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THESIS

OPTIMAL ALLOCATION OF SELECTED T-SERIES ADVANCED BASE FUNCTIONAL COMPONENT EQUIPMENT PACKAGES

by

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June 2000

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ABSTRACT ***(maximum 200 words)***

Advanced Base Functional Components (ABFCs) are pre-planned modular units of equipment and personnel designed to extend or create the logistic infrastructure required to support naval expeditionary operations. The ABFC program is structured to combine trained personnel with the equipment needed to perform a particular logistic mission such as seaport operations and cargo handling, warehousing, or freight terminal operations. If the ABFC must deploy to a theater of operations, individual equipment packages containing material handling equipment and/or civil engineering support equipment (CESE) vehicles tailored to the operational situation are required. This thesis presents an optimization model that determines the minimum number and type of ABFC equipment packages required for the land-based naval logistic requirements of several hypothetical scenarios, some of which illustrate dual major theater war scenarios. The model quickly and efficiently provides the user with the minimum required number of material handling equipment and CESE vehicles for selected T-series ABFCs.

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OPTIMAL ALLOCATION OF SELECTED T-SERIES ADVANCED BASE FUNCTIONAL COMPONENT EQUIPMENT PACKAGES

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Advanced Base Functional Components (ABFCs) are pre-planned modular units of equipment and personnel designed to extend or create the logistic infrastructure required to support naval expeditionary operations. The ABFC program is structured to combine trained personnel with the equipment needed to perform a particular logistic mission such as seaport operations and cargo handling, warehousing, or freight terminal operations. If the ABFC must deploy to a theater of operations, individual equipment packages containing material handling equipment and/or civil engineering support equipment (CESE) vehicles tailored to the operational situation are required.

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LIST OF ACRONYMS

ABFC	Advanced Base Functional Component
ALSS	Advanced Logistics Support Site
CESE	Civil Engineering Support Equipment
CINC	Commander-In-Chief
DLR	Depot Level Repairable
FLS	Forward Logistics Site
FTC	Freight Terminal Company
FY	Fiscal Year
HNS	Host Nation Support
MHE	Material Handling Equipment
MMC	Mobile Mail Company
MPS	Maritime Prepositioning Ship
MTW	Major Theater War
NAVCHAPGRU	Naval Cargo Handling and Port Group
NAVELSF	Naval Expeditionary Logistics Support Force
NCHB	Navy Cargo Handling Battalion
OPLAN	Operational Plan
OPNAV	Office of the Chief of Naval Operations
SSB	Supply Support Battalion
T-AKR	Roll-on/Roll-off Ship
WPS	Worldwide Port System

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EXECUTIVE SUMMARY

Advanced Base Functional Components (ABFCs) are pre-planned modular units of equipment and personnel designed to extend or create the logistic infrastructure required to support naval expeditionary operations. The ABFC program is structured to combine trained personnel with the equipment needed to perform a particular logistic mission such as seaport operations and cargo handling, warehousing, or freight terminal operations. If the ABFC must deploy to a theater of operations, individual equipment packages containing material handling equipment (MHE) and/or civil engineering support equipment (CESE) vehicles tailored to the operational situation are required.

This thesis presents an optimization model that determines the minimum number and type of ABFC equipment packages required for the land-based naval logistic requirements of several hypothetical scenarios, some of which illustrate dual major theater war scenarios. The model quickly and efficiently provides the user with the minimum required number of MHE and CESE vehicles for selected T-series ABFCs. The results obtained from the optimization model indicate that for the five hypothetical scenarios considered, the existing inventory of MHE and CESE vehicles cannot meet all of the equipment package requirements. Rather, substantial reliance on Host Nation Support is necessary to ensure that deployed T-series personnel-only units have an adequate number of MHE and CESE vehicles available.

