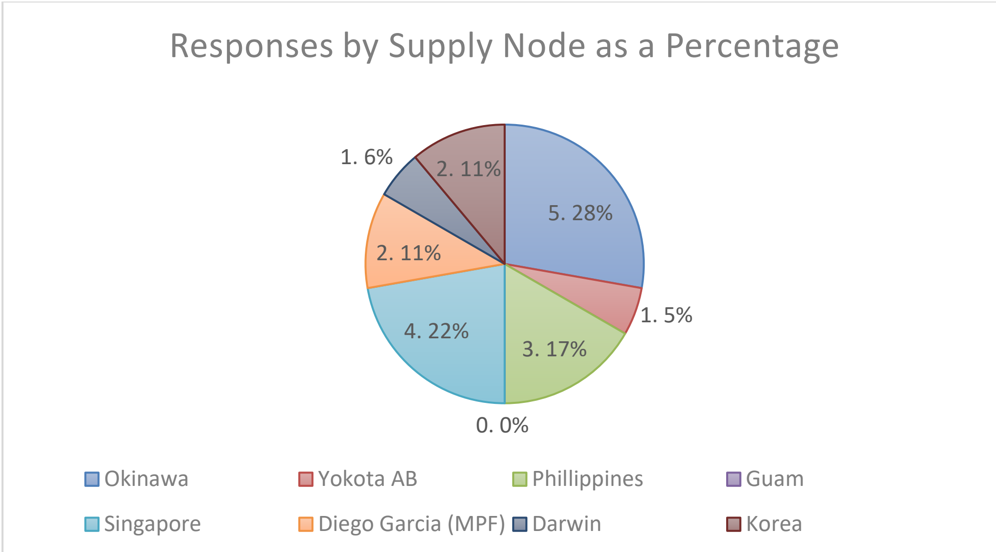


Figure 13. Responses by supply node as a pie chart

Figure 14 takes response time into consideration, which is important in determining the success of a HA/DR mission where the livelihood of a population is dependent on rapid response. Figure 14 illustrates that four of the six demand nodes are at a significant risk of not receiving the necessary equipment within the time constraint of three days. That is, the Philippines, Indonesia, India, and Thailand are projected to incur more unnecessary suffering due to HA/DR response times over three days. Of the four at risk demand locations, India illustrates the largest concern as no supply nodes were able to respond within the three-day time constraint. The three other at risk locations; Philippines, Indonesia, and Thailand, were each able to receive equipment from at least one supply node within the three-day time constraint, with the remainder of the equipment projected to arrive after the three-day mark.

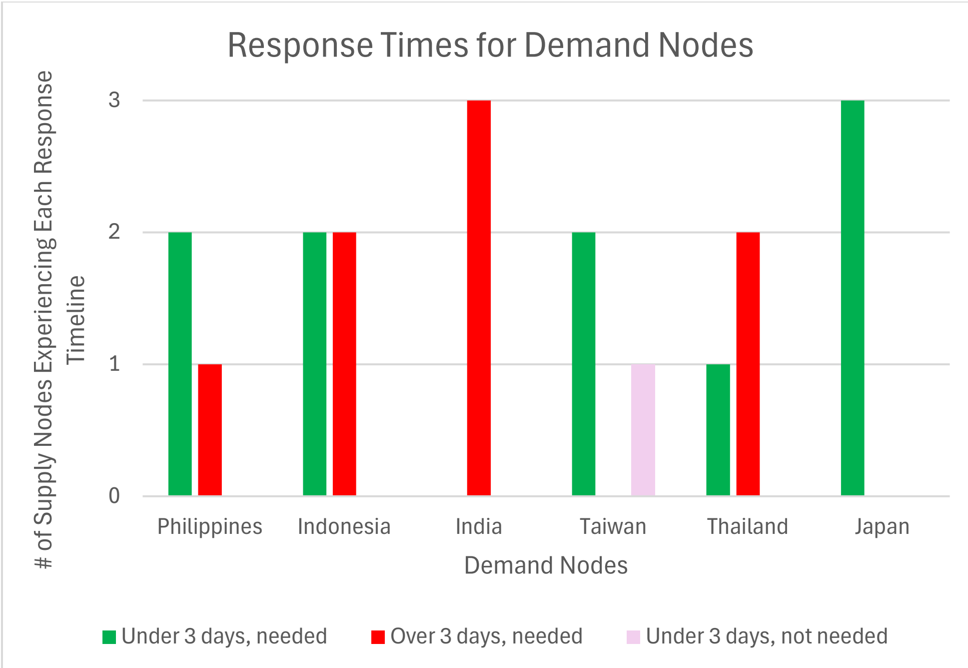


Figure 14. Response times for demand nodes

Japan and Taiwan are the lowest risk demand nodes in terms of receiving equipment within the time constraint to limit unnecessary suffering. Japan is projected to receive equipment from all three of its supply nodes within the three-day time constraint. Of the six demand nodes, the modeled prepositioning network is postured the best to support Taiwan. Taiwan was the only demand node that received all required equipment within the three-day time constraint and had an additional supply node capable of responding within the time limit, though it was not needed to meet demand requirements. Overall, Figure 14 illustrated that the modeled prepositioning posture is not sufficient for response to the six selected demand nodes. Resource re-allocation and the potential addition of another supply node in closer proximity to India is required to meet response demand requirements within the three-day time constraint.

There are a multitude of potential second and third order effects of prepositioning equipment throughout the Indo-Pacific for the purpose of HA/DR response. First, prepositioning is logistically complex in that managing maintenance and readiness of equipment assets requires manpower and storage facilities. Prepositioned equipment for HA/DR response is near useless if it is not operationally available on a moment's notice. Next, permanent or temporary presence of U.S. equipment and personnel on the supply node locations may ignite geopolitical tensions and potentially cause sovereignty concerns among the host nation's population. Even considering the current presence of U.S. personnel and equipment on Marine and Naval bases and at DLA disposition centers in the Indo-Pacific, any composition change may cause concern.

