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THESIS

ANALYSIS OF STRYKER BRIGADE COMBAT TEAM STRATEGIC SEALIFT DEPLOYMENT OPTIONS

by

Preston L. Gill

December 2003

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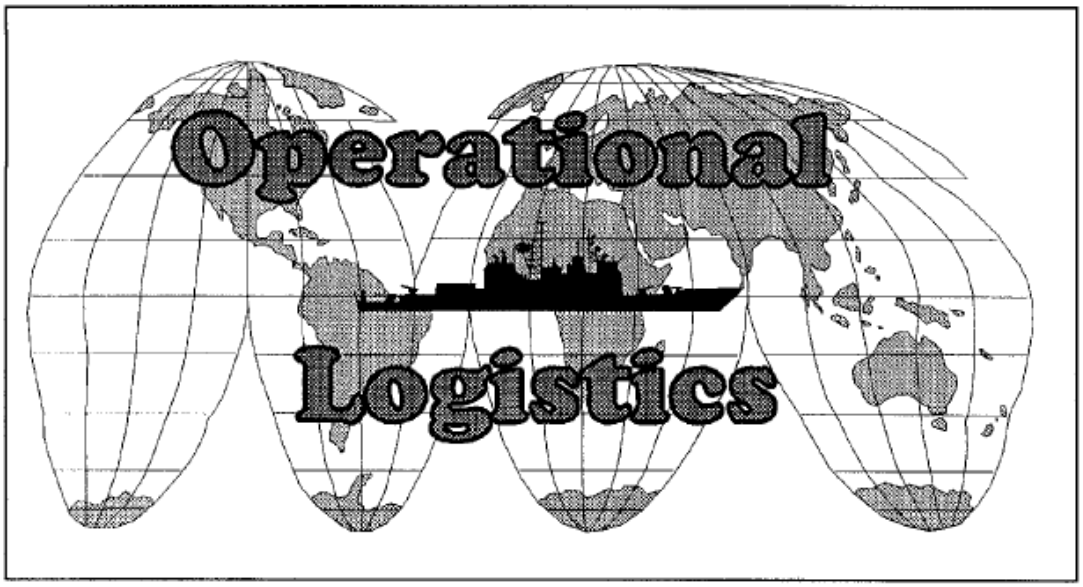
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This thesis determines the mix of sealift assets best suited for different scenarios that differ by distance and port accessibility as well as analyzes the implications of these findings on Army deployment doctrine. This is accomplished in two ways. First, two specific scenarios are used to develop the initial requirements and best mix of assets for SBCT deployment based on a fictional Kosovo campaign. Additionally, a preliminary analysis is conducted of the three feasible configuration options. The options are (1) TSVs only, (2) LMSRs only or (3) a combination of the two. These three options are compared using fixed cargo requirements and their performance versus cost is analyzed based on the Kosovo campaign distances.

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ABSTRACT

Projecting a credible land combat power to a potential conflict area in a timely manner requires rapid strategic sealift mobility with high capacity. A highly deployable, light, yet sufficiently lethal force capable of deterrence or sustaining combat is necessary to accomplish this objective.

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LIST OF ACRONYMS

AMCS	Advanced Mobility Concepts Study
AOR	Area of Responsibility
CAA	Center for Army Analysis
CASCOM	Combined Arms Support Command
CJCS	Chairman, Joint Chiefs of Staff
CONUS	Continental United States
DOD	Department of Defense
DPG	Defense Planning Guidance
IAW	In Accordance With
ILP	Integer Linear Program
ISB	Intermediate Staging Base
JLOTS	Joint Logistics-Over-the Shore
JOA	Joint Operational Area
LMSR	Large, Medium-speed Roll-on/Roll-off
LO/LO	Lift-on/Lift-off
LOTS	Logistics-Over-the Shore
LP	Linear Program or Programming
MARAD	Maritime Administration
MEB	Marine Expeditionary Brigade
MOE	Measure of Effectiveness
MPS	Maritime Prepositioning Ship
MRS	Mobility Requirements Study
MRS BURU	Mobility Requirements Study Bottom-up Review Update
MSC	Military Sealift Command
MTM/d	Million ton-miles per day
NM	Nautical Miles
NPS	Naval Postgraduate School
PREPO	Pre-positioned
POE	Point of Embarkation
RO/RO	Roll-on/Roll-off
SBCT	Stryker Brigade Combat Team
SS3	Sea State 3
TPFDD	Time Phased Force Deployment Data
TSV	Theater Support Vessel
USAF	United States Air Force
USMC	United States Marine Corps
USTRANSCOM	U.S. Transportation Command

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EXECUTIVE SUMMARY

Projecting a credible land combat power to a potential conflict area in a timely manner requires rapid strategic sealift mobility with high capacity. A highly deployable, light, yet sufficiently lethal force capable of deterrence or sustaining combat is necessary to accomplish this objective.

The Army's initial steps towards transformation seek to establish that ability. This transformation requires having lighter forces with quicker deployment times, thereby turning the Army from the Legacy Force, made up of both well-equipped heavy war fighting forces which are difficult to deploy strategically, and rapidly responding light forces which lack staying power against heavy mechanized forces, into an Interim Force of Stryker Brigade Combat Teams (SBCT). The SBCT combines the capacity for rapid deployment with survivability and tactical mobility. The Army's objective is to deploy the Stryker Brigade Combat Team, a brigade-sized force equipped with medium weight armored vehicles, anywhere in the world within 96 hours (Vick, 2002).

This thesis determines the mix of sealift assets best suited for different scenarios that differ by distance and port accessibility as well as analyzes the implications of these findings on Army deployment doctrine. This is accomplished in two ways. First, two specific scenarios are used to develop the initial requirements and best mix of assets for SBCT deployment based on a fictional Kosovo campaign. Additionally, a preliminary analysis is conducted of the three feasible configuration options. The options are (1) TSVs only, (2) LMSRs only or (3) a combination of the two. These three options are compared using fixed cargo requirements and their performance versus cost is analyzed based on the Kosovo campaign distances.

From the analysis conducted in this paper it would appear that the 96-hour time requirement to deploy a SBCT using sealift assets would only be viable within short pre-positioned (PREPO) intra-theater ranges vice a global response, meaning that the SBCT cannot meet the 96-hour global deployment time frame from CONUS. This highlights the advantage and need of PREPO units for rapid response.

Specifically, this analysis finds that the best mix of assets depends on the scenario distance and port accessibility. Two scenarios are modeled based on a fictional Kosovo campaign. The first scenario deploys the SBCT from the PREPO location of Camp Darby, Italy. The second scenario deploys the SBCT from the CONUS location of Beaumont, Texas. Next, a hybrid of this CONUS scenario is conducted by changing the destination port characteristics to test the sensitivity of the model solution.

These results show that for PREPO ranges up to 1250 nautical miles the TSV is better suited for SBCT deployment with its greater speed and shallower draft regardless of port conditions. For greater ranges, the LMSR is the preferred platform because of its endurance and capacity. Introducing port degradation at increased ranges may change the optimal solution depending if the time delays associated with the LMSRs is greater than the time for the additional refueling required by the TSVs.

Cost versus performance analysis shows that for short ranges better performance can be achieved at higher costs using TSVs. As the range increases, the use of LMSRs becomes the preferred option for performance at moderate cost. If time is not important then the less expensive combination of mixing one of each asset becomes an attractive option at longer ranges.

The Army's transformation objective of a 96-hour global deployment time implies a rapid strategic sealift at speeds that are currently not possible from CONUS. With increased efficiency in loading/unloading and refueling times as well as other mobility enhancements it will be possible to further reduce SBCT deployment times within one to two weeks for global response.

I. INTRODUCTION

A. HISTORICAL OVERVIEW

Traditionally, to deter and defeat major threats in select regions with joint forces, the United States has relied on forward-deployed Army and U.S. Air Force (USAF) forces, Navy and United States Marine Corps (USMC) forces afloat, long-range aircraft in the continental United States (CONUS), pre-positioned elements in key regions, and reinforcing units from CONUS. For emergent crises with short-warning in other regions, Marine Expeditionary Units, the 82nd Airborne Division, Special Operations Forces, and USAF/Navy air would be combined as appropriate to provide a limited capability that is usually sufficient for noncombatant evacuations and other lesser contingencies. (Vick, 2002) As a result of the challenging logistics involved in transportation, a major problem facing the United States is its inability to project land power into a crisis area or within a theater of operations at the speed and tempo required.