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I. INTRODUCTION

A. BACKGROUND

Advanced Base Functional Components (ABFCs) are pre-planned modular units of equipment personnel "designed to extend or create the logistic infrastructure required to support naval expeditionary operations" [Ref. 1: p. 2]. Examples of naval expeditionary operations include amphibious assault operations, attack of targets ashore, or sea control operations [Ref. 2: p. 74]. The ABFC program is structured to combine trained personnel with the equipment needed to do a job. Some ABFCs, known as *equipment packages*, contain a specific type of forklift, vehicle, or some combination of hardware required to perform a task such as moving a pallet of cargo from a delivery truck into a warehouse. If, for example, a forklift constitutes an ABFC equipment package, the forklift operator would be a member of a group of people organized into a military unit known as a Warehouse Company, which is a type of ABFC identified as a *personnel-only unit*. Service members in a personnel-only unit can operate specific ABFC equipment packages.

Code N412 (Supply Programs and Policy) of the Office of the Chief of Naval Operations (OPNAV), the manager of the ABFC program, is interested in determining if the present ABFC force is structured to meet the requirements of a dual *major theater war* (MTW) scenario, i.e., a situation in which the United States must fight two simultaneous or nearly-simultaneous conflicts in different regions of the world. This thesis presents an optimization model that determines the minimum number and type of

ABFC equipment packages required for the land-based naval logistic requirements of several hypothetical scenarios, some of which illustrate dual MTW scenarios. In each dual MTW scenario explored, ABFCs provide varying levels of support.

Advanced Base Functional Components serve the eight functional areas listed in Table 1. Each functional area identifies the primary mission of the ABFCs in that series. For example, N-series (Camp and Welfare) ABFCs include tent camps for personnel housing and field kitchens that provide galley services. This thesis focuses on the T-series (Transportation) ABFCs, which are part of the Naval Expeditionary Logistics Support Force (NAVELSF). NAVELSF plans and directs "the peacetime support, training, and mobilization readiness" [Ref. 3] of most T-series ABFCs.

Series	Functional Area
A	Administration
B	Harbor Control and Defense
C	Communications
E	Ship and Boat Repair
H	Aviation
J	Ordnance
M	Medical and Dental
N	Camp and Welfare
P	Construction and Public Works
T	Transportation

Table 1: Advanced Base Functional Component Identification System. Each functional area identifies the primary mission of the ABFCs in that series.

The T-series "Transportation" designation is slightly misleading. NAVELSF T-series ABFCs fulfill a wide range of logistic support functions. T-series ABFCs provide bulk fuel storage and distribution facilities, Barber, Laundry and Ship's Store (BLSS) support, air cargo terminal operations, warehousing, freight forwarding services, and seaport cargo handling operations.

The number of personnel-only units that are required to support a naval expeditionary force is a function of the number and type of deployed naval forces in a theater of operations. Aircraft carrier battle groups, amphibious readiness groups and the U.S. Marine Corps' Maritime Prepositioning Force are all examples of naval expeditionary forces supported by ABFCs. The ABFC personnel-only units and their associated equipment packages support the deployed forces by creating or augmenting a naval advanced base, which is located in an "overseas area ... in or near the theater of operations from which we organize logistic facilities to conduct and support naval operations" [Ref. 4: p. 55]. A naval advanced base may consist of one or more Advanced Logistics Support Sites (ALSSs). The naval Advanced Logistics Support Site is the primary transshipment point for material and personnel destined for naval forces deployed in the theater of operations. Established at a secure location readily accessible to a seaport and/or airport, the ALSSs handle the reception, storage, consolidation and forwarding of supplies and personnel for naval forces deployed in the area. In some situations, the operating forces need an intermediate logistics site located between them and the ALSS. This intermediate support area is a Forward Logistics Site (FLS).

The naval Forward Logistics Site (FLS) is the transshipment point located closest to deployed naval forces. Like the ALSS, a Forward Logistics Site is established near a port and/or airfield and is linked to the ALSS by intra-theater sealift, airlift and/or ground transportation. Fixed and/or rotary wing aircraft deliver personnel and material from the FLS to the deployed forces. Figure 1 displays a possible arrangement of two ALSSs, two FLSs, and the types of ABFCs supporting the expeditionary naval forces deployed in the area. In Figure 1, two Advanced Logistics Support Sites have been established, one at a seaport and the other at a nearby airport. The two ALSSs support two Forward Logistics Sites located at remote airfields, which supply the at-sea naval forces. The T-series units employed include Navy Cargo Handling Battalions, Air Cargo Companies, Fuel Companies, Freight Terminal Companies, and a Mobile Mail Company. The other support units, such as the Naval Coastal Warfare unit, Fleet Hospitals, and the P-3 Mobile Maintenance Facility, are ABFCs not considered in this research.

