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ONLINE MULTIPLE FACILITY PROBLEMS FOR MEDICAL RESUPPLY IN INDOPACOM

by

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14. ABSTRACT

Current concepts of operation for the United States Indo-Pacific Command (INDOPACOM) area of responsibility assume that in the event of a maritime conflict, all theater medical resupply will flow through organizational units called Theater Lead Agents for Medical Materiel (TLAMMs). There is currently a single TLAMM that serves INDOPACOM, located on Kadena Air Base in Okinawa, Japan. United States Pacific Fleet planners have determined that this location is high-risk, which implies that relocating this TLAMM or establishing additional TLAMMs for INDOPACOM may be required to support a high-end maritime fight. We formulate the problem of optimally locating one or more TLAMMs as an optimization problem and leverage this formulation to develop recommendations regarding the number of TLAMMs, and where to locate them, for INDOPACOM. Based on a notional base planning scenario that uses only unclassified information, we recommend a single TLAMM for INDOPACOM located on Andersen Air Force Base in Guam. We also consider three excursions relative to the base planning scenario, and the corresponding changes in recommendations.

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ABSTRACT

Current concepts of operation for the United States Indo-Pacific Command (INDOPACOM) area of responsibility assume that in the event of a maritime conflict, all theater medical resupply will flow through organizational units called Theater Lead Agents for Medical Materiel (TLAMMs). There is currently a single TLAMM that serves INDOPACOM, located on Kadena Air Base in Okinawa, Japan. United States Pacific Fleet planners have determined that this location is high-risk, which implies that relocating this TLAMM or establishing additional TLAMMs for INDOPACOM may be required to support a high-end maritime fight. We formulate the problem of optimally locating one or more TLAMMs as an optimization problem and leverage this formulation to develop recommendations regarding the number of TLAMMs, and where to locate them, for INDOPACOM. Based on a notional base planning scenario that uses only unclassified information, we recommend a single TLAMM for INDOPACOM located on Andersen Air Force Base in Guam. We also consider three excursions relative to the base planning scenario, and the corresponding changes in recommendations.

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List of Acronyms and Abbreviations

DLA	Defense Logistics Agency
DoW	Department of War
DF	Dong Feng
INDOPACOM	U.S. Indo-Pacific Command
KM	kilometer
MILP	mixed-integer linear program
NPS	Naval Postgraduate School
OR	Operations Research
OPNAV N4L4	Office of the Chief of Naval Operations – Expeditionary Health
PACFLT	U.S. Pacific Fleet
PLARF	People's Liberation Army Rocket Force
TLAMM	Theater Lead Agent for Medical Materiel
TLAMM-P	Theater Lead Agent for Medical Materiel – Pacific
TLAMM-K	Theater Lead Agent for Medical Materiel – Korea
USD	U.S. Dollars
USN	U.S. Navy

CHAPTER 1: Introduction and Background

The Theater Lead Agent for Medical Materiel – Pacific (TLAMM-P), located on Kadena Air Base in Okinawa, Japan and operated by the U.S. Air Force's Eighteenth Medical Support Squadron since 15 October, 2021, serves as

> the epicenter to deliver medical supplies and equipment to the U.S. Indo-Pacific Command (INDOPACOM) theater outside of the Republic of Korea (Pulter 2021).

Figure 1.1 shows the main operations building of TLAMM-P. This Theater Lead Agent for Medical Materiel (TLAMM) is currently the only one that serves INDOPACOM (Theater Lead Agent for Medical Materiel-Pacific 2021). The Theater Lead Agent for Medical Materiel – Korea (TLAMM-K), operated by U.S. Army Medical Materiel Command Korea, serves organizations on the Korean Peninsula; see Figure 1.2. Moreover, current concepts of operation for the INDOPACOM area of responsibility assume that in the event of a maritime conflict, all theater medical resupply will flow through TLAMM-P. U.S. Pacific Fleet (PACFLT) planners have determined that TLAMM-P is in a high-risk area with respect to potential maritime conflicts, and have identified the need for a study that can inform future concepts of employment for TLAMMs in this area of responsibility.

This technical report summarizes the results of a research effort conducted at the Naval Postgraduate School (NPS) during Fiscal Year 2025 to develop an optimization model that can inform future decisions regarding how many TLAMMs should serve INDOPACOM, and where the TLAMM(s) should be located. This research was conducted in collaboration with the Office of the Chief of Naval Operations – Expeditionary Health (OPNAV N4L4) and Captain Rashad Brown of the U.S. Marine Corps while he was a student in the Operations Analysis curriculum of the Department of Operations Research (OR) at the NPS. Captain Brown's NPS OR Master's thesis (Brown 2025) formulated and analyzed an earlier version of the optimization model described in this report, and also describes the development of a Streamlit dashboard (Brown 2025, Section 4.5) for doing quick-turn scenario analyses and visualizations of the model solutions.