The Army's initial steps towards transformation seek to establish that ability which equates to having lighter forces with quicker deployment times thereby, turning the Army from the Legacy Force made up of well-equipped heavy war fighting forces, which are difficult to deploy strategically, and rapidly responding light forces, which lack staying power against heavy mechanized forces, into an Interim Force of Stryker Brigade Combat Teams (SBCT). The SBCT combines the capacity for rapid deployment with survivability and tactical mobility. The Army's objective is to deploy the Stryker Brigade Combat Team, a brigade-sized force equipped with medium weight armored vehicles, anywhere in the world within 96 hours (Vick, 2002).

B. BACKGROUND

Historically, large U.S. Joint Operations comprised of at least one ground force brigade equivalent and one air wing equivalent have been concentrated in just a few regions: Europe, Latin America, the Persian Gulf and Asia. Currently the Defense Transportation system cannot support the Army's strategic mobility requirement to move a medium brigade anywhere in the world in 96 hours, a division in 120 hours, and five

divisions in 30 days. (Hickins, 2002) Despite the use of aircraft to transport troops and equipment to distant theaters, sealift will remain vital since 95 percent of dry cargo and 99 percent of liquid cargo will most likely move by sea (Ronis, 2003). Thus, having high speed sealift capability promises even greater payload throughput.

For the Army the primary advantage of using strategic sealift as a means of force projection is its ability to transport all of the Army's equipment. The ability to transport complete packages of combat units intact via high speed sealift ships such as the Theater Support Vessel (TSV) and the large, medium-speed roll-on/roll-off ships (LMSRs) would enable the Army to sustain operational momentum. High-speed sealift is a powerful tool in bridging the gap to allow U.S. forces to close fast enough but heavy enough to accomplish the mission.

C. PROBLEM STATEMENT

As described above, the Army needs to be able to provide rapid, yet sustainable, forces for joint operations within short notice. Therefore, trade-off analysis must be conducted between the strategic sealift assets (TSVs and LMSRs) and their ability to fulfill the requirements for payload, cost and speed. Using response time as a metric, an individual TSV provides a clear speed advantage, but at a significant cost premium with less range and capacity. Larger vessels have greater range and transport capacity and can meet the cargo requirements, if given enough time. The objective is to determine the best mix of sealift assets to ensure the Stryker Brigade deployments are met in the minimal amount of time for different scenarios, while also establishing the likelihood of meeting the 96-hour deployment requirement. This is accomplished in two ways. First, two specific scenarios are used to develop the initial requirements and best mix of assets for SBCT deployment based on a fictional Kosovo campaign. Additionally, a preliminary analysis is conducted of the three feasible configuration options. The options are (1) TSVs only, (2) LMSRs only or (3) a combination of the two. These three options are compared using fixed cargo requirements and their performance versus cost is analyzed based on the Kosovo campaign distances.

D. APPROACH

1. Preliminary Analysis

Prior to beginning an in-depth, quantitative analysis, it was apparent that a preliminary evaluation of solutions to this problem could be helpful. To meet the basic requirement of cargo space for the Army SBCT, three options mentioned earlier are proposed. Each of these options is feasible, in terms of delivering the minimum required cargo. But when considering the cost and deployment time of each option, the differences among the options become significant. Additionally, when the minimum cargo requirement is adjusted, the best option changes. This analysis is conducted in Chapter IV.

2. Detailed Analysis

Through the use of an integer linear program (ILP) model developed in Microsoft Office Excel this thesis determines the mix of sealift assets best suited for different scenarios that differ by distance and port accessibility as well as analyzes the implications of these findings on Army deployment doctrine. The Army's SBCT transformation concept is focused around the goal of a 96-hour deployment time frame. There are several military planning factors that affect the time required to deploy units that are considered in this research:

- Composition of deploying units (size and weight)
- Proximity and suitability of seaport infrastructure (distance, draft and capacity)
- Mobility assets allocated to deployment (quantity and type of assets available)

Using the above military planning factors this research develops a spreadsheet to analyze the different scenarios incorporating sealift options to aid in global mobility. The objective is to compare TSV and LMSR performance against varying ranges and port characteristics to determine a feasible mix that meets or exceeds the 96-hour time requirement.

The military planning factors described above serve as inputs to the integer linear program model, and their actual model input value is determined from the author's

experience, historic operations and discussions with experts. The aim of the model is to evaluate and propose a recommended number of sealift assets required for different scenarios based on minimizing response time.

II. SEALIFT CONSIDERATION

A. MOBILITY REQUIREMENTS

The Army's transformation efforts toward lighter forces with quicker deployment times has manifested in the form of a Stryker Brigade Combat Team and Theater Support Vessels (TSVs) to assist the current inventory of ships to transport them. This is due in part to some of the strategic mobility deficiencies noted by the Department of Defense.

1. Department of Defense (DoD) Requirements

Sealift is the foundation of the DoD's strategic mobility structure. As a result of the 1992 Mobility Requirements Study (MRS) and the 1995 Mobility Requirements Study/Bottom-up Review Update (MRS BURU), the Department of Defense is attempting a sealift expansion to increase its ability to quickly move military equipment in the event of a contingency or war. The studies highlighted a strategic sealift shortfall and recommended the acquisition of ships to meet the requirements.

The DoD was not fully prepared to meet the logistics sealift challenge posed by a full mobilization during the Gulf War in 1991 (Hickins, 2002). Since then, military planners have identified the required forces that need lift during a contingency. To provide a sense of the Army's mobility requirement, Table 1 below shows the average number of shiploads using LMSRs based on data from the Army's 1994 Tables of Organization and Equipment (Congressional Budget Office, 1997). The estimated weights include accompanying supplies, equipment, and ammunition; and the number of LMSRs required to transport each unit assumes minimum containerization of unit equipment.

Approximate Lift Requirements for Army Contingency Forces

Notional Army Unit	Number of Personnel	Unit Weight (Tons)	Airlift Sorties (C-141/C-17 mix)	Number of LMSRs
Airborne Division	13,242	26,699	1,101/78	2.8
Air Assault Division	15,840	35,860	1,412/195	3.9
Armored Division	17,756	110,431	1,761/1,274	6.2
Mechanized Division	17,982	109,116	1,708/1,275	6.2
Light Infantry Division	11,036	17,092	769/41	1.8
Corps-Support Command	22,410	98,717	3,599/500	8.5

SOURCE: Congressional Budget Office based on Department of Defense, Military Traffic Management Command, Deployment Planning Guide, 94-700-5 (Newport News, Va., September 1994).

Table 1. Approximate Lift Requirements for Army Contingency Forces.

2. TSV Operational Requirements

To contribute to power projection capability, an emerging transportation option known as the Theater Support Vessel (TSV) is a reliable strategic high-speed sealift ship. In accordance with statutory (Title 10 USC), Joint Logistics Over-The-Shore (JLOTS) and Defense Planning Guidance (DPG), the Combined Arms Support Command (CASCOM) outlined the following mandatory requirements in an industry brief dated March 2003 that are explained below:

1. Intra-theater lift
2. Roll On / Roll Off (RO/RO)
3. Cargo Deck & Ramp
4. Load/Unload non-RO/RO
5. Passengers
6. Self-Deployment
7. Interoperability
8. Shallow Draft

a. Intra-Theater Lift Requirements

The TSV will provide the Army an internally controlled intra-theater sealift capability for movement and maneuver of combat ready unit sets within the Joint Operational Area (JOA) from Intermediate Staging Bases (ISB) and Ports of Embarkation (POE). The threshold data in Table 2 indicates the existing capabilities of the TSV in a fully loaded condition in a sea state-3 with soldiers and passengers. The

objective data represents the projected capabilities utilizing military and commercial technologies to improve the TSV's productivity, survivability and supportability. (Crum, 2003)

	Threshold	Objective
Speed:	36 Knots	50 Knots
Range:	1250 NM	2500 NM
Payload:	754 ST	1250 ST

Table 2. TSV Performance Goals.

b. RO/RO Operations Requirements

The TSV must be Roll-on-roll-off (RO/RO). RO/RO is a method of transport by which vehicles or cargoes are rolled on a platform (such as a ship) at the embarkation point and then rolled off at the destination. Approximately 62% to 75% of the Army's maneuver element cargoes are roll-on-roll-off. Loading & discharging is 400% faster than using shore side cranes as this type of cargo has the ability to move on and off an ocean vessel under its own power (Crum, 2003). Additionally, the TSV will likely have to operate in minor or degraded ports where shore side cranes are not available. Therefore, RO/RO capability is essential for the TSV to accomplish many of its intended missions.