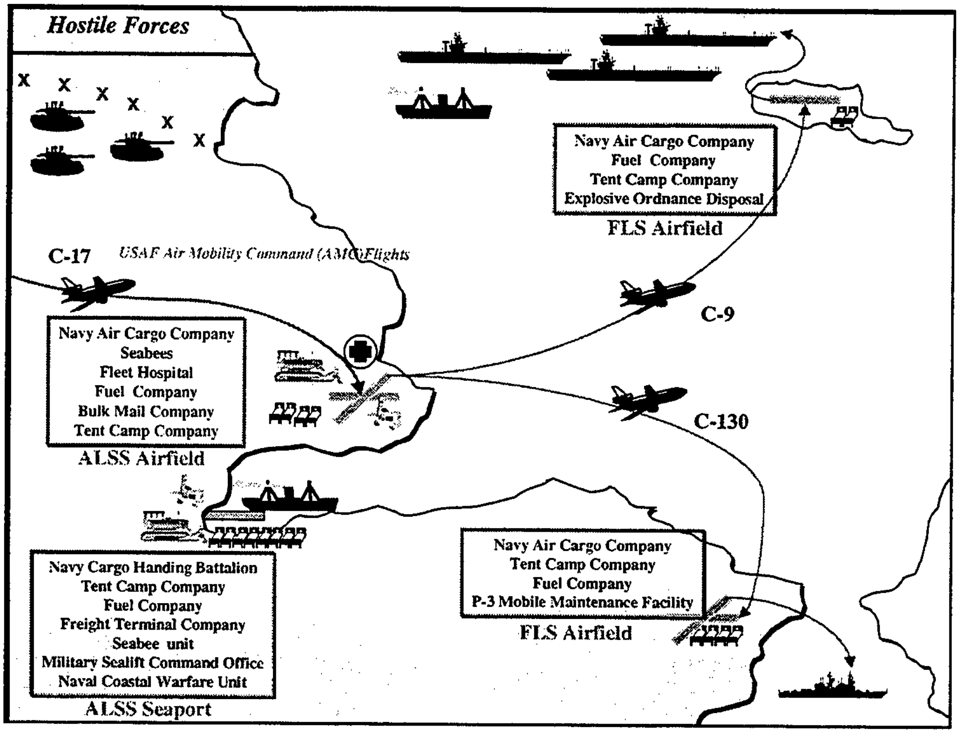

Figure 1: Possible Advanced Logistics Support Site/Forward Logistics Site arrangement supported by ABFCs [After Ref. 5]. Two Advanced Logistics Support Sites have been established, one at a seaport and the other at a nearby airport. The two ALSSs support two Forward Logistics Sites at remote airfields, which supply the at-sea naval forces. The T-series units employed include Navy Cargo Handling Battalions, Air Cargo Companies, Fuel Companies, Freight Terminal Companies, and a Mobile Mail Company. The other support units, such as the Naval Coastal Warfare Unit, Fleet Hospitals, and the P-3 Mobile Maintenance Facility, are ABFCs or active duty forces not considered in this research.

B. PAST WORK

The Naval Postgraduate School thesis *Prioritization of Advanced Base Functional Components* by Lieutenant Commander Linda A. Guadalupe explores two analytical survey methods for ranking the priority of eleven ABFCs during the early days of a general wartime scenario. Commander Guadalupe provides a foundation for "meaningful quantitative measurements of the need for selected ABFCs" [Ref. 6: p. iii]. Her research is useful for determining the types of ABFCs that should be funded based on regional Commander-in-Chiefs (CINCs) prioritization.