Prepositioning in such a strategic and vulnerable region of the world also yields benefits. Most importantly, it serves as an enabler for the U.S. military's deterrence mission. It sends a strong message to both regional adversaries such as the PRC, and U.S. partners and allies, that the U.S. is postured for sustained presence and rapid escalation if needed. The dispersion of equipment throughout the region also enables a more resilient military supply chain, making it difficult for adversaries to disrupt the logistics network.

C. RECOMMENDATIONS

This research produces two primary categories of recommendations. The first is recommendations based on the outputs of the model and the second is the recommendations on the use of the mathematical model framework in the creation of decision-making aids for Marine Corps planners.

1. The Logistics Coalition

Based on the output of these models, reallocation of resources across supply nodes is recommended to form the optimal logistics coalition. That is, the supply nodes that are most optimal for response to the greatest number of demand nodes should be prioritized. Highly utilized supply nodes with lower supply capacities, such as Singapore and the Philippines should increase their supply capacities for all equipment types. Concurrently, underutilized supply nodes such as Guam, Diego Garcia, and Darwin could effectively reallocate some of those needed resources without degrading their operational readiness. The implementation of these recommendations has potential to aid the Marine Corps in balancing modernization and crisis response capability. Figure 15 depicts the recommended optimal logistics coalition for the purposes of HA/DR response in the Indo-Pacific region based on the outputs of the six models.

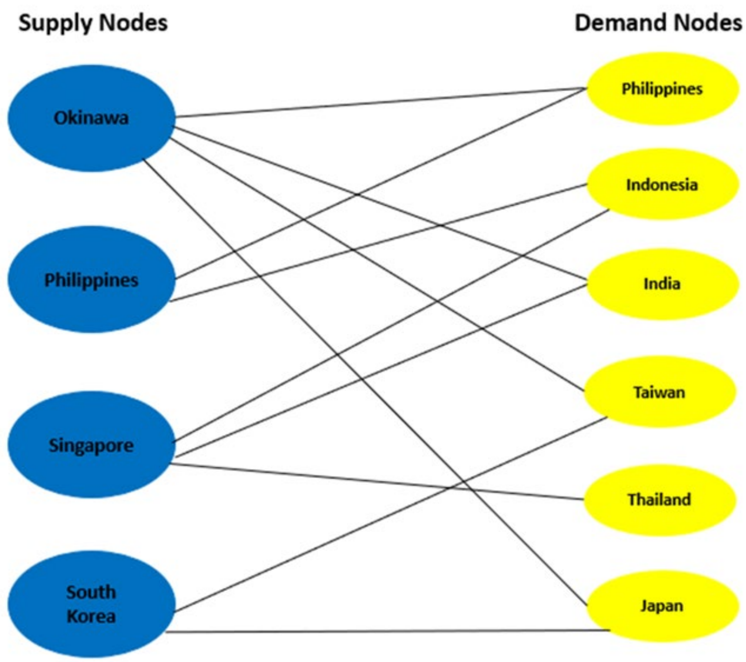


Figure 15. The recommended optimal logistics coalition for HA/DR response in the Indo-Pacific represented as a network model

Based on this research, the optimal logistics coalition consists of four supply nodes responsible for the following responses:

- Okinawa: responsible for responses for Philippines, India, Taiwan, and Japan
- Philippines: responsible for responses for Philippines and Indonesia
- Singapore: responsible for responses for Indonesia, India, and Thailand
- South Korea: responsible for responses for Taiwan and Japan

It is recommended that the DoD prioritize the capabilities on Okinawa, Singapore, Philippines, and South Korea to form an effective logistics coalition. To do this, the DoD should reallocate resources from Guam, Diego Garcia, and Darwin to the four most optimal locations. The highly utilized supply nodes with lower supply capacities should increase the supply capacities of all equipment sets. In this case, it is recommended that the supply capacities of Singapore and the Philippines be increased for all equipment types. The outputs of the models showed that the supply capacities for both Okinawa and South Korea were sufficient for the hypothetical HA/DR responses.

The recommended updates to the supply capacities for each of the supply nodes are shown in Table 10. The changes from the original supply capacity table depicted in

Table 4 are highlighted in green if the supply capacity was increased and in red if the supply capacity was decreased. These updates would enable more efficient responses, in some cases requiring equipment from two less supply nodes to meet demand requirements.

Table 10. Recommended updates to supply capacities for each of the supply nodes

	Supply Capacities (# of pieces of equipment)				
	Ground Transportation Assets	Vertical Lift Asset	MHE	Generators	Fuel Storage
Okinawa	65	24	65	130	30
Yokota AB	10	100	10	10	21
Philippines	20	0	5	50	10
Guam	15	20	15	10	10
Singapore	30	20	20	100	10
Diego Garcia (MPF)	112	0	137	240	92
Darwin	15	8	15	20	5
South Korea	15	6	15	30	5

The reallocation of resources denoted in Table 10 was used to compute the HA/DR response scenarios for Thailand, the node with the hypothetically most expensive response, and for Indonesia, the demand node that required equipment from the most supply nodes to meet demand requirements. For the Thailand response, the operational cost decreased by upwards of $57,000,000 and was able to be conducted with response by only two demand nodes, versus the original three. For the Indonesia response, the operational cost decreased by over $93,000,000 and was able to be conducted with equipment from only two demand nodes versus the original three. The results of recomputing the response scenarios with the new supply capacities illustrate the value of proper resource allocation.