Figure 1.1. The TLAMM-P is located on Kadena Air Base in Okinawa, Japan, and serves the entire INDOPACOM area of responsibility outside of the Korean Peninsula. (Image Credit: Yasuo Osakabe, U.S. Air Force)

The rest of this report is organized as follows. The remainder of this chapter provides additional context for the problem. Chapter 2 presents the optimization model. Chapter 3 describes and analyzes the model outputs obtained for a notional scenario that reflects unclassified aspects of the TLAMM location problem for INDOPACOM. Chapter 4 provides conclusions and recommendations.

1.1 Medical (Class VIII) Materiel

Class VIII (medical and dental) materiel is one of the ten classes of supply that are used in U.S. military logistics; for definitions of each class, see e.g. the Department of War (DoW) Supply Chain Terms and Definitions maintained by the Office of the Assistant Secretary of War for Logistics (Office of the Assistant Secretary of War 2024). Class VIII materiel is divided into two sub-classes: Class VIIIA and Class VIIIB. Class VIIIA materiel refers to all medical/dental consumables that are not blood-related, medical/dental equipment, and medical/dental repair parts (Office of the Assistant Secretary of War 2024, p. 8). All blood-related products (e.g, whole blood, plasma, platelets) are considered to be Class VIIIB materiel (Department of Defense 2023, p. 3). TLAMMs such as TLAMM-P deal primarily with Class VIIIA materiel (Department of Defense 2023; Theater Lead Agent for

Figure 1.2. Medical (Class VIII) materiel is loaded onto a CH-47 helicopter at the TLAMM-K, which is located at Camp Carroll in South Korea and serves U.S. Forces Korea. (Image Credit: Shawn Hardiek, Army Medical Logistics Command)

Medical Materiel-Pacific 2021). Rules and procedures for the management of Class VIIIB materiel can be found in Joint Publication 4-02 (Joint Chiefs of Staff 2023). For the U.S. Navy (USN), all Class VIII materiel is managed by the Defense Logistics Agency (DLA) through DLA Troop Support in Philadelphia, Pennsylvania.

1.2 Theater Lead Agents for Medical Materiel

A TLAMM is an organizational unit designated by the Chairman of the Joint Chiefs of Staff. The mission of each TLAMM is to

> provide direct medical materiel support to theater medical forces, ensure tactical units are integrated into the end-to-end medical materiel supply chain, and assist combatant commands and the service component command assigned to support the combatant commands in medical logistics planning (Department of Defense 2023).

The DLA Director, who also serves as the DoW Medical Materiel Executive Agent, is responsible for nominating organizations that have the potential to serve as TLAMMs to the Chairman of the Joint Chiefs of Staff. This nomination is provided in coordination with Combatant Commanders and the Secretaries of the Military Departments.

Figure 1.3. Map of the INDOPACOM area of responsibility. (Image Source: INDOPACOM)

1.3 INDOPACOM Area of Responsibility

INDOPACOM is headquartered at the Nimitz-MacArthur Building on Camp H. M. Smith in Halawa on Oahu, Hawaii. It is one of the six Unified Combatant Commands of the U.S. Armed Forces, and

> encompasses about half the earth's surface, stretching from the waters off the west coast of the U.S. to the western border of India, and from Antarctica to the North Pole. (USINDOPACOM 2026)

Figure 1.3 shows a map that depicts the boundaries of the INDOPACOM area of responsibility. In addition to being the largest of the six Unified Combatant Commands, it is also the oldest, having been established on January 1, 1947 in the form of the Far East Command led by General Douglas MacArthur (USINDOPACOM 2026). INDOPACOM is supported by five component commands, which include PACFLT, headquartered at Joint Base Pearl Harbor-Hickam and U.S. Marine Forces, Pacific, headquartered at Camp H. M. Smith.

CHAPTER 2:
Location Model

This chapter presents the optimization-based location model for the problem of determining how many TLAMMs should serve INDOPACOM, and where they should be located. The formulation can be viewed as an extension of classic facility location models from the field of OR; see, for example, Simchi-Levi et al. (2014, Chapter 15). Section 2.1 describes the decision variables, Section 2.2 describes the input data, and Section 2.3 describes the tuning parameters. The objective function is defined in Section 2.4, and the constraints are defined in Section 2.5. Finally, the full optimization formulation is presented in Section 2.6.