II. MODELING APPROACH

A. PROBLEM DESCRIPTION

Recall that a personnel-only unit is a group of people trained to perform a specific mission such as operating a warehouse or unloading a ship. When a personnel-only unit deploys to support a regional Commander-in-Chief's operational plan (OPLAN), the personnel travel (usually by air) to the theater of operations. The required equipment packages, which contain one specific type of material handling equipment (MHE) or civil engineering support equipment (CESE) vehicle, are determined by planning factors such as the type of cargo to be handled. (Subsection B-3 of this chapter discusses planning factors in more detail.) The equipment packages, tailored by the planning factors to meet specific operational requirements, travel to the theater of operations by strategic airlift or sealift.

This thesis determines the minimum number of equipment packages necessary for a given set of personnel-only units through the use of an *integer linear program*. An integer linear program seeks to minimize a linear objective function, in this case, the total number of equipment packages, subject to several linear equality or inequality constraints that represent restrictions on equipment and vehicle use. The process used to determine which personnel-only units are required in-theater is beyond the scope of this research.

B. ASSUMPTIONS

The T-series Advanced Base Functional Components Equipment Package Optimization Model includes the following T-series personnel-only units: Supply Support Battalion (SSB) Warehouse Companies, SSB Freight Terminal Companies, SSB Mobile Mail Companies, and Navy Cargo Handling Battalions (NCHBs). Appendix A contains a detailed description of these personnel-only units. Each T-series personnel-only unit is trained to handle the different types of cargo relevant to its particular specialty. The possible cargo types are break-bulk cargo, break-bulk ammunition, containerized cargo in 20-foot containers, vehicles, and *all-purpose* cargo. (The all-purpose cargo type requires a variety of MHE capable of handling both 20-foot containers and break-bulk cargo.) However, not every T-series personnel-only unit can handle each type of cargo. For instance, a Mobile Mail Company will never handle break-bulk ammunition because the training requirements for ammunition are significantly different from those required for handling bulk mail. All of the T-series personnel-only units are capable of operating at existing or expeditionary facilities. An *existing facility* is an established seaport or airfield with permanent buildings and hard surface cargo handling areas. An *expeditionary facility* is an ALSS or FLS located at an unimproved location, i.e., a site at which the cargo handling area may be little more than an open field with cargo containers and tents serving as a warehouse.

1. Personnel-only Units

This thesis assumes that when an ABFC personnel-only unit is included in an OPLAN, the full capability of the unit is required. Therefore, all of naval personnel assigned to the personnel-only units will deploy and the units must have sufficient equipment packages to conduct around-the-clock operations. In short, the model assumes all personnel assigned to the personnel-only unit are actively supporting the assigned tasks and that the full capability of the personnel-only unit is utilized, i.e., no personnel are idle.

The Freight Terminal Companies, Warehouse Companies, and Mobile Mail Companies are essentially single-mission units. For example, a Mobile Mail Company cannot maintain a general warehouse; its mission is to unload, store and distribute bulk mail arriving as break-bulk or containerized cargo. Navy Cargo Handling Battalions, on the other hand, are capable of performing more than one type of cargo handling operation. For modeling purposes, NCHBs are limited to seaport cargo handling operations and will only work with ships.

There are two types of NCHBs, the active-duty Navy Cargo Handling and Port Group (NAVCHAPGRU) and the NCHBs of the U.S. Naval Reserve. NAVCHAPGRU is the only active-duty NCHB; there are presently twelve reserve NCHBs. NAVCHAPGRU and the reserve NCHBs perform essentially the same mission. However, NAVCHAPGRU is twice the size of one reserve NCHB and, consequently, can handle larger amounts of cargo. This thesis considers NAVCHAPGRU as one type of NCHB. In practice NAVCHAPGRU operates and maintains its own equipment. However, for the purposes of this thesis, the model treats NAVCHAPGRU as a T-series personnel-only unit that requires equipment packages.