c. Cargo Deck/Ramp Weight Requirements

The TSV will be optimized to support operational movement and maneuver of the SBCT while continuing to provide support to current heavy forces. Assets such as the M1A2 (Main Battle Tank) will remain in the Army's inventory for the foreseeable future. Therefore the weight of such assets must be taken into consideration. Without M1A2 cargo loading/transport capability the TSV can only support 30-40% of active Army division level maneuver element (Crum, 2003).

d. Non-RO/RO Cargo Requirements

The TSV mission profile is to insert forces and follow-on sustainment through minor or degraded ports where shore side cranes and other material handling

equipment may not be available. Therefore, the TSV must be able to receive and discharge non-RO/RO containers and pallets to the support the Army's remaining non-RO/RO requirements. (Crum, 2003)

e. Passenger Requirements

The TSV is designed to transport 354 combat ready soldiers. Without passenger capability the TSV cannot accomplish intended mission of operational movement of ready to fight elements. (Crum, 2003)

f. Self Deployment Requirements

The Army's TSV will possess the capability to strategically self-deploy and mass within an area of responsibility (AOR) to provide the commander with a potent theater distribution asset (Crum, 2003).

g. Interoperability Requirements

The focus of interoperability, in this case the ability to operate with other units, is in communications. The TSV must possess the capability to communicate secure /unsecured data and voice with higher, lower and adjacent units in a joint environment. (Crum, 2003)

h. Shallow Draft Requirements

To increase worldwide accessibility the maximum draft is defined at 18 feet with an optimal objective of 15 feet. These figures align with the results from other top-level port studies of some 282 ports in US Central Command and US Pacific Command as of December 2002. (Crum, 2003)

B. TSV CAPABILITIES

1. Technical Specifications

The technical specifications of the TSV addressed in this report are obtained mainly from the Advanced Mobility Concepts Study (AMCS) data from the Center for Army Analysis (CAA) (Burger, 2003). These adopted specifications shown in Figure 1 are used to serve as baseline identifications of a TSV in terms of physical characteristics and capabilities, especially in the areas of speed and payload.

Length 393 feet
Beam 104 feet
Measurement 754 tons
Cargo capacity 25,000 sq. ft.
Speed: 40 knots
Endurance 1250 nautical miles at 40 knots
Troops: 354 combat ready soldiers.

Figure 1. TSV Characteristics. (From CAA)

2. Operational Assumptions

The refueling of the TSV will be conducted at 1,250 nm intervals at sea. The refueling time at sea is calculated to be 4-5 hours per refueling based on CAA deployability analysis which includes times for approach, set-up, refuel, disengage and pull off. (Burger, 2003)

C. LMSR CAPABILITIES

The characteristics below in Figure 2 are taken from published data of a representative class ship (T-AKR 295 Shughart) and outline the capabilities of the Large, Medium-speed roll-on/roll-off (LMSR). The adopted specifications are used to serve as

baseline identifications of a LMSR in terms of physical characteristics and capabilities, especially in the areas of speed and payload.

Length 956 (289.4 meters)
Beam 105.9 feet (32.2 meters)
Measurement 55,422 tons (56,303.21 long tons)
Cargo capacity 284,064 sq. ft. plus 49,991 sq. ft. deck cargo
Speed: 24 knots (27.6 mph)
Endurance 12,200 nautical miles at 24 knots
Crew: 26 civilian crew (up to 45); up to 50 active duty

Figure 2. LMSR Characteristics. (From CAA)

A single LMSR is capable of supporting combat missions by carrying an entire U.S. Army Task Force, including 58 tanks, 48 other track vehicles, plus more than 900 trucks and other wheeled vehicles. In addition, LMSRs have a slewing stern ramp and a removable ramp, which services two side ports making it easy to drive vehicles on and off the ship. Two 110-ton single pedestal twin cranes make it possible to load and unload cargo where shore-side infrastructure is limited or nonexistent. (www.fas.org/man/dod-101/sys/ship/takr-295.htm)

These sealift ships are capable of self-sustained RO/RO and Lift on/Lift off (LO/LO) operations at a pier and in a Logistics-Over-the Shore (LOTS) scenario through stern and side port ramps to a RO/RO Discharge Facility (RRDF). In addition, the LMSR is capable of self-sustained LO/LO cargo operations in a LOTS scenario by interfacing with lighterage or barges alongside to load and unload. The LMSR ships are not armed and do not have a combat system. However, they do have C3I suite sufficient to perform their intended mission in conjunction with other Naval vessels. (www.fas.org/man/dod-101/sys/ship/takr-295.htm)

D. STRYKER BRIGADE COMBAT TEAM (SBCT)

> We must provide early entry forces that can operate jointly, without access to fixed forward bases, but we still need the power to slug it out and win decisively. Today, our heavy forces are too heavy and our light forces lack staying power. We will address those mismatches. -- GEN Eric Shinseki, CSA, 23 June 1999

The Stryker Concept reflects the vision of the previous Chief of Staff of the Army, General Shinseki, who argued that the existing force was either too heavy to be deployed quickly (tanks and infantry fighting vehicles) or too light to be effective (airborne or light infantry). To attempt to solve the deployment problem, the forces underwent restructuring making them more agile, and cues were taken from the Air Force and the Navy about lift to create the concept of the Stryker Brigade Combat Team (SBCT). The SBCT is configured to arrive early in a crisis, but is not intended to serve as an assault force. Normally, it would be deployed to an area already under friendly control.

Experiences and lessons learned from the stationing of the first two SBCTs (3/2 IN and 1/25 IN) at Fort Lewis, Washington are still under review according to the Army Modernization Plan 2003. The Stryker Brigade Combat Team (SBCT) is an infantry-centric unit with 3,600 soldiers that combines many of the best characteristics of the current Army forces and exploits technology to fill a current operations capability gap between the Army's heavy and light forces. (www.lewis.army.mil/transformation)

The SBCT capabilities differ significantly from those found in traditional divisional brigades, primarily due to an array of units organic to the SBCT. In addition to its three infantry battalions, the SBCT has a cavalry squadron for reconnaissance, surveillance and target acquisition (RSTA), a brigade support battalion, a field artillery battalion, a military intelligence company, an engineer company, a signal company, an anti-tank company, and a headquarters company. More details on the variants and composition of the SBCT are shown in Appendices A and B.

The fielding of six Stryker Brigades supports the execution of the Defense Planning Guidance (DPG), and enables the Army to deploy worldwide to combat future threats where U.S. access is limited essentially to provide the right force to the right place at the right time (www.lewis.army.mil/transformation). The SBCT composition size and weight which will be used for the basis of modeling is obtained from data provided by CAA and is listed as 14,406 short tons, 261,989 sq. ft with 3,848 passengers. (Burger, 2003)

E. SEALIFT PLANNING FACTORS AND CALCULATIONS

Sealifting the SBCT presents a variety of issues that must be considered. Sealift planning factors include sail time, loading and unloading times, and refueling time. Sealift deployment time is calculated from the moment the ship begins to load at the port of embarkation to when the ship is completely unloaded at the port of debarkation.

The sealift analysis is based on the assumptions that in the 96-hour timeframe the deploying units prepare to deploy, move to the port, and begin to load as soon as the ships are available.

The difficulty is in finding good ports in the regions of the world where the SBCT is most likely to be deployed. The TSVs do not have the range and payload to be ideal for longer-range deployments, but they are better suited for regional deployments where shallow or undeveloped port conditions may exist. The poorer the port condition, the less attractive the use of deep draft long range sealift assets such as the LMSR.