The equipment residing in Guam, Diego Garcia, and Darwin should not be totally divested and reallocated to the four optimal locations. This is because there is a significant amount of value in having contingency logistics nodes to account for variability in the network. The vulnerability of the region to natural disasters and the geopolitical tensions that could lead to route disruptions signal risk in maintaining a logistics coalition with only four supply nodes. For example, if a typhoon strikes Taiwan, a demand node, and concurrently Okinawa, which is Taiwan's primary supply node, other logistics nodes not effected by the disaster will be crucial in meeting demand requirements. Similarly, if the PRC disrupts the passage of vessels through the East China Sea, two of the supply nodes within the optimal logistics coalition, Okinawa and South Korea, may be rendered unusable for any responses to their south. For these reasons, the logistics coalition should build in redundancy by having a multitude of secondary supply nodes.

2. Decision-Making Models in the Marine Corps

Decision-making models serve to aid decision-makers in complex, dynamic environments. The use of data-driven models in crisis response decision-making has potential to streamline humanitarian logistics and heighten operational efficiency. The network model and mathematical model frameworks used in this thesis serve as a building block for the creation of a decision-making tool. This research requires the Microsoft Excel "Solver" and "Data Analysis" macro add-ins, which are blocked on Marine Corps Enterprise Network systems due to cybersecurity risks. To be used within the Marine Corps, the model must be adapted to a more secure platform, such as Python.

There are a multitude of software systems and mediums that are enabled on Marine Corps Enterprise Network assets that could translate the model frameworks used in this thesis into a decision-making tool. However, the use of said software systems is out of the scope of the defense logistics management program curriculum. Further recommendations on the translation of the model frameworks used in this thesis to a decision tool are discussed in the Future Work Section of Chapter VI.

Models like the ones used in this thesis enable the adjustment of parameters such as equipment type and node locations, to facilitate planning for a wide array of HA/DR response scenarios. The models can be tailored to fit the scope of operations for a specific unit. Additionally, the models can be tailored to assist in other Marine Corps operations, to include campaigning. These models also have potential to be expanded to the scope of joint operations.

VI. CONCLUSION AND FUTURE WORK

There are a multitude of problems that have arisen as the Marine Corps battlefield shifts to the Indo-Pacific. These problems have been met with new concepts and force restructuring; however, they have not been solved entirely. This thesis serves as a data-driven contribution to the solving of this relatively new and complex problem as it pertains to the Marine Corps HA/DR mission.

The mathematical model framework used throughout this research is relatively simple and has plenty of room for growth and improved data inputs. There is an abundance of future work to be done on this problem and a multitude of alternative methods that could be applied to solve the problem.

A. CONCLUSION

Building an optimal prepositioning network in the Indo-Pacific is a complex problem with an abundance of considerations. Strategic planners must consider not only where equipment will be prepositioned and how much of each type, but also how it will be secured, maintained, and transported when response is required.

The computation of data-driven models can largely impact the efficiency and effectiveness of prepositioned logistical hubs in the Indo-Pacific. Mathematical modeling is a powerful technique that serves to aid in making those critical decisions. More specifically, linear programming, which can be conducted on low computing power applications, is a tool that is underused in the military. It serves to aid in data-driven decisions as they pertain to resource allocation, overall efficiency of a logistics network, and cost effectiveness. The model framework in this thesis serves as a single example of how simple mathematical modeling can be used to aid decision-makers in complex, dynamic problems that require rapid responses. The model framework used throughout this thesis can be modified to apply to prepositioning for the purpose of military operations as well.

B. FUTURE WORK

Given the timeframe and scope of this thesis, there is a plethora of work that can still be done on the topic. To start, a systematic sensitivity analysis is necessary anytime a data-based model or method is used. The primary topics of scrutiny in these models are the supply capacities, demand requirements and the transportation costs for the equipment used in the model. The model solutions of each disaster scenario depend heavily on the assumptions in estimating the supply capacities for each supply node and on the demand requirements. Any changes in these values could significantly impact the supply nodes used to meet the demand of each of the disaster-stricken locations. Additionally, transportation costs of each piece of equipment directly affect the optimal solution. There were multiple factors that were not considered in the transportation costs such as the origin of the vessels and whether they are military or commercial assets. Changes in data input and assumptions in these models could shift the outcomes.

There is potential to improve and increase the complexity of the mathematical model framework used in this thesis. First, the number of supply nodes could be increased to include joint force infrastructure in the Indo-Pacific. Similarly, the demand nodes could be inclusive of all the countries involved in the Indo-Pacific Economic Framework. The decision variables of the models could be expanded to include commodities such as food, water, shelter, and medical supplies.

The physical distribution of equipment and supplies from supply nodes to demand nodes could be considered more, taking the origin location of ships into account. Additionally, adding the capacity constraints of the ships used in the responses could add a whole degree of complexity to the problem. Next, concepts of contested logistics and area denial could be added, rendering certain supply nodes or routes between nodes unavailable or impassable, respectively. Lastly, this model framework could be altered to consider equipment readiness. For example, if ground transportation asset readiness is assumed to be 50%, the supply nodes required to meet demand requirements will certainly shift. The more realistic the model is, the more realistic the results are. This work should also be further developed as the nature of foreign partnerships with the United States continues to expand and shift.

Figure 16 depicts a complex network model using all eight supply nodes and all six demand nodes concurrently, demonstrating a framework for a more advanced version of the models used in this thesis. There is room to implement the model depicted in Figure 16 in a more powerful computing tool than Microsoft Excel, such as Python, using optimization software. The use of more powerful optimization software has the potential to streamline the computation of the program. It would enable the use of a three-dimensional decision variable that would enable the combination of the six individual models used in this thesis into a single model. There is also room to incorporate the time constraint within the model that would make it a more powerful and useful tool for Marine Corps planners.