2.1 Decision Variables

The primary decision variables represent whether to open a TLAMM at each of the potential TLAMM sites. The potential sites are indexed by $i = 1, \ldots, n$, where n is the total number of possible sites. For each site index i, the binary decision variable x_i reflects the decision to establish a TLAMM at i or not:

$$x_i = \begin{cases} 1 & \text{if a TLAMM is established at location } i, \\ 0 & \text{otherwise.} \end{cases}$$

The secondary decision variables represent how medical materiel will flow from the established TLAMMs to where they are needed. This is included for the purpose of representing the TLAMM-related shipping costs that will be incurred. For each location $i = 1, \ldots, n$ where a TLAMM can potentially be established, and for each customer location $j = 1, \ldots, m$, the amount of medical materiel that will flow from location i to j is represented by the decision variable $y_{i,j}$:

$$y_{i,j} = \text{amount of medical materiel sent from a TLAMM at location } i \text{ to customer } j.$$

If no TLAMM has been established at location i, then we assume that $y_{i,j} = 0$ for every customer $j = 1, \ldots, m$. This is reflected in the constraints that are described in Section 2.5.

2.2 Input Data

There are two types of input data. One type of input data involves characteristics of each potential TLAMM location $i = 1, \ldots, n$ or customer location $j = 1, \ldots, m$. The other type of input data models the cost of shipping medical materiel from each location $i = 1, \ldots, n$ to each customer $j = 1, \ldots, m$.

For each potential TLAMM location $i = 1, \ldots, n$, the model requires

- an estimate of the cost $\mathtt{f}_i$ of establishing a TLAMM at i,
- whether or not location i is "high-risk," represented by the indicator

$$\mathtt{r}_i^{\text{hi}} = \begin{cases} 1 & \text{if location } i \text{ is high-risk,} \\ 0 & \text{otherwise,} \end{cases}$$

- whether or not location i is "medium-risk," represented by the indicator

$$\mathtt{r}_i^{\text{md}} = \begin{cases} 1 & \text{if location } i \text{ is medium-risk,} \\ 0 & \text{otherwise,} \end{cases}$$

  and
- whether or not location i has an existing airstrip or port, represented by the indicator

$$\mathtt{a}_i = \begin{cases} 1 & \text{if location } i \text{ already has an airstrip or port,} \\ 0 & \text{otherwise.} \end{cases}$$

The inclusion of whether each location i has an airstrip or port is motivated by the need for each TLAMM to be connected to the broader military medical logistics network.

For each customer location $j = 1, \ldots, n$, the model requires the estimated demand $\mathtt{d}_j$ for medical materiel over the planning horizon. Finally, for each potential TLAMM location i and customer j, the model requires an estimate of the per-unit (e.g., per-ton) cost $\mathtt{c}_{i,j}$ to ship medical materiel from i to j.

2.3 Tuning Parameters

In addition to the input data, a per-site penalty $\alpha_{\text{risk}}^{\text{hi}}$ is assessed for each TLAMM established at a "high-risk" location. Similarly, a per-site penalty $\alpha_{\text{risk}}^{\text{md}}$ is assessed for each TLAMM established at a "medium-risk" location. Finally, a per-site bonus of α_{site} is earned for establishing a TLAMM at a location that already has an airstrip or port. These penalties/bonuses can be viewed as tuning parameters, through which the importance of these attributes relative to each other and to the opening/shipping costs can be adjusted.

2.4 Objective Function

The objective is to select the locations at which to establish TLAMMs through the x_i's, and to select the medical materiel flows though the $y_{i,j}$'s, in order to minimize the total cost that will be incurred over the planning horizon. The total cost is the sum of four cost components, minus a bonus component related to the use of locations with existing airstrips or ports. The four cost components are the total cost

$$\sum_{i=1}^{n} \mathtt{f}_i x_i,$$

of establishing TLAMMs at the selected locations, the total shipment cost

$$\sum_{i=1}^{n} \sum_{j=1}^{m} \mathtt{c}_{i,j} y_{i,j},$$

the total penalty

$$\alpha_{\text{risk}}^{\text{hi}} \sum_{i=1}^{n} \mathtt{r}_i^{\text{hi}} x_i$$

for establishing TLAMMs at high-risk locations, and the total penalty

$$\alpha_{\text{risk}}^{\text{md}} \sum_{i=1}^{n} \mathtt{r}_i^{\text{md}} x_i$$

for establishing TLAMMs at medium-risk locations. The bonus component is the total bonus