The times in Figure 3 below are based upon 20 knots sailing speed (LMSR) and 40 knots sailing speed (TSV). The distance is reported in nautical miles with the corresponding times for transit based on speed for an LMSR and a TSV. From the graph it would take LMSRs five to six days to reach ports in the vicinity of most Asian littoral hot spots from the forward positions of Diego Garcia and Guam. Utilizing TSVs would reduce the time approximately in half, as longer ranges requiring refueling would lengthen the times shown somewhat. (Peltz, 2003)

Figure 3 also highlights the advantage of having pre-positioned assets. Based on these estimates and depending on their location, the pre-positioned assets may arrive within acceptable time frames. During Desert Storm the ships from Diego Garcia arrived in the Southwest Asian Theater within a week. The ships at Guam and Saipan took as long as two weeks to reach Southwest Asia, but they were less than a week away from most of the potential hot spots in the Pacific Rim. (Nabor, 1999)

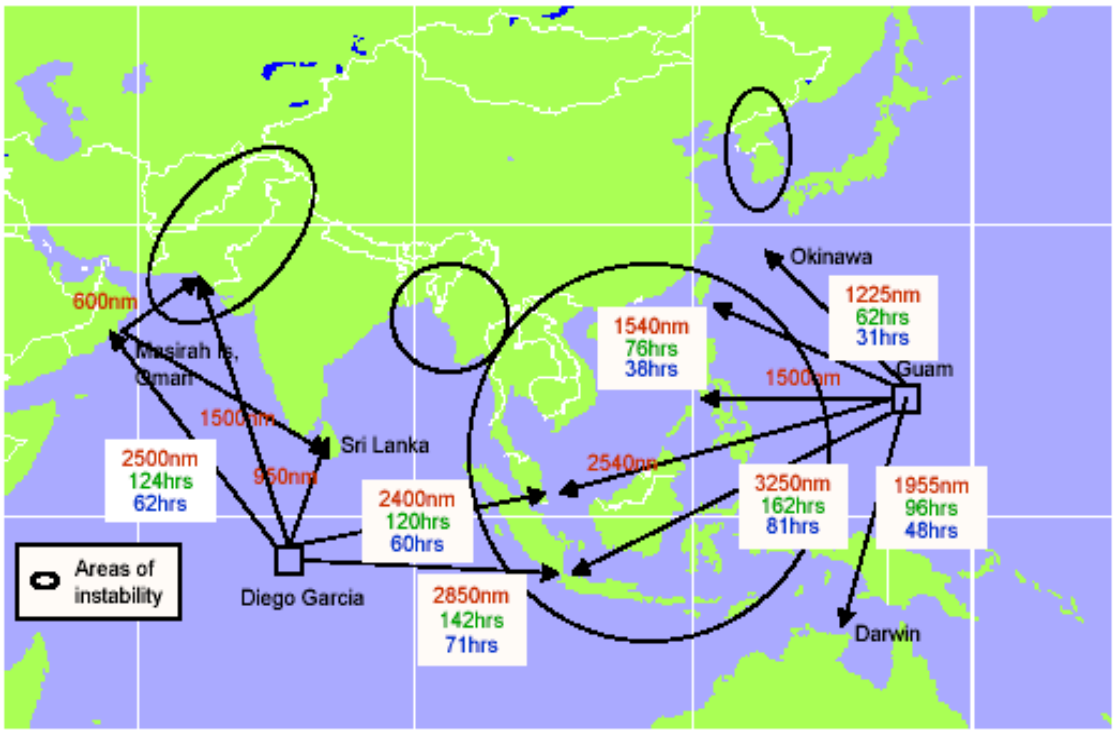

Figure 3. Graphic Travel Times.

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III. MODEL DEVELOPMENT

A. SCENARIOS

In order to explore the implications of a wide range of assumptions regarding location of contingency, use of pre-positioning sites and general operational characteristics related to deployments, this thesis models two scenarios comparing TSVs and LMSRs with the objective of minimizing the time to deploy one SBCT in each scenario. In the first scenario the deployment is made from a pre-positioned site; the second scenario models the deployment from CONUS under ideal port conditions.

The scenarios used for modeling purposes support a fictional Kosovo campaign. This campaign involves the deployment of an SBCT to Skopje, Macedonia, for operations in Kosovo. The sealift piece of the Kosovo campaign establishes the Port of Embarkation (POE) as either Beaumont, Texas or Camp Darby, Italy. The Port of Debarkation (POD) is Thessaloniki, Greece. All equipment, material, and personnel arrive in Thessaloniki via sealift and then are moved to Skopje via land transportation. The area of interest in this thesis is the sealift portion from POE to POD. The first scenario route is from the pre-positioned Point of Embarkation (POE) location of Camp Darby, Italy. The steaming distance from Camp Darby to Thessaloniki is about 1,100 nms (Vick, 2002). The second scenario route is from the Beaumont, Texas, across the Atlantic Ocean, through the Strait of Gibraltar and the Mediterranean Sea, then to the Point of Debarkation (POD) Thessaloniki, Greece which is approximately 6,378 nms. Both Beaumont and Thessaloniki have well-developed ports capable of accommodating either a TSV or LMSR. (Vick, 2002) The representative distances listed in Tables 3 and 4 below are used as input into the ILP model.

	SEALIFTING THE SBCT		
	PREPO		
Destination	POE	POD	Distance (nms)
Skopje, Macedonia	Camp Darby, Italy	Thessaloniki, Greece	1,100

Table 3. PREPO Sealift Scenario.

	SEALIFTING THE SBCT		
	CONUS		
Destination	POE	POD	Distance (nms)
Skopje, Macedonia	Beaumont Tx	Thessaloniki, Greece	6,378

Table 4. CONUS Sealift Scenario.

A slight twist to the second scenario is introduced which utilizes the CONUS Kosovo scenario but degrades the port characteristics to test the sensitivity of the model solution.

B. MODEL DESCRIPTIONS

This thesis develops two models to determine the Army's sealift requirements for a 96-hour global response. Two sets of analysis are conducted to determine if the assets available meet the 96-hour time requirement and to make recommendations on the fleet size by establishing the baseline requirements for TSVs and LMSRs. First, an analysis of baseline requirements is conducted to determine what number of TSVs and LMSRs are needed to in order to move a SBCT varying distances within 96 hours for selected units. The second analytical effort is to determine the optimal number of TSVs and LMSRs needed for a given scenario to minimize time.

These models are developed in order to gain perspective into the scope of the problem and are used to estimate the time and quantity necessary to complete the mission of delivering a SBCT across varying distances. More elaborate programs may exist, but Microsoft Excel is used because of its widespread availability and commonality.

1. Snap Shot Model

The first model is the Snap Shot model. The model inputs are based on data and parameters used by the Center for Army Analysis (CAA) to determine intra-theater lift requirements from similar vessels. The objective of this model is to estimate the time required to move the SBCT given a number of ships of each type (LMSR and TSV) in order to establish baseline requirements based on distance. For planning purposes, this

aids the decision maker in determining the minimum number of assets needed to be available and the time required. Range, speed, ship's draft and cargo capacity, and unloading/loading times are inputs to the model as shown in Table 5.

	Stryker Brigade Combat Team (SBCT)				261,989 ft^2
SHIP DATA	**One-Way**	**Cruise**	**Full Load**	**Capacity**	**Load/Unload**
Assets	**Range (nms)**	**Speed (kts)**	**Draft (ft)**	**ft^2**	**Time (hrs)**
LMSR	12,000	24	36	250,000	48
TSV	1,250	40	15	25,000	4

Table 5. Snap Shot Inputs.

A number of assumptions are made in the modeling process for ease of computation such as unrestricted port availability and eliminating any refueling requirements to provide the rough estimates for each individual platform. In addition, the model indicates for each range category the percentage of the SBCT delivered. For planning purposes when using this model 50% of the SBCT is the minimum combat capability required to be combat effective, which is based on a strategic responsiveness study done by the RAND Corporation (Peltz, 2003).

The snap shot model ascertains the performance of each sealift asset based on their individual characteristics. The data compiled is based on ship type, speed, range, capacity and unload/loading times

The model provides the decision maker with a snapshot of the number of trips it would take for an incremental amount of ships from one to twenty to deliver an SBCT based solely on their respective cargo capacity. This is a straightforward calculation of the SBCT size (sq. ft) divided by the total capacity of the ships assigned (sq. ft). The corresponding time is based on the prescribed quantity of ships transiting the upper range distance listed for each range category and adding the loading/unloading times for each. Subsequently, the amount of respective cargo capacity for each vessel correlates to a percentage of the SBCT delivered based on the number of stated trips.

2. Sealift Optimization Model

The second analytical effort focuses on the possible mix and match of TSVs and LMSRs rather than a mere baseline calculation of transportation assets based on distance. It is important to consider other factors while also including possible mixes of assets in the solution set to perform this analysis. In addition to the snap shot model inputs the following are developed: cost, port penalty times for violating draft or capacity constraints, destination port's distance, depth and capacity, and the number of each ship available. The inputs listed in Table 6 are based on data and estimates obtained from CAA.