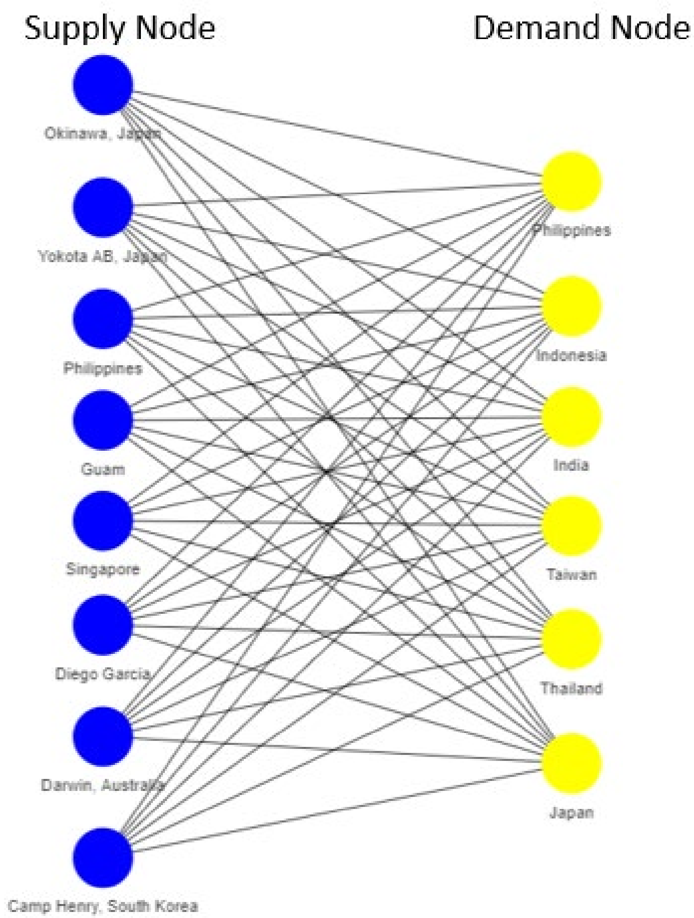


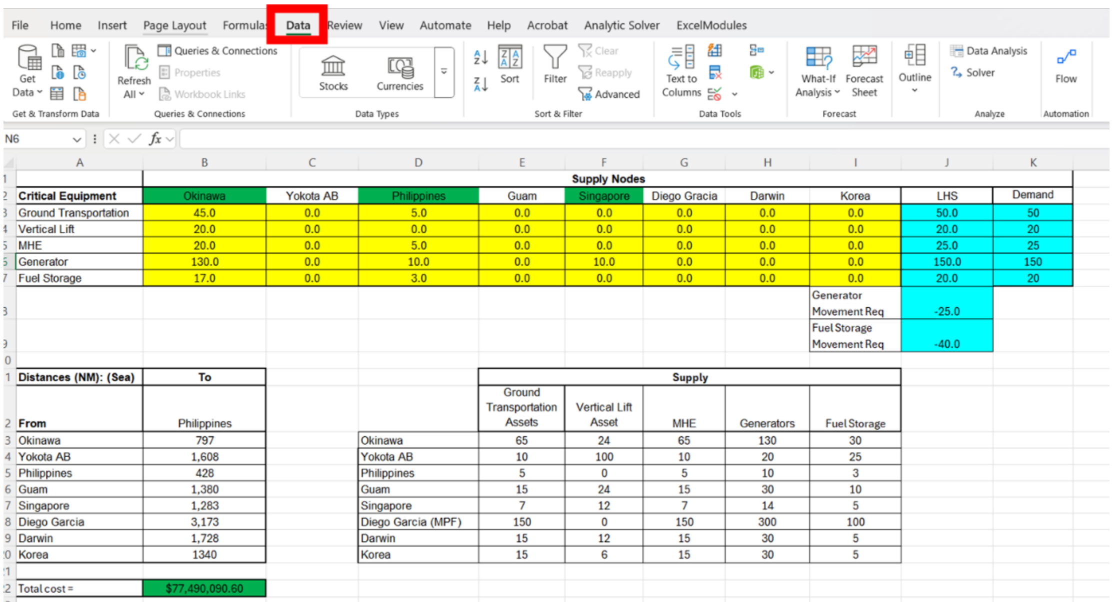
Figure 16. Network model with all eight supply nodes, six demand nodes, and arcs between every supply node and demand node

From a broader perspective, the DoD should explore alternative technologies and modeling techniques to deepen its understanding of the problem, and the complexities involved in solving it. The solution to optimize the Marine Corps' HA/DR response in the Indo-Pacific extends far beyond simply establishing an optimal prepositioning network. This thesis represents just one potential component of a much larger, more comprehensive solution across the joint force.

C. DISCLAIMER

During the writing of this thesis, USAID was unfunded and closed by the administration of the 47th President of the United States. This action creates significant uncertainty in the DoD's mission and capability to conduct HA/DR response in the future. Solutions to HA/DR response in the Indo-Pacific, including the one offered in this thesis, will need to adapt to new strategic level guidance once released in the future.