$$\alpha_{\text{site}} \sum_{i=1}^{n} \mathtt{a}_i x_i$$

for establishing TLAMMs at locations with existing airstrips or ports. The total cost incurred for given decision variables values $x_1, \ldots, x_n$ and $y_{1,1}, y_{1,2}, \ldots, y_{n,m}$ is denoted by

$$\begin{aligned} c(x_1, \ldots, x_n, y_{1,1}, y_{1,2}, \ldots, y_{n,m}) = \sum_{i=1}^{n} \mathtt{f}_i x_i + \sum_{i=1}^{n} \sum_{j=1}^{m} \mathtt{c}_{i,j} y_{i,j} + \alpha_{\text{risk}}^{\text{hi}} \sum_{i=1}^{m} \mathtt{r}_i^{\text{hi}} x_i \\ + \alpha_{\text{risk}}^{\text{md}} \sum_{i=1}^{m} \mathtt{r}_i^{\text{md}} x_i - \alpha_{\text{site}} \sum_{i=1}^{m} \mathtt{a}_i x_i. \end{aligned}$$

2.5 Constraints

For locations $i = 1, \ldots, n$, the decision variable x_i indicating whether or not a TLAMM should be established at location i must be either 1 (if a TLAMM is established at i) or 0. For $i = 1, \ldots, n$ and the customer locations $j = 1, \ldots, m$, the amount of medical materiel shipped from i to j must be non-negative, and satisfy two additional constraints. The first is that every customer's demand must be fully met, i.e.,

$$\sum_{i=1}^{n} y_{i,j} = \mathtt{d}_j \quad \text{for } j = 1, \ldots, m;$$

the second is that a location with a TLAMM can send at most the amount demanded to each customer and none if no TLAMM is established there, i.e.,

$$y_{i,j} \leq \mathtt{d}_j x_i \quad \text{for } i = 1, \ldots, n,\ j = 1, \ldots, m.$$

2.6 Full Optimization Model Formulation

If there are n candidate TLAMM locations and m customer locations, the optimization model is a mixed-integer linear programming problem with n binary decision variables, nm continuous decision variables, and $m + nm$ constraints:

Indices

- i = location where a TLAMM can be established; total of n candidate locations
- j = customer location; total of m customers

Decision Variables

- TLAMM Site Selection:

$$x_i = \begin{cases} 1 & \text{a TLAMM is established at location } i \\ 0 & \text{otherwise} \end{cases}$$

- Demand Assignment:

$$y_{i,j} = \text{amount of medical materiel sent from a TLAMM at location } i \text{ to customer } j$$

Data

- $\mathtt{f}_i$ = cost to open a TLAMM at site i
- $\mathtt{r}_i^{\text{hi}}$ = 1 if location i is high-risk, 0 otherwise
- $\mathtt{r}_i^{\text{md}}$ = 1 if location i is moderate-risk, 0 otherwise
- $\mathtt{a}_i$ = 1 if location i already has an airstrip or port, 0 otherwise
- $\mathtt{d}_j$ = demand from customer j
- $\mathtt{c}_{i,j}$ = per-unit shipping cost between site i and customer j

Tuning Parameters

- $\alpha_{\text{risk}}^{\text{hi}}$ = cost per TLAMM located at a high-risk site
- $\alpha_{\text{risk}}^{\text{md}}$ = cost per TLAMM located at a medium-risk site
- α_{site} = savings per site that already has an airstrip or port

Objective to Minimize

$$\begin{aligned} c(x_1, \ldots, x_n, y_{1,1}, y_{1,2}, \ldots, y_{n,m}) = \sum_{i=1}^{n} \mathtt{f}_i x_i + \sum_{i=1}^{n} \sum_{j=1}^{m} \mathtt{c}_{i,j} y_{i,j} + \alpha_{\text{risk}}^{\text{hi}} \sum_{i=1}^{m} \mathtt{r}_i^{\text{hi}} x_i \\ + \alpha_{\text{risk}}^{\text{md}} \sum_{i=1}^{m} \mathtt{r}_i^{\text{md}} x_i - \alpha_{\text{site}} \sum_{i=1}^{m} \mathtt{a}_i x_i \end{aligned}$$

Optimization Model

$$
\begin{aligned}
\text{minimize} \quad & c(x_1, \ldots, x_n, y_{1,1}, y_{1,2}, \ldots, y_{n,m}) & \\
\text{subject to} \quad & \sum_{i=1}^{n} y_{i,j} = \mathtt{d}_j & \text{for } j = 1, \ldots, m \\
& 0 \le y_{i,j} \le \mathtt{d}_j x_i & \text{for } i = 1, \ldots, n,\ j = 1, \ldots, m \\
& x_i = 1 \text{ or } 0 & \text{for } i = 1, \ldots, n
\end{aligned}
$$