SHIP DATA						Additional Time Delays			
		One-Way	Cruise	Full Load	Capacity	Load/Unload	Refueling	Port Penalty	
SHIP	Cost ($M)	Range (nms)	Speed (kts)	Draft (ft)	ft^2	Time (hrs)	Time (hrs)	Draft	Capacity
LMSR	$309	12,000	24	36	250,000	48	24	36	2
TSV	$65	1,250	40	15	25,000	4	4	8	2

	Distance	Cargo	Port Depth	Port Capacity	Available Ships	
PORT	(nms)	Required (ft)	(ft)	(k sq. ft)	TSV	LMSR
A	1,100	261,989	50	300,000	20	31

Table 6. Sealift Optimization Inputs.

A number of assumptions are made in the modeling process. Many of these are made for ease of modeling purposes, or because the author felt that the added complexity did not warrant the impact that they would have in significantly affecting the output. The assumptions are:

- There are an adequate number of ships available.
- All ships meet activation times.
- No attrition of sealift ships.
- Ships operate at a constant speed in sea state 3.
- Each ship makes only one trip.
- Refueling occurs at the one-way range distance.
- The ships are offloaded in series.

An assumption that may have significant impact but is not modeled is the consideration of ship capacity in tonnage. The SBCT is compared based on square feet capacity of each vessel. It is possible that the SBCT could meet the square feet requirements of a vessel, yet be too heavy to transport. Studies by the Rand Corporation

and the U.S. Transportation Command have shown fluctuations in the weight of the SBCT from 12,840 to 14,663 short tons and the final weight seems uncertain (Vick, 2002). The weight constraint is not likely to affect the LMSR, however the estimates for the capacity of the TSV range from 754 short tons to an objective of 1,250 short tons (Burger, 2003). For modeling purposes, the ships can accommodate the SBCT weight based on size in square feet as indicated.

C. SEALIFT INTEGER LINEAR FORMAT

This formulation is formatted to facilitate reader understanding. Explanations follow the equations.

1. Sealift Formulation

INDICES:

i	: (2) ship type (LMSR, TSV)
j	: (2) ports of embarkation (CONUS, PREPO)

DATA:

$SPEED_i$	: Speed of ship type (i) in knots
CAP_i	: Cargo Capacity of ship (i) in sq. ft
$LOADUT_i$	: Load/unload time in hours of ship type (i)
$REFUEL_i$	: Refueling time in hours of ship type (i)
$PORTPD_i$	: Port Penalty time for draft in hours for ship type (i) at POD
$PORTPC_i$	: Port Penalty time for capacity in hours for ship type (i) at POD
CARGO	: Required Cargo at POD in sq. ft
$DIST_j$	: Distance from port (j) to the port of debarkation in nautical miles
$FLEET_i$	: Number of available ships of type(i) to transit from port (j) (Integer)
$DRAFT_i$	: Draft in feet of ship type(i).
PCAP	: Cargo capacity of POD
PDEPTH	: Depth in feet of POD
$TIME_{ij}$	: Amount of time in hours for ship type (i) to transit to POD from port (j) $=(DIST_j / SPEED_i) + (LOADUT_i * X_{ij}) + REFUEL_i + PORTPD_i + PORTPC_j)$

DECISION VARIABLE:

X_{ij} : Number of ships (i) assigned to transit $DIST_j$

FORMULATION:

Objective Function:

Minimize $\sum_{ij} TIME_{ij} X_{ij}$

S.T. $\sum_j X_{ij} <= FLEET_i$ for all i

$\sum_j X_{ij} CAP_i => CARGO$ for all j

$X_{ij} = INTEGER$ for all i,j

$X_{ij} => 0$ for all i,j

2. Model Specifics

The indices (i,j) are used to represent the ship types and destination ports. The data parameters represent the individual ship characteristics such as speed ($SPEED_i$), capacity (CAP_i), and associated times for refueling ($REFUEL_i$) and unloading/loading ($LOADUT_i$). The other data inputs listed above are additional sealift planning factors. They are part of the equation to calculate specific transit times. Essentially, the time associated with each ship's transit time is the following:

$$\mathbf{TIME_{ij}} = (DIST_j / SPEED_i) + (LOADUT_i * X_{ij}) + REFUEL_i + PORTPD_j + PORTPC_j$$

This equation for time is where the remaining data inputs are entered into the model. First, a statement is embedded to check to see if the ship can reach the port based on each ship's one-way range. If it cannot then the necessary refueling ($REFUEL_i$) times for each ship is added to the time of arrival. For example, one TSV leaving Beaumont for Thessaloniki requires six refuelings. Refueling would then equal twenty-four hours.

The next step checks ship drafts against port depths ($DRAFT_i <= PDEPTH$) to ensure that completion of the trip is possible, otherwise a port draft penalty time ($PORTPD_i$) is for each ship to compensate for other avenues to load/unload cargo

($LOADUT_i$). The same applies to port capacity. If the ship's cargo capacity (CAP_i) exceeds port capacity (PCAP), then a port capacity penalty time ($PORTPC_i$) is added for each ship to account for stages of loading and unloading. These port penalty times avoid infeasible solutions by allowing for a comparison of trip completion times where otherwise a vessel would have been excluded because of physical limitations.

The number of ships assigned (X_{ij}) is the decision variable that is calculated by the model subject to constraints:

1. $\sum_j X_{ij} \quad <= \quad FLEET_i \quad$ for all i
2. $\sum_j X_{ij}CAP_i \quad => \quad CARGO \quad$ for all j
3. $X_{ij} \quad = \quad INTEGER \quad$ for all i,j
4. $X_{ij} \quad => 0 \quad$ for all i,j

The first constraint ensures that the total number or ships assigned (X_{ij}) are less than or equal to the total number of ships available ($FLEET_i$). The second constraint ensures that the total amount of cargo delivered by the assigned ships ($\sum_j X_{ij}CAP_i$) meets the cargo requirements requested (CARGO), in this case the size of the SBCT. The third constraint requires that the assigned number of ships required (X_{ij}) be integers. The final constraint restricts the model from assigning a negative number of ships.

The objective function of this model (**Minimize** $\sum_{ij} TIME_{ij} X_{ij}$**)**,

minimizes time by changing the number of ships assigned (X_{ij}), not to exceed those available ($FLEET_i$) while ensuring that the cargo requirements (CARGO) are met. Having met these constraints, the model then computes the number of ships (integer only) required and the travel time to reach the destination port.

D. DATA COLLECTION AND SOURCES

There are numerous sources of information on this topic such as existing texts on strategic mobility, professional articles, research papers and Department of Defense sponsored studies. Conflicting information or data was resolved through coordination

with Army and civilian analysts in conjunction with the Center for Army Analysis (CAA) and Military Sealift Command (MSC). Whenever possible, factual data is used to provide realism and relevance, yet some generic data is imposed in order to remain at an unclassified level. A synopsis of the data used in the models and its source is provided in Table 7 below. (Callahan, 1998)

Data	Rationale/Source
Existing Ship data	Averages of ship types and current designs.
Representative Port Capacities	Based on historic accounts and accumulated observations.
Representative Load Times	Averages based on ship type.
Cargo Requirements	Based on CAA data
Port Drafts, distances, Refueling/loading/unloading times and penalties	Author's estimates based on accumulated observations and historic accounts and studies.
Cost Information	Author's estimates based on various reports and input from the Military Sealift Command.

Table 7. Data Assumptions.

IV. IMPLEMENTATION AND APPLICATION

A ANALYSIS AND FINDINGS

The general methodology used to analyze the data is to establish a baseline and vary parameters within the baseline first singularly and later in combination to test the sensitivity of the model solution. This approach is used to attempt to gain insight into the various effects of certain variables on the model.

1. Snap Shot Model Results

From the quick look snapshot model it is evident that a 96-hour time requirement for SBCT team delivery is range dependent. In Tables 8 and 9, the unshaded portion of the "% SBCT" row represents those ranges that meet the minimum 50% delivery requirement of the SBCT. Although, complete SBCT delivery is the Army's goal, this is significant because it represents the minimum level believed to be combat effective (Peltz, 2003).