APPENDIX. USING THE SOLVER IN MICROSOFT EXCEL

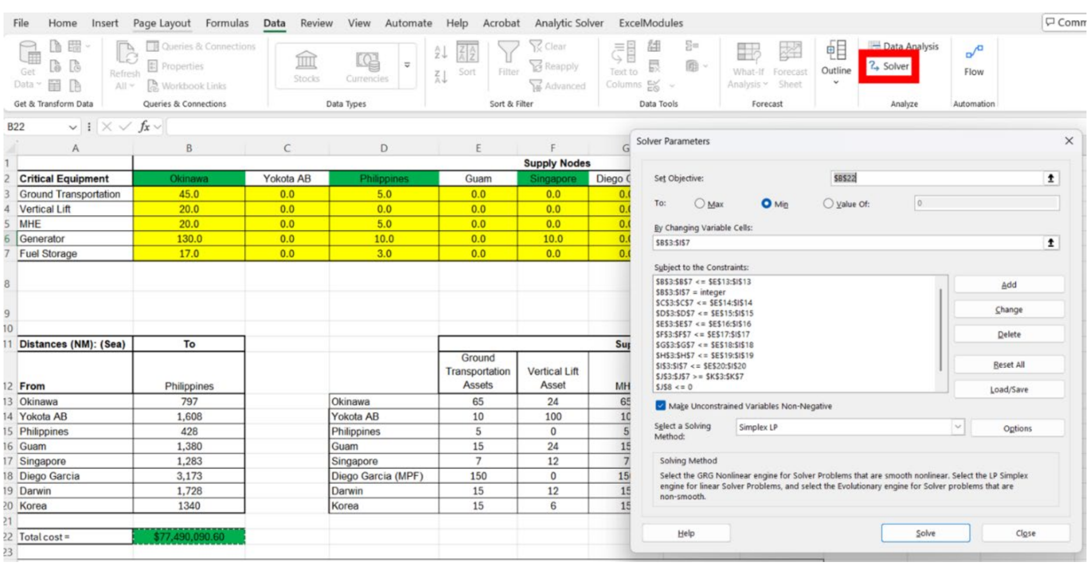


	Supply Nodes									
Critical Equipment	Okinawa	Yokota AB	Philippines	Guam	Singapore	Diego Gracia	Darwin	Korea	LHS	Demand
Ground Transportation	45.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	50.0	50
Vertical Lift	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	20
MHE	20.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	25.0	25
Generator	130.0	0.0	10.0	0.0	10.0	0.0	0.0	0.0	150.0	150
Fuel Storage	17.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	20.0	20
								Generator Movement Req	-25.0	
								Fuel Storage Movement Req	-40.0	

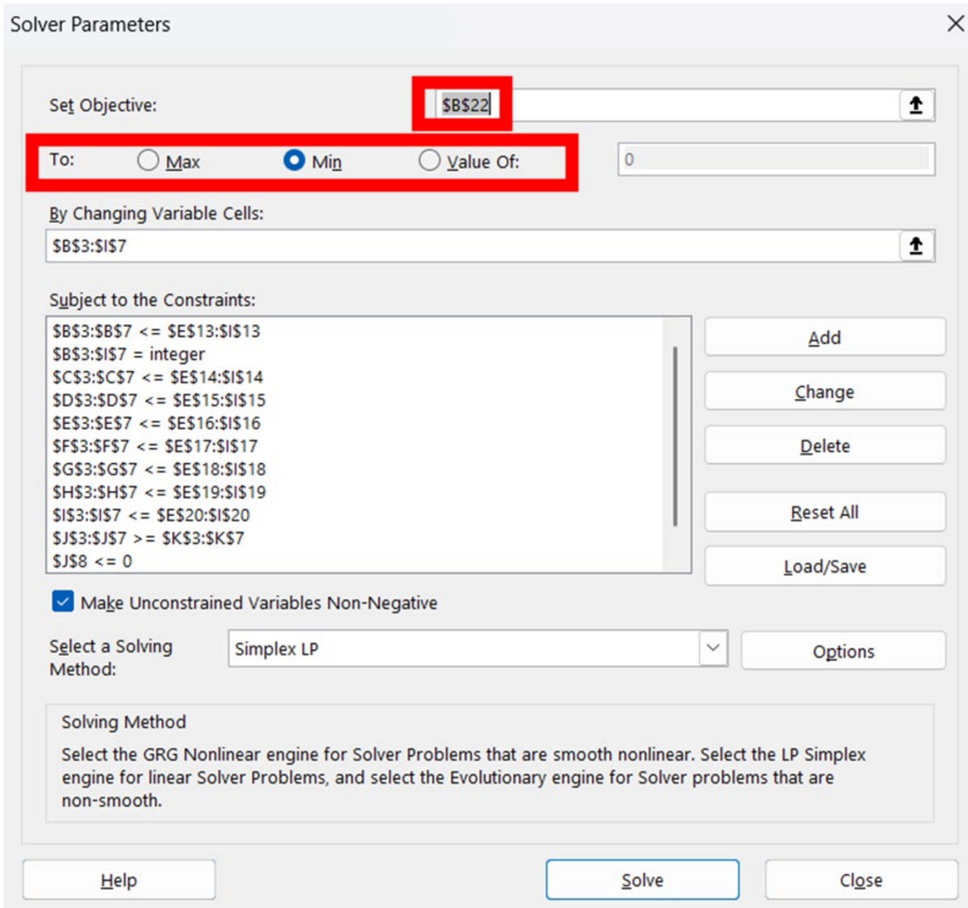
Distances (NM): (Sea)	To
From	Philippines
Okinawa	797
Yokota AB	1,608
Philippines	428
Guam	1,380
Singapore	1,283
Diego Garcia	3,173
Darwin	1,728
Korea	1340
Total cost =	$77,490,090.60

	Supply				
	Ground Transportation Assets	Vertical Lift Asset	MHE	Generators	Fuel Storage
Okinawa	65	24	65	130	30
Yokota AB	10	100	10	20	25
Philippines	5	0	5	10	3
Guam	15	24	15	30	10
Singapore	7	12	7	14	5
Diego Garcia (MPF)	150	0	150	300	100
Darwin	15	12	15	30	5
Korea	15	6	15	30	5