CHAPTER 3: Location Analysis

In this chapter, we describe the application of the location model presented in Chapter 2 to a notional INDOPACOM planning scenario that is based on input from OPNAV N4L4 and PACFLT. The scenario features twenty-five potential TLAMM locations, which are shown in the context of INDOPACOM in Figure 3.1 and listed in Table 3.1 with attributes that are explained in Section 3.1. Section 3.1 also includes the description of this base scenario (Section 3.1.1) and the corresponding outputs of the location model (Section 3.1.2). Section 3.2 presents three excursions relative to the base planning scenario, and the corresponding changes in the outputs of the location model. In all cases, the associated mixed-integer linear program (MILP) had 25 binary variables, 625 continuous variables, and 650 constraints, and required roughly 0.1 seconds to solve using the COIN-OR Branch-and-Cut (CBC) solver (COIN-OR Foundation 2026).

3.1 Base Scenario

Each of the twenty-five locations represents a potential TLAMM location as well as a potentially significant consumer of medical materiel in the event of a high-end conflict in INDOPACOM. The current location of the TLAMM-P (Kadena Air Base) is included among these twenty-five locations. For each location other than Kadena Air Base, the cost to open a TLAMM at the location is set to \$100 million U.S. Dollars (USD); for Kadena Air Base, the "opening cost" is set to \$0 USD.

The remaining features of each location are whether it has an existing airstrip or port, whether it is "high-risk," whether it is "medium-risk," and its estimated demand (e.g., in short tons) for medical materiel during the planning horizon. The existence of an airstrip or port is based on open-source intelligence. The designation of a location as "high-risk" or "medium-risk" is based on its proximity to People's Liberation Army Rocket Force (PLARF) Bases 61–66; see, for example, Logan (2019, p. 401). Specifically, we consider a location to be "high-risk" if its distance to the closest PLARF base is within 2,500 kilometers (KMs), which is the upper estimated range of a Dong Feng (DF)-17 medium-range ballistic missile (Center for