For example as shown in Table 8, one LMSR at a range up to 52 nms would deliver 95.42% of the SBCT in 50.17 hours. Adding an additional LMSR would ensure 100% SBCT delivery at a range of 144 nms in 102 hours. This baseline for the LMSRs indicates that two LMSRs are needed for SBCT deployment and that meeting the 96-hour time constraint is not guaranteed for ranges exceeding 52nms.

The TSV baseline requirement to meet the minimum 50% requirement within 96 hours requires ten TSVs at a range up to 1,104 nms as seen in Table 9. For this number of TSVs it would take 67.6 hours to deliver 52.34% of the SBCT. For planning, at least that number of ships must be available to deliver the SBCT within that timeframe. At greater ranges using TSVs it is quite evident that the distance would preclude a successful deployment within the time constraints.

SNAP SHOT (LMSR)

LMSR Distance (NM)	1 - 52	53 - 144	145 - 227	228 -344	345 - 453	454 - 648	649 - 1104	1105 - 3384
# ships	1	2	3	4	5	7	10	20
# Trips	2	1	1	1	1	1	1	1
Trip time (hrs)	50.17	102.00	153.46	206.33	258.88	363.00	526.00	1101.00
% SBCT	95.42%	190.85%	286.27%	381.70%	477.12%	667.97%	954.24%	1908.48%

Table 8. LMSR Snap Shot.

SNAP SHOT (TSV)

TSV Distance (NM)	1 - 52	53 - 144	145 - 227	228 -344	345 - 453	454 - 648	649 - 1104	1105 - 3384
# ships	1	2	3	4	5	7	10	20
# Trips	11	6	4	3	3	2	2	1
Trip time (hrs)	5.30	11.60	17.68	24.60	31.33	44.20	67.60	164.60
% SBCT	5.23%	10.47%	15.70%	20.94%	26.17%	36.64%	52.34%	104.68%

Table 9. TSV Snap Shot.

The range-bracketed distances used for analysis are based on parametric analysis conducted by CAA in similar studies. The incremental number of ships listed in Tables 8 and 9 is selected to show changes in the number of trips required for completion (Burger, 2003).

2. Sealift Optimization Model Results

The Sealift Optimization model calculates the optimal number of ships to minimize the time to deliver the SBCT for each scenario. The model takes into account all previously mentioned sealift planning factors, specifically those listed in the tables below. Table 10 summarizes the ship data used for calculation including cost and associated penalty times for delays in the PREPO Kosovo campaign.

SHIP DATA						Additional Time Delays			
		One-Way	Cruise	Full Load	Capacity	Load/Unload	Refueling	Port Penalty	
SHIP	Cost ($M)	Range (nms)	Speed (kts)	Draft (ft)	ft^2	Time (hrs)	Time (hrs)	Draft	Capacity
LMSR	$309	12,000	24	36	250,000	48	24	36	2
TSV	$65	1,250	40	15	25,000	4	4	8	2

Table 10. Kosovo PREPO Ship Data.

Table 11 summarizes the specific assumptions for the port characteristics and number of ships available used in the PREPO Kosovo campaign.

PORT	Distance (nms)	Cargo Required (ft)	Port Depth (ft)	Port Capacity (k sq. ft)	Available Ships	
					TSV	LMSR
A	1,100	261,989	40	300,000	20	31

Table 11. Kosovo PREPO Port Data.

Table 12 shows the optimized solution for the PREPO Kosovo campaign. For this scenario the route was from the pre-positioned site Camp Darby, Italy to Thessaloniki, Greece and the results are based on the specific settings mentioned above.

SEALIFT OPTIMIZATION MODEL

Kosovo (PREPO)

Destination Port	PREPO DISTANCE (nm)	Depth ft	Capacity k sq. ft.
Thessaloniki	1,100	40	300,000

Destination Port	LMSR TIME (hrs)	TSV TIME (hrs)
Thessaloniki	0.00	71.50

Total Time (hrs)	71.50

SHIP	Number of ships Required	Number of ships Available	Cost Millions
LMSR	0	31	$0.00
TSV	11	20	$715.00

SHIP	Cargo Delivered	Cargo Required	% SBCT
LMSR	0	261,989.00	0.00%
TSV	275,000	261,989.00	104.97%
TOTAL:	275,000	261,989.00	104.97%

Table 12. Kosovo PREPO Range Optimization.

The results show that by using eleven TSVs, it would take 71.50 hours to deliver the SBCT a distance of 1,100 nms from the pre-positioned location. The cargo required (CARGO) is the stated SBCT size (261,989 sq. ft). The cargo requirement is met based on the model solution of 275,000 sq. ft, which equates to 104.97% SBCT delivery at a cost of $715 million.

In the next scenario, the SBCT is deployed to Kosovo from CONUS embarking from Beaumont, Texas to Thessaloniki, Greece with optimal port conditions. The ship data remains the same as in Table 8, however the distances are different as shown below in Table 13.

PORT	Distance (nms)	Cargo Required (ft)	Port Depth (ft)	Port Capacity (k sq. ft)	Available Ships	
					TSV	LMSR
A	6,378	261,989	40	300,000	20	31

Table 13. Kosovo CONUS Port Data.

Table 14 below shows the optimized solution for the CONUS Kosovo vignette. The model chooses two LMSRs, which illustrates the shift to larger capacity and endurance over lesser capacity and speed at increased ranges.

SEALIFT OPTIMIZATION MODEL

Kosovo (CONUS)

Destination Port	DISTANCE (nm)	Depth ft	Capacity k sq. ft.
Thessaloniki	6,378	40	300,000

Destination Port	LMSR TIME	TSV TIME
Thessaloniki	361.75	0.00
Total Time	361.75	

SHIP	Number of ships Required	Number of ships Available	Cost Millions
LMSR	2	31	$618.00
TSV	0	20	$0.00

SHIP	Cargo Delivered	Cargo Required	% SBCT
LMSR	500,000	261,989.00	190.85%
TSV	0	261,989.00	0.00%
TOTAL:	500,000	261,989.00	190.85%

Table 14. Kosovo CONUS Range Optimization.

The results show that by using two LMSRs, it would take 361.75 hours to deliver the SBCT a distance of 6,378 nms from CONUS. The cargo required (CARGO) is the stated SBCT size (261,989 sq. ft). The cargo requirement is met based on the model solution of 500,000 sq. ft, which equates to 190.85% SBCT delivery at a cost of $618 million.

The last scenario utilizes the same CONUS Kosovo campaign, but with different port characteristics to measure the effect. Table 15 shows the reduction in port depth to accommodate only ships with a 20 ft or less draft and port capacity limited to 100,000 sq. feet. These changes in port characteristics are done to evaluate the effect of potential port penalty times being added to the ship arrival times. Port penalties are incurred as a result of draft or capacity constraints being exceeded. Also, these changes in model input serve to reflect real situations that may be faced by our forces during a combat mission such as degraded or inaccessible ports.

PORT	Distance (nms)	Cargo Required (ft)	Port Depth (ft)	Port Capacity (k sq. ft)	Available Ships	
					TSV	LMSR
A	6,378	261,989	20	100,000	20	31

Table 15. Kosovo CONUS Degraded Port.

Table 16 below shows that there is no change in the optimal solution for the CONUS Kosovo vignette if the port is degraded. The results show that by continuing to utilize two LMSRs, it would take 437.75 hours to deliver the SBCT a distance of 6,378 nms from CONUS. The cargo required (CARGO) is the stated SBCT size (261,989 sq. ft). The cargo delivered based on the model solution is 500,000 sq. ft, which equates to 190.85% SBCT delivery at a cost of $618 million.

Kosovo (CONUS)
DEGRADED

SEALIFT OPTIMIZATION MODEL

Destination Port	PREPO DISTANCE (nm)	Depth ft	Capacity k sq. ft.
Thessaloniki	6,378	20	100,000

Destination Port	LMSR TIME (hrs)	TSV TIME (hrs)
Thessaloniki	437.75	0.00

Total Time (hrs)	437.75

SHIP	Number of ships Required	Number of ships Available	Cost Millions
LMSR	2	31	$618.00
TSV	0	20	$0.00

SHIP	Cargo Delivered	Cargo Required	% SBCT
LMSR	500,000	261,989.00	190.85%
TSV	0	261,989.00	0.00%
TOTAL:	500,000	261,989.00	190.85%

Table 16. Degraded Kosovo CONUS Optimization.