One Navy Cargo Handling Battalion, active or reserve, can perform several different types of cargo handling operations simultaneously on a 24-hour basis. The total number of cargo ships that one NCHB can load or unload depends on what additional cargo handling functions the NCHB must perform. For example, a NCHB may be tasked to only unload the cargo from a group of ships and leave all other cargo handling functions to civilian longshoremen. Because the NCHB is not responsible for any task except unloading, it can use its excess personnel to perform other support functions including unloading one or more other ships. If longshoremen are not available, then the NCHB must clear the pier of cargo--known as a pier-clearing operation--after the cargo is unloaded from the ship. This pier-clearing operation requires additional equipment operators, which decreases the number of ships that can be simultaneously unloaded. Ideally, another type of ABFC or combat unit would take custody of the cargo from the NCHB as soon as the cargo clears the pier. If no other unit is available to pick up the cargo, then the cargo is held in a temporary storage area known as a *marshal yard.* Operating a marshal yard requires additional NCHB personnel and reduces the number of ships that one NCHB can unload. Table 2 summarizes the operational capabilities of the two NCHB types. The NCHB operational capabilities used in this model are approximate. They assume 24-hour, continuous operations and that all NCHB personnel are available strictly for cargo-handling duties.

One reserve NCHB can: --Offload two ships or, --Offload one ship and conduct a pier-clearing operation, or --Offload one ship, conduct a pier-clearing operation, and operate a marshal yard
One active-duty NCHB, i.e., NAVCHAPGRU can: --Offload four ships, or --Offload two ships and conduct a pier-clearing operation for both, or --Offload two ships, conduct pier-clearing operations for both, and operate two marshal yards

Table 2: Summary of Navy Cargo Handling Battalion Operational Capabilities. This information assumes 24-hour, continuous operations and that all NCHB personnel are available for cargo-handling duties.

2. Equipment Packages

There are two basic types of equipment packages for the T-series personnel-only units: material handling equipment (MHE) and civil engineering support equipment (CESE) vehicles. The proper use of the various types of material handling equipment is situation-dependent. The four characteristics of material handling equipment are weight-handling class, engine type, height profile, and the type of terrain over which the MHE can operate. Weight-handling class refers to the maximum load that the piece of MHE can lift. Military MHE generally uses two types of propulsion: electric motors or diesel engines. Electric-drive MHE is preferred when working with ammunition and/or when operating in enclosed areas (such as a ship's cargo hold) where diesel exhaust is hazardous to personnel. The identifier *DED*, found in several tables displayed later in this thesis, indicates that the equipment is powered with diesel propulsion. Special "low profile" MHE is required when operating in areas with restricted overhead clearance such as around aircraft or while loading or unloading cargo containers. Finally, MHE intended for an expeditionary facility, i.e., a facility that has mostly dirt, mud, or gravel operating areas, requires "rough terrain" MHE. Rough terrain MHE is specifically designed for operating areas that are not paved. On the other hand, an existing facility with concrete or asphalt cargo handling areas does not require MHE with rough terrain capabilities. "Standard" MHE—material handling equipment designed for use in paved operating areas—is better suited for use at existing facilities. Figure 2 displays a 4,000-lb. capacity, DED, low-profile, rough terrain forklift.

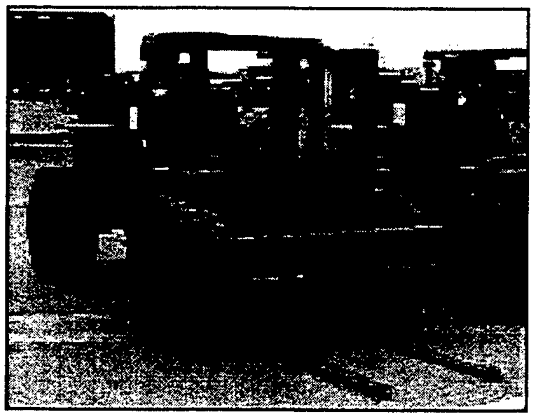

Figure 2: 4,000-lb. capacity, DED, low-profile, rough terrain forklift [Ref. 7].

Weight-handling class is always listed when identifying a particular type of MHE. In practice, however, it is common for the propulsion type, height profile, and