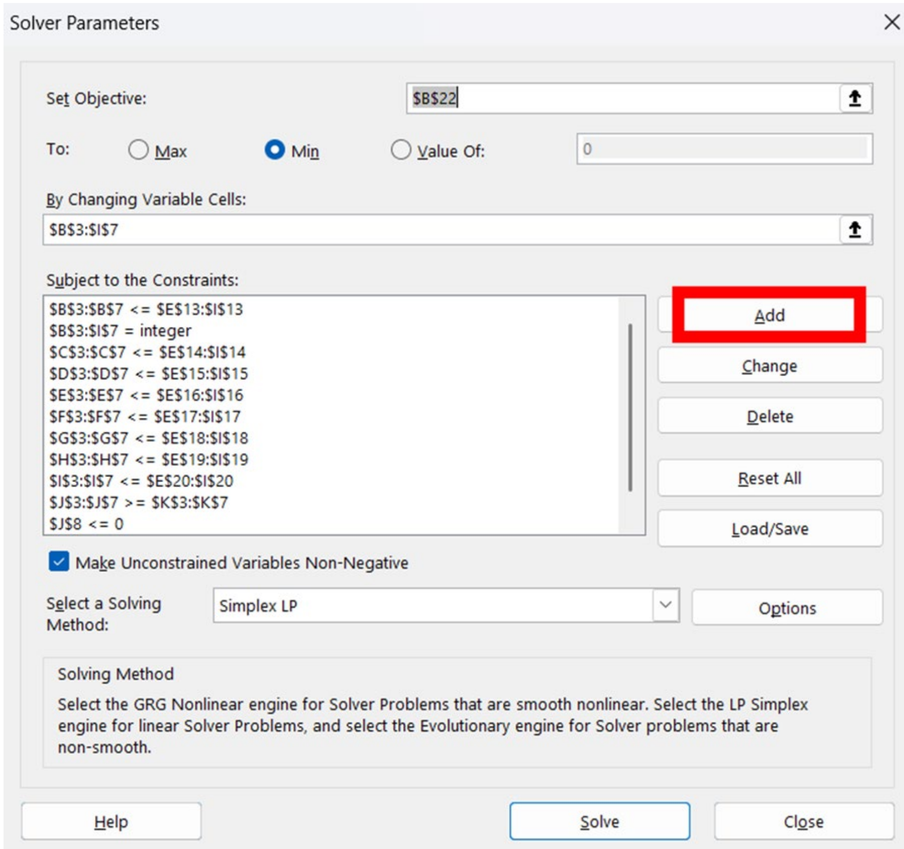
Step 1. After the Microsoft Excel spreadsheet is set up with the correct data and select the "Data" tab on the top banner.



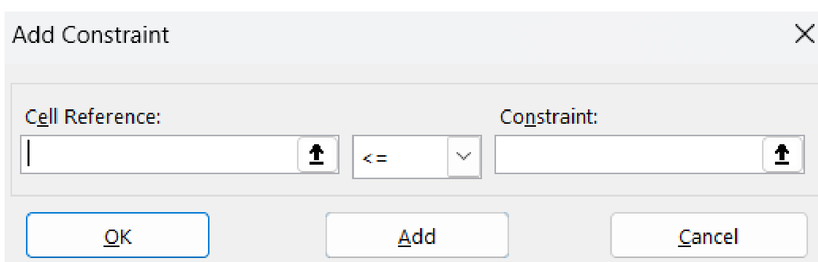
Step 2. Select the "Solver" button to enable the "Solver Parameter" box.



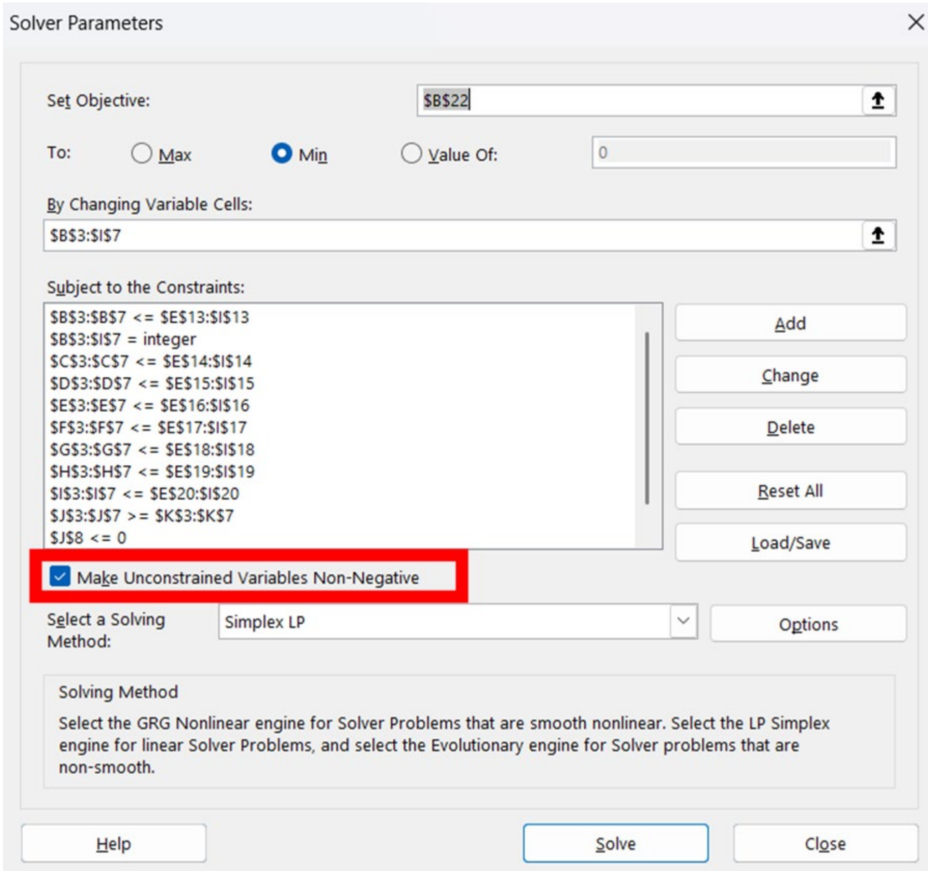
Step 3. Select the cell that represents the objective function, choose “max,” “min,” or “value of” to distinguish whether the objective of the model is the maximize, minimize, or equal a specified value.