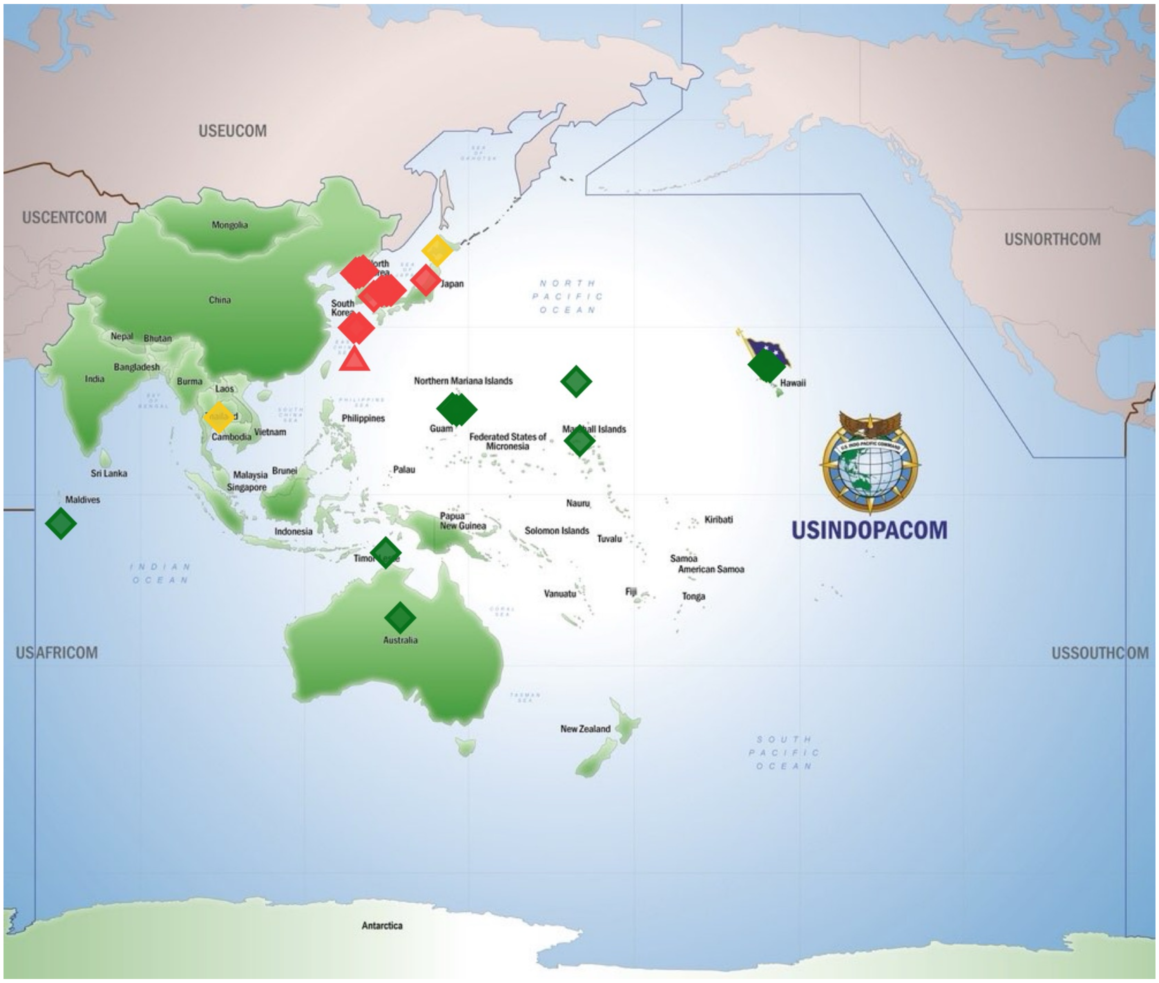

Figure 3.1. Locations of the twenty-five potential TLAMM locations for INDOPACOM in the base scenario. Red diamonds indicate "high-risk" locations, yellow diamonds indicate "medium-risk" locations, and green diamonds indicate locations that are neither high- nor medium-risk. The red triangle indicates the location of Kadena Air Base, which is the current location of TLAMM-P and is "high-risk."

Strategic & International Studies 2026a). We consider a location to be "medium-risk" (and not "high-risk") if its distance to the closest PLARF base is within 4,000 KM, which is the estimated range of a DF-26 intermediate-range ballistic missile (Center for Strategic & International Studies 2026b). In the base scenario and all of the excursions, we consider the case where the cost $\alpha_{\text{risk}}^{\text{hi}}$ per TLAMM located at a high-risk site is double the cost $\alpha_{\text{risk}}^{\text{md}}$ per

Location	Airstrip/Port?	High-Risk?	Medium-Risk?
Andersen Air Force Base	Yes	No	No
Diego Garcia Naval Support Facility	Yes	No	No
Joint Base Pearl Harbor-Hickam	Yes	No	No
Marine Corps Base Hawaii	Yes	No	No
Naval Base Guam	Yes	No	No
Misawa Air Base	Yes	No	Yes
Fleet Activities Sasebo	Yes	Yes	No
Fleet Activities Yokosuka	Yes	Yes	No
Kadena Air Base	Yes	Yes	No
Kunsan Air Base	Yes	Yes	No
Marine Corps Air Station Futenma	Yes	Yes	No
Marine Corps Air Station Iwakuni	Yes	Yes	No
Naval Air Facility Atsugi	Yes	Yes	No
Osan Air Base	Yes	Yes	No
Yokota Air Base	Yes	Yes	No
Camp Blaz	No	No	No
Darwin, Australia	No	No	No
Kwajalein Atoll	No	No	No
Pine Gap, Australia	No	No	No
Schofield Barracks	No	No	No
Wake Island Airfield	No	No	No
Utapao Royal Thai Navy Airfield	No	No	Yes
Camp Hansen	No	Yes	No
Camp Humphreys	No	Yes	No
Camp Zama	No	Yes	No

Table 3.1. Each of the twenty-five locations is a potential TLAMM location as well as a source of demand for medical materiel. The designation as "high-risk" or "medium-risk" is based on the location's proximity to potential weapons engagement zones.

TLAMM located at a medium-risk location, i.e., that

$$\alpha_{\text{risk}}^{\text{hi}} = 2 \cdot \alpha_{\text{risk}}^{\text{md}}. \tag{3.1}$$

The per-unit shipping cost $\mathsf{c}_{i,j}$ between each pair (i, j) of locations is assumed to have the form

$$\mathsf{c}_{i,j} = \alpha_{\text{ship}} \cdot \mathtt{dist}_{i,j},$$

where α_{ship} is a parameter that can be interpreted as the shipping cost per ton-KM, and $\mathtt{dist}_{i,j}$ is the distance between locations i and j.

3.1.1 Scenario Description

In the base scenario, we use a per ton-KM shipping cost of

$$\alpha_{\text{ship}} = \$10 \text{ per ton-KM.}$$

For the risk parameters, we use a cost of

$$\alpha_{\text{risk}}^{\text{hi}} = \$200 \text{ million}$$

per TLAMM located at a high-risk location, which in light of (3.1) implies a cost of $\alpha_{\text{risk}}^{\text{md}} = \$100$ million per TLAMM located at a medium-risk location. Finally, we include a savings of

$$\alpha_{\text{site}} = \$10 \text{ million}$$

for each TLAMM established at a location that already has an airstrip or port.