B. INTERPRETATION OF RESULTS

1. Summary of Initial Results

With the objective being to minimize time it is readily observed that for short PREPO distances the TSV is preferred. For distances within the one-way range (1250 nms) of the TSV it will always be preferred because of the speed advantage. As such, by increasing the number of TSVs to ensure cargo capacity is met (in this case eleven ships) the 96-hour time line is met as well. However, for distances greater than 1250 nms the necessity to include refueling times no longer permits completion within the prescribed 96-hour time frame using TSVs.

For distances greater than the one-way range of a TSV, the 96-hour time goal is no longer feasible and the greater endurance and capacity of the LMSR becomes more prominent. In the event of port degradation, it is the LMSR arrival time that is affected by the poorer port condition as expected. Because the penalties are time related they do not necessarily preclude a ship from completing its mission.

In the CONUS Kosovo with port degradation vignette, the high endurance and capacity of the LMSR prevails over the TSV because the additional time delay for port penalties is less than the time it would take for refueling of eleven TSVs over this distance. The time using the two LMSRs is 437.75 hours vice the 467.45 hours it would take eleven TSVs to complete the trip.

The majorities of ports are more accommodating to the TSV because of its shallower draft and, depending on the real time scenario, increased or weighted values assigned to the port penalties may render the use of LMSRs less attractive or no longer feasible. In this case the time saved was 29.7 hours and depending on operational commitments the extra day delay may not be significant.

Using response time as a metric, the TSV provides a clear advantage at PREPO ranges over the LMSR. When the distance is extended, the additional cargo capacity of the LMSR compensates for the slower speed in the overall minimization of time required to deliver an SBCT. Limiting or restricting the amount of ships available, may reduce time, but fails to deliver the required amount of cargo.

The Sealift Optimization model shows that for PREPO ranges the TSV does provide faster response times with all under the 96-hour Army requirement. This requires using 11 TSVs with a slightly greater cost than two LMSRs, yet better efficiency as measured by the percentage of SBCT delivered. The most economical solution (using two LMSRs vice 11 SBCTs) would be cheaper yet slower and would have excess capacity.

2. Lower Cargo Threshold

Depending on the operational environment, complete SBCT deployment may not be necessary. The minimum level required for combat effectiveness is 50% of the SBCT, therefore it is important that the Army assess the requirements at this level to reduce vulnerability (Peltz, 2003).

The observed result is that if the cargo requirement is reduced to 50% of SBCT, the model solution still chooses the same platform for delivery, however the number of assets required is reduced and the subsequent completion time as well to account for less ships to load/unload and refuel. For example, at a range of 1,100 nms if the cargo requirement is reduced to 50% SBCT, the solution still utilizes only TSVs, but instead of eleven ships it only requires six ships to complete the mission and in less time.

3. Cost Performance Analysis

While the model is not designed to optimize a solution based on cost, it is important to provide the decision maker with a cost comparison because of the reality of fiscal constraints. Cost estimates for ships tend to vary based on Army and Military Sealift Command data. The TSV is estimated to cost between $65 and $85 million compared to the price tag of $309 to $349 million for an LMSR (Hickins, 2003). These cost figures are strictly construction costs and do not take into consideration any other factors associated with life cycle costs. The TSV cost could differ depending on upgrades for military command/communication or self-defense suites. The cost of two LMSRs is less than that of eleven TSVs required to deliver a complete SBCT however this economical solution does not use all asset space implying excess capacity.

As described in the preliminary analysis, in Chapter I, there are three reasonable, and feasible, configurations to deploy the SBCT. Option 1 utilizes TSVs only, Option 2 utilizes only LMSRs and Option 3 utilizes a combination of both. For each option, I compare cost versus performance for 50% and 100% SBCT delivery. As mentioned previously, these percentages are important because they represent the minimum and full requirement for SBCT combat effectiveness. The ranges are chosen to represent the distances in the PREPO and CONUS Kosovo campaigns. Performance is defined as

1/Time in hours to make graphical analysis more obvious as higher values for performance variable show improvement. The ideal situation would be to obtain the highest performance (shortest time) at the lowest cost.

The first case deals with 50% SBCT delivery at a range of 1,100 nms and the solution for each option, based on cargo requirements and distance is listed in Table 17.

Distance: 1,100 nms	**Assets**	**Cost**	**Time**
Option 1	6 TSVs	$390 Million	51.5 hours
Option 2	1 LMSR	$309 Million	93.83 hours
Option 3	1 TSV/ 1 LMSR	$374 Million	125.33 hours

Table 17. Solutions for 50% SBCT at 1,100 nms.

Figure 4 below shows the cost performance analysis versus time for 50% SBCT delivery at a range of 1,100 nms. This output is treated as essentially a utility curve (Sage, 2000). It allows a decision maker to choose the best alternative based on their assessment of the need to provide greater performance at a specified cost. Here, there are only two legitimate choices, options 1 and 2. Essentially, option 2 (1 LMSR @ $309 Million) dominates option 3 (1 TSV/ 1 LMSR @ $374 Million), as option 2 has higher performance and costs less, so there is no reason to choose option 3. However, from the graph it is clear that option 1 (6 TSVs @ $390 Million) results in nearly twice the performance capability of option 2, but at the cost of an additional nearly $100 million. Therefore, a decision between these two options would be based on whether providing twice the performance is worth the additional cost.

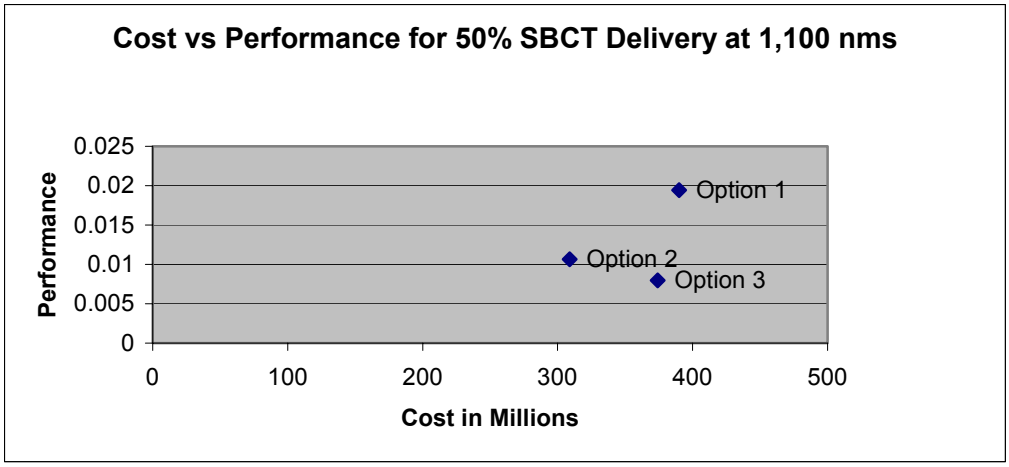

Figure 4. 50% SBCT Cost Performance Analysis.

The second case deals with 100% SBCT delivery at a range of 6,378 nms and the solution for each option, based on cargo requirements and distance is listed in Table 18.

Distance: 6,378 nms	**Assets**	**Cost**	**Time**
Option 1	11 TSVs	$715 Million	467.45 hours
Option 2	2 LMSR	$618 Million	361.75 hours
Option 3	1 TSV/ 1 LMSR	$374 Million	501.20 hours

Table 18. Solution for 100% SBCT at 6,378 nms.

Figure 5 below shows the cost performance analysis versus time for 100% SBCT delivery at a range of 6,378 nms. Essentially, option 2 (2 LMSR @ $618 Million) dominates option 1 (11 TSVs @ $715 Million), as it has higher performance and costs less, so there is no reason to choose option 1. However, from the graph it is clear that option 3 (1 TSV/ 1 LMSR @ $374 Million) results in the least overall costs, but also with the lowest overall performance. The choice for a decision maker is therefore between options 2 and 3, based on the need to have nearly a 30% reduction in time performance, yet at an additional cost of over $240 million.