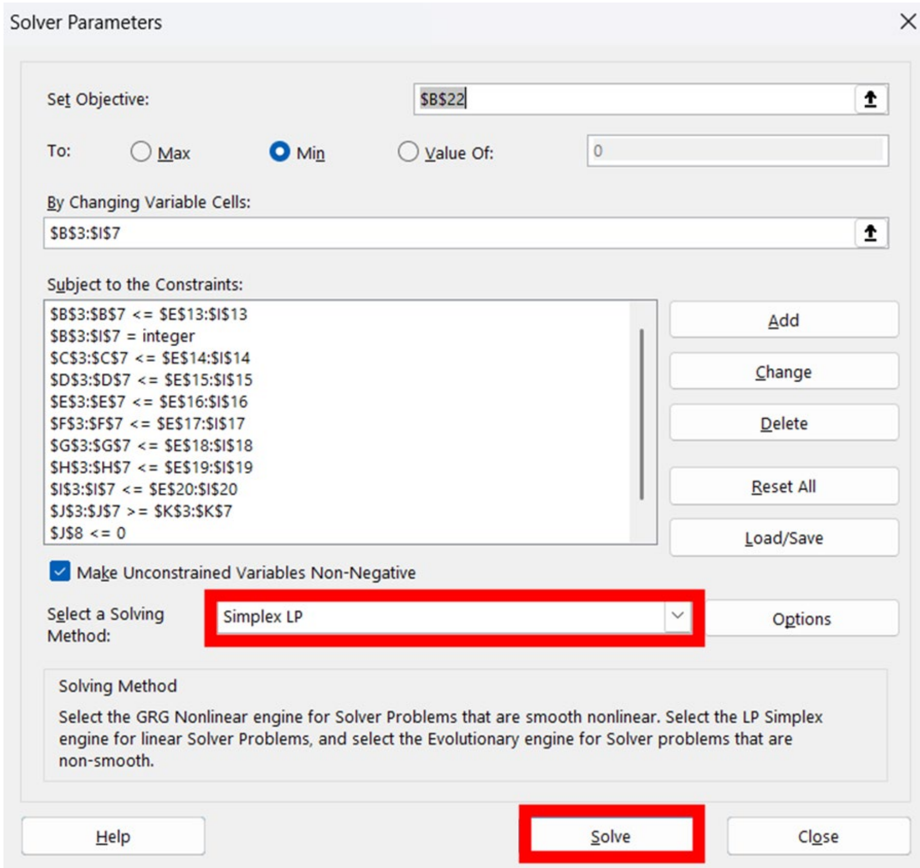
Step 4. Click the "Add" button.



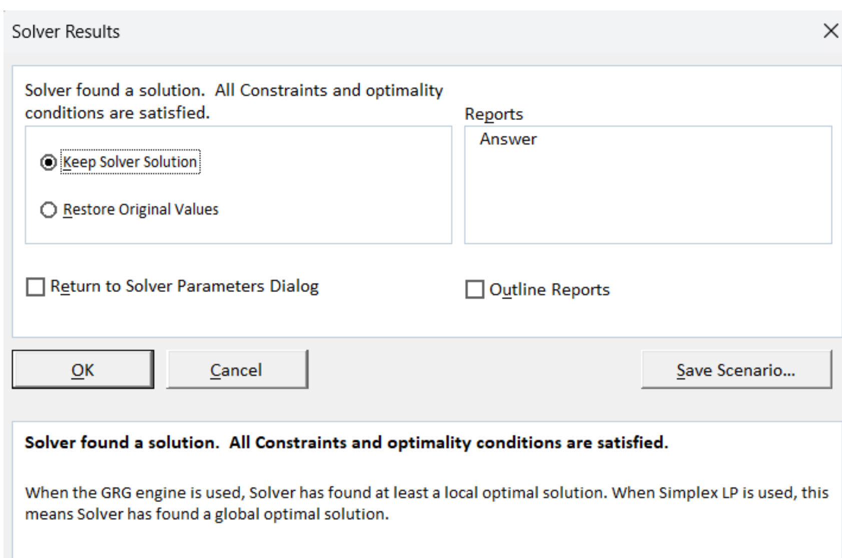
Step 5. Input the cell references, the equality parameter, and the constraint, then click the "Add" button. After inputting the final constraint, click the "OK" button.



Step 6. Check the “Make Unconstrained Variables Non-Negative”



Step 7. Select the “Simplex LP” solving method, then click the “Solve” button.



Step 8. Confirm that the solver found a solution, if there is a solution, click “OK.”

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LIST OF REFERENCES

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

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

Asia-News. (2023). *UN: Asia-Pacific, region most prone to natural disasters in the world.* https://www.asianews.it/news-en/UN%3A-Asia-Pacific%2C-region-most -prone-to-natural-disasters-in-the-world-58886.html

Berger, D. (2019). *Commandant's Planning Guidance: 38th Commandant of the Marine Corps*. United States Marine Corps. https://www.marines.mil/Portals/1/Publications/Commandant's%20Planning%20Guidance_2019.pdf?ver=2019-07-17-090732-937

Boyd, L. (2023). *I MEF announces Marine Rotational Force – Southeast Asia deployment.* Marines: the official site of The United States Marine Corps. https://www.marines.mil/News/News-Display/Article/3554744/i-mef-announces-marine-rotational-force-southeast-asia-deployment/

Chairman of the Joint Chiefs of Staff. (2019). *Foreign humanitarian assistance* (JP 3-29). https://irp.fas.org/DoDdir/DoD/jp3_29.pdf

Committee on International Relations & Committee on Foreign Relations. (2003). *Legislation on foreign relations through 2002*. United States Agency for International Development. https://www.usaid.gov/sites/default/files/2022-05/faa.pdf

Defense Logistics Agency. (2025). *DLA Indo-Pacific*. https://www.dla.mil/

Department of Defense. (2021). *Military and security developments involving the People's Republic of China*. https://media.defense.gov/2021/Nov/03/2002885874/-1/-1/0/2021-CMPR-FINAL.PDF

Duran, S., Gutierrez, M. A., & Keskinocak P. (2011) *Pre-Positioning of emergency items for CARE International*. Interfaces 41(3), 223–237. http://dx.doi.org/10.1287/inte.1100.0526

Economic and Social Commission for Asia and the Pacific. (2015). *Overview of natural disasters and their impacts in Asia and the Pacific 1970–2014*. United Nations. https://www.unescap.org/resources/overview-natural-disasters-and-their-impacts-asia-and-pacific-1970-2014

Economy, E. C. (2022). *The world according to China* (1st ed.). Polity.