3.1.2 Results

The solution to the MILP defined in Section 2.6, with the given input data data and parameter values for the base scenario, recommends maintaining a single TLAMM for INDOPACOM. However, instead of remaining at its present "high-risk" location on Kadena Air Base in Okinawa, the TLAMM should be relocated to Andersen Air Force Base in Guam, which is neither high- nor medium-risk; see Figure 3.2. In this scenario, it is cheaper to move and operate the TLAMM outside the range of DF-17s and DF-26s, than to operate it at its current "high-risk" location.

3.2 Excursions

In addition to the base scenario, we consider three excursions with respect to the parameters of the location model. Section 3.2.1 deals with a situation where it is less costly for the TLAMM to be at a "high-risk" location. Section 3.2.2 deals with a situation where the shipping costs are higher than in the base scenario. Finally, Section 3.2.3 deals with a

Figure 3.2. In the base scenario, the location model recommends a single TLAMM for INDOPACOM. Moreover, this TLAMM should be located at Andersen Air Force Base in Guam, whose location is indicated by the green diamond.

situation where there are no savings associated with establishing a TLAMM at a location with an existing airstrip or port.

3.2.1 Lower Cost for High-Risk Locations

In this excursion, the risk parameter $\alpha_{\text{risk}}^{\text{hi}}$ for operating a TLAMM at a "high-risk" location is reduced from \$200 million in the base scenario, to \$100 million. This makes the cost of operating a TLAMM at a "high-risk" location equal to the cost of establishing a TLAMM

Figure 3.3. In the excursion where the cost of operating a TLAMM at "high-risk" location is equal to the cost of establishing a new TLAMM, the location model recommends the status quo of a single TLAMM located at Kadena Air Base, whose location is indicated by the red triangle.

at a new location. Recalling (3.1), in this excursion the cost of operating a TLAMM at a "medium-risk" location is $\alpha_{\text{risk}}^{\text{md}}$ = \$50 million.

Results: In this excursion, the location model again recommends a single TLAMM for INDOPACOM. Moreover, this TLAMM should be at its existing location on Kadena Air Base in Okinawa; see Figure 3.3.

3.2.2 Higher Shipping Cost

In this excursion, the per ton-KM shipping cost α_{ship} is increased ten-fold relative to the base scenario, from \$10 per ton-KM to \$100 per ton-KM.

Results: When the shipping costs are high enough, it makes sense to have more than one TLAMM in order to reduce the overall distance that materiel needs to be moved. Such is the case in this excursion, where the location model recommends three TLAMMs for INDOPACOM. Specifically, in addition to the existing TLAMM on Kadena Air Base in Okinawa, two additional TLAMMs should be established. One should be at Andersen Air Force Base in Guam, and the other should be at Joint Base Pearl Harbor-Hickam in Hawaii. See Figure 3.4.

3.2.3 No Savings for Existing Airstrip/Port

In this excursion, the savings α_{site} associated with each TLAMM established at a location with an existing airstrip or port is reduced to \$0.

Results: Here, the location model makes the same recommendation as in the base scenario, to have a single TLAMM for INDOPACOM located at Andersen Air Force Base in Guam; see Figure 3.5.

Figure 3.4. In the excursion with a ten-fold increase in shipping costs per ton-KM, two additional TLAMMs (at Andersen Air Base and Joint Base Pearl Harbor-Hickam) should be established to help reduce shipping distances.