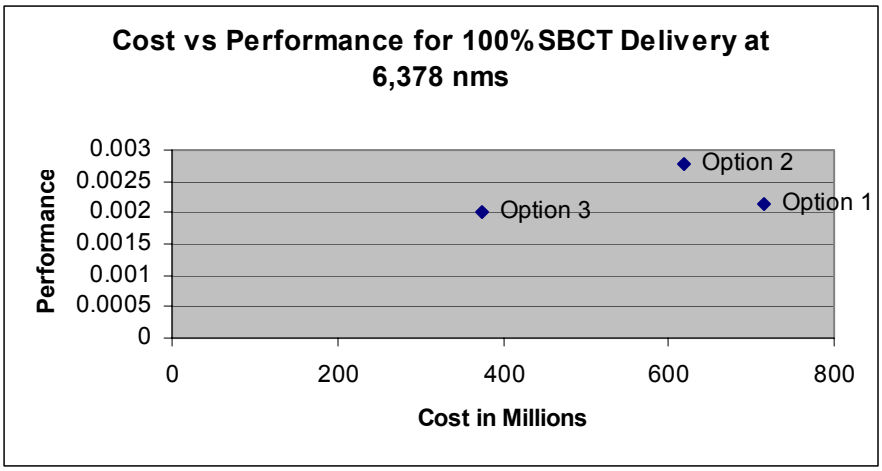

Figure 5. 100% SBCT Cost Performance Analysis.

For short ranges, option 1 clearly provides the best performance but always at the highest costs. The more the range increases the more option 2 improves in performance with a lesser increase in cost than option 1. Since all three options can complete the mission, if time is not a concern then option 3 over longer ranges may prevail because of its lower cost.

V. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSION

The Army has set very aggressive goals for force projection and strategic responsiveness through its efforts to transform into an interim force (SBCT) capable of deploying globally in 96-hours. However, from the analysis conducted in this research it would appear that the 96-hour time requirement to deploy a SBCT using sealift assets would only be viable within short PREPO intra-theater ranges vice a global response. Essentially, the SBCT cannot meet the 96-hour global deployment time frame from CONUS, which highlights the advantage and need for pre-positioning units for rapid response.

Specifically, this analysis finds that the best mix of assets depends on the scenario distance and port accessibility. Two scenarios are modeled based on a fictional Kosovo campaign. The first scenario deploys the SBCT from the PREPO location of Camp Darby, Italy. The second scenario deploys the SBCT from the CONUS location of Beaumont, Texas. Next, a hybrid of this CONUS scenario is conducted by changing the port characteristics to test the sensitivity of the model solution.

These results show that for PREPO ranges up to 1250 nautical miles the TSV is better suited for SBCT deployment with its greater speed and shallower draft regardless of port conditions. For greater ranges, the LMSR is the preferred platform because of its endurance and capacity. Introducing port degradation at increased ranges may change the optimal solution depending if the time delays associated with the LMSRs is greater than the time for the additional refueling required by the TSVs.

Cost versus performance analysis shows that for short ranges better performance can be achieved at higher costs using TSVs. As the range increases, the use of LMSRs becomes the preferred option for performance at moderate cost. If time is not important then the less expensive combination of mixing one of each asset becomes an attractive option at longer ranges.

Although minimizing time remains a concern, it is important to note that with advanced or strategic warning to deploy taken into consideration, the speed advantage of TSVs may not be as significant if the Army's time constraints are relaxed. However, the TSVs may still serve to decrease response time by enabling pre-positioned equipment to be brought closer to shore. In addition, the TSVs are better equipped to be multi-tasked and have less impact on the mission in the event of loss in terms of tonnage and cargo.

The Army's transformation objective of a 96-hour global deployment time implies a rapid strategic sealift at speeds that are currently not possible from CONUS. With increased efficiency in loading/unloading and refueling times as well as other mobility enhancements it will be possible to further reduce SBCT deployment times within one to two weeks for global response.

B. RECOMMENDATIONS FOR FUTURE RESEARCH

A more robust model would be needed to more accurately represent the detailed movement of the SBCT. Information could be gained by tracking and accounting for each level of equipment broken down by weight and square feet based on a time-phased approach. For realism, actual Time Phased Force Deployment Data (TPFDD) could be used to ascertain where potential backlogs or choke points may occur. This may aid in the determination of how the SBCT must doctrinally deploy. Since the SBCT is too big to deploy all at once rapidly, a more detailed model would assist the decision maker in determining the required and optimal force flow to best use available assets. In assessing the efficiency of operations, other measures of effectiveness may be proposed based on actual operational data such as the percentage of ships available, activation and vessel turnaround time as well as operating cost data.

APPENDIX A. VARIANTS

A. THE STRYKER VARIANTS

- Stryker ICV Infantry Carrier Vehicle
- Stryker MGS Mobile Gun System
- Stryker ATGM Anti Tank Guided Missile
- Stryker CV Commander's Vehicle
- Stryker MC Mortar Carrier
- Stryker RV Reconnaissance Vehicle
- Stryker ESV Engineer Squad Vehicle
- Stryker NBC RV NBC Reconnaissance Vehicle
- Stryker MEV Medical Evacuation Vehicle
- Stryker FSV Fire Support Vehicle

B. THE TWO MAIN VARIANTS

1. Infantry Carrier Vehicle (ICV)

- Carries nine troops (driver and a commander)
- 40mm Grenade Launcher
- .50 Caliber Machine Gun

2. Mobile Gun System (MGS)

- 105 mm Cannon
- 18 Ready Rounds every 16 seconds.

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APPENDIX B. STRYKER ILLUSTRATIONS

ICV Infantry Carrier Vehicle

MGS Mobile Gun System

ATGM Anti Tank Guided Missile

CV Commander's Vehicle

MC Mortar Carrier

RV Reconnaissance Vehicle

ESV Engineer Squad Vehicle

NBC RV NBC Reconnaissance Vehicle

MEV Medical Evacuation Vehicle

FSV Fire Support Vehicle

Figure 6. Stryker Variations.

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LIST OF REFERENCES

Army Watercraft, [http://www.globalsecurity.org/military/systems/ship/army.html] December 2003.

Callahan, Shawn M., LCDR, USN, *The Impact of Fast Ship and High Speed Sealift on Strategic Sealift*, Maxwell Air Force Base, Alabama, Air Command and Staff College, 1998.

Congressional Budget Office (CBO), Moving U.S. Forces: Options for Strategic Mobility. *"The Army's Goals for Strategic Mobility", Appendix A,* February 1997, [http://www.cbo.gov/showdoc.cfm?index=11&sequence=0] December 2003

E-mail correspondence between Mr. Jim O'Brasky, Principal Engineer, Basic Commerce and Industries, Inc. and the author, 14 October 2003.

Hickins, Kenneth E., *"Strategic Mobility: The U.S. Military's Weakest Link"*, [http://www.almc.army.mil/alog/issues/NovDec02/MS813.htm] December 2003.

Naber, Jim, CDR, USN, *Army After Next and High Speed Sea Lift*, Carlisle Barracks, Pennsylvania, U.S. Army War College, 1999.

Optimizing Using Excel Solver –Frontline Systems, [http://www.frontsys.com] December 2003

Peltz Eric, John Halliday, and Aimee Bower, *Speed and Power: Toward an Expeditionary Army*. RAND: Santa Monica, California, MR-1755, 2003.

Ronis, R. *"Army Will Deploy Faster With Theater Support Vessels",* National Defense, p. 28, October 2003.

Sage, Andrew P. and James E. Armstrong, Jr., Introduction to Systems Engineering. John Wiley and Sons, 2000.

Stryker Brigade Combat Team (SBCT). "What is a Stryker Brigade Combat Team?", [http://www.lewis.army.mil/transformation/What%20is%20a%20SBCT.pdf] December 2003.

T-AKR 295 Shugart Large, Medium-Speed, Roll-On/Roll-Off Ships [LMSR], [http://www.fas.org/man/dod-101/sys/ship/takr-295.htm] December 2003.

Theater Support Vessel (TSV) Industry Day Requirements Briefing. Briefing by Mr. David Crum, Watercraft Branch Chief, Combined Arms Support Command (CASCOM), 18 March 2003.

Theater Support Vessel Deployability Analysis (TSV-DA). Briefing by CPT Joseph Burger, ORSA Analyst, Mobilization and Deployment Division, Center for Army Analysis, June 2003.

U.S. Joint Chiefs of Staff, *Mobility Requirements Study, Bottom-up Review Update (MRS BURU) (U)*, Washington D.C., March 1995.

U.S. Joint Chiefs of Staff, *Mobility Requirements Study Vol. 1(U)*, Washington D.C., January 1992.

Vick, Alan, and others, *The Stryker Brigade Combat Team: Rethinking Strategic Responsiveness and Assessing Deployment Options*. RAND: Santa Monica, California, MR-1606-AF, 2002.

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