Emergency Events Database. (2015). *Overview of natural disasters and their impacts in Asia and the Pacific, 1970–2014*. https://www.emdat.be

Emergency Events Database. (2023). *UN: Asia-Pacific, region most prone to natural disasters in the world*. https://www.emdat.be

Gale, E. L., & Saunders, M. A. (2013). The 2011 Thailand flood: Climate causes and return periods. *Weather*, *68*(9), 233–237. https://rmets.onlinelibrary.wiley.com/doi/10.1002/wea.2133

Google Earth. (2025). *Map view of Indo-Pacific* [Annotated Screenshot]. Retrieved March 12, 2025, from https://earth.google.com/

Headquarters United States Marine Corps. (2013). *Marine Corps prepositioning programs* (MCO3000.17). https://www.marines.mil/Portals/1/MCO%203000.17.pdf

Hovey, E. (2022). Staying first to fight: Reaffirming the Marine Corps' role in foreign humanitarian assistance missions. *Journal of Advanced Military Studies*, 13(1), 192–209.

Katzman, D. (2022). Sustaining stand-in forces: Evaluating the logistical supportability for expeditionary advanced base operations. *The Marine Corps Gazette*. pp.14–16. https://www.mca-marines.org/wp-content/uploads/Sustaining-Stand-in-Forces.pdf

Lendon, B., & Stambaugh, A. (2025). Rescue hopes fading four days after quake kills more than 2,700 in Myanmar and Thailand. *CNN World News.* https://www.cnn.com/2025/03/30/asia/myanmar-thailand-earthquake-what-we-know-intl-hnk/index.html

Marine Corps Systems Command. (2009). *U.S. Marine Corps technical manual for principal technical characteristics of U.S. Marine Corps engineer equipment* (TM 11275-15/3D). https://info.publicintelligence.net/USMC-EngineerEquipment.pdf

Marine Corps Systems Command. (2010). *U.S. Marine Corps technical manual: Principal technical characteristics of U.S. Marine Corps motor transportation equipment* (TM 11240-ODA). https://info.publicintelligence.net/USMC-MotorEquipment.pdf

Maurer, D. and Oakley, S. S. (2024). *Amphibious Warfare Fleet: Navy needs to complete key efforts to better ensure ships are available for Marines* (GAO-25-106728). Government Accountability Office.

McCall, V. M. (2006). *Designing and prepositioning humanitarian assistance pack-up kits (HA PUKs) to support Pacific fleet emergency relief operations* [Master's thesis, Naval Postgraduate School]. NPS Archive: Calhoun. https://calhoun.nps.edu/handle/10945/2480

Carbutt, J. (2011). The 10th Anniversary of the Tohoku Earthquake and Tsunami. *Metropolis*. https://metropolisjapan.com/tohoku-earthquake-and-tsunami-10th-anniversary/

Military Sealift Command. (n.d.). *Prepositioning (PM3)*. America's Navy. Retrieved April 14, 2025, from https://www.msc.usff.navy.mil/Ships/Prepositioning-PM3/

Ozdamar, L., Ekinci, E., & Kucukyazici, B. (2004). *Emergency Logistics Planning in Natural Disasters*. Kluwer Academic Publishers.

Rafferty, J. P. (2016, March 9). Five years later: The Great Sendai earthquake. *Encyclopedia Britannica*. https://www.britannica.com/story/five-years-later-the-great-sendai-earthquake

Smith, E. (2024). *Commandant's Planning Guidance: 39th Commandant of the Marine Corps*. United States Marine Corps. https://media.defense.gov/2025/Mar/14/2003667169/-1/-1/0/39th_commandants_planning_guidance-august_2024.pdf

Upadhyay, A. (2019). *Haversine formula – Calculate geographic distance on Earth*. IGISMAP. Retrieved March 12, 2025, from https://www.igismap.com/haversine-formula-calculate-geographic-distance-earth/

UNISCO. (2025, February 3). *Hub and spoke model*. https://www.unisco.com/freight-glossary/hub-and-spoke-model

United Nations High Commissioner for Refugees, International Federation of Red Cross and Red Crescent Societies, and United Nations Settlements Programme. (2010). *Shelter projects 2010.* https://shelterprojects.org/shelterprojects2010/A22-A25-Pakistan2010.pdf

United States Marine Corps. (2023, June). *Force design 2030 annual update*. https://www.marines.mil/Portals/1/Docs/Force_Design_2030_Annual_Update_June_2023.pdf

United States Marine Corps History Division. (2007). *Selected humanitarian operations*. https://www.usmcu.edu/Research/Marine-Corps-History-Division/Information-for-Units/Operations/

U.S. Embassy in the Philippines. (2023, March 20). *Enhanced Defense Cooperation Agreement (EDCA) fact sheet*. U.S. Department of State. https://ph.usembassy.gov/enhanced-defense-cooperation-agreement-edca-fact-sheet/

The White House. (2022). *Statement on Indo-Pacific economic framework for prosperity*. https://www.whitehouse.gov/briefing-room/statements-releases/2022/05/23/statement-on-indo-pacific-economic-framework-for-prosperity/

Wingfield-Hayes, R. (2024, April 5). *Taiwan earthquake: How the island's two-decade preparation saved it*. BBC. https://www.bbc.com/news/world-asia-68738694

Yamaguchi, M. (2024). *U.S. Marines start partial transfer from Okinawa in Japan to Guam under plan agreed 12 years ago*. World News. https://apnews.com/article/japan-us-military-marines-okinawa-guam-realignment-84ba9050bc77c49ac76a2c4eabdb9ffb

Yoho, K., & Apte, A. (2014). Strategies for logistics in case of a natural disaster. International Journal of Operations and Quantitative Management, 20(4), 101–119.

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