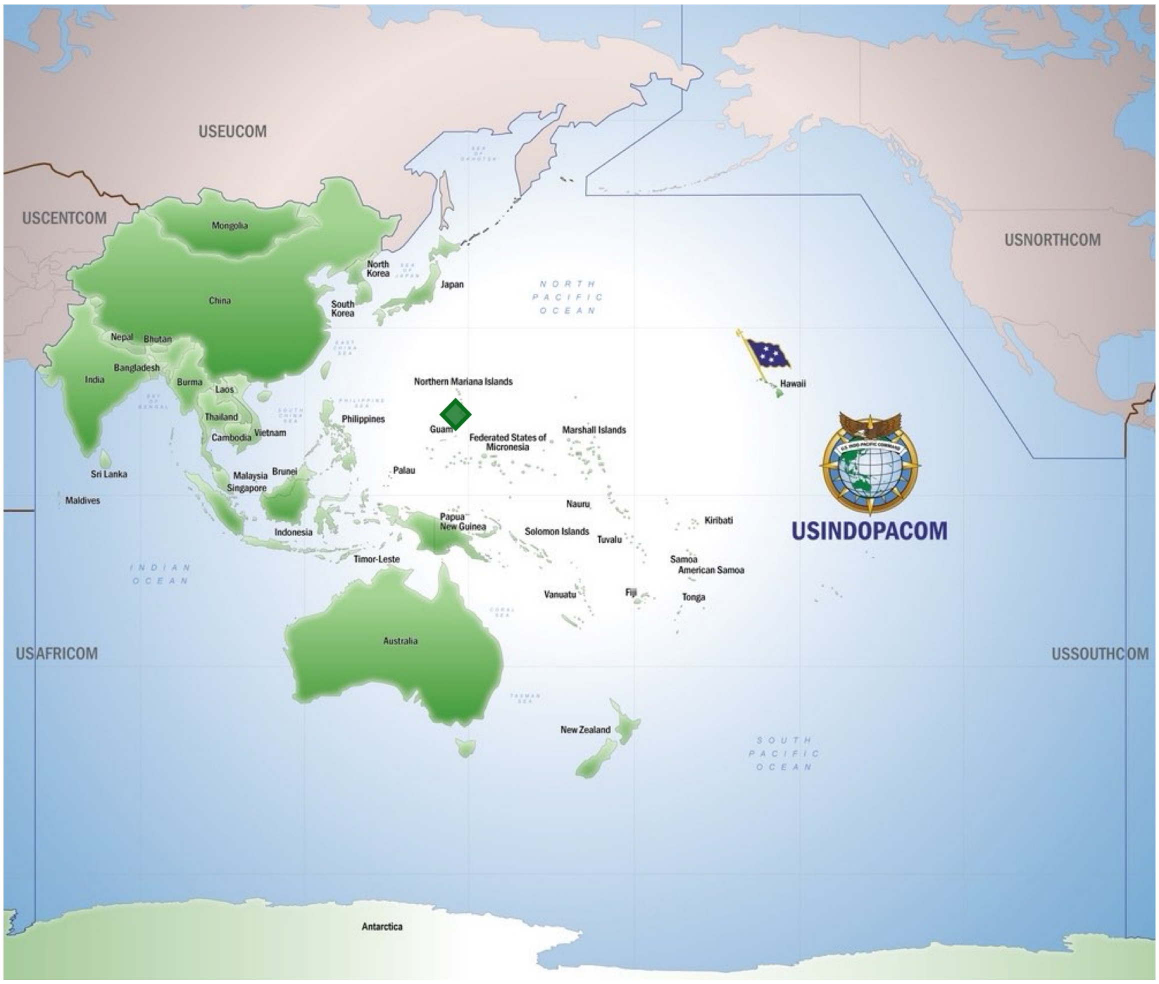

Figure 3.5. Even with no savings associated with establishing TLAMMs at locations with existing airstrips or ports, the location model recommends a single TLAMM for INDOPACOM located at Andersen Air Force Base in Guam.

CHAPTER 4: Conclusions and Recommendations

In Chapter 2, a facility location model is proposed to address the problem of how many TLAMMs should serve INDOPACOM, and where they should be located. The input data for this model includes for each candidate location the cost to open a TLAMM there, whether the location is "high-risk," whether the location is "medium-risk," and whether the location has an existing airstrip or port. For each potential TLAMM location and potential medical materiel customer, the per-ton shipping cost is required as well. The parameters of the model include the penalty for each TLAMM in a "high-risk" location, the penalty for each TLAMM in a "medium-risk" location, and the savings from establishing a TLAMM at a location that already has an existing airstrip or port. The resulting optimization model is a MILP where the number of decision variables is equal to the number of candidate locations, and the number of constraints equals the number of customer locations plus the number of candidate locations times the number of customer locations.

In Chapter 3, we applied the facility location model to a notional base scenario, where the location model recommended a single TLAMM for INDOPACOM located on Andersen Air Force Base in Guam instead of its current location on Kadena Air Base in Okinawa. The results in the excursions confirm, for example, that the current location at Kadena is optimal if being in a "high-risk" area is less costly, and that increased shipping costs make having more than one TLAMM more desirable. For the range of savings obtainable by selecting locations with existing airstrips or ports ($10 million to $0), the resulting recommendation (of a single TLAMM located at Andersen Air Force Base) does not change.

There are many potential directions for follow-on research. For example, more realistic (and likely classified) planning scenarios can be considered. In addition, the current location model is deterministic in the sense that there is no uncertainty in the demands and availability of shipping routes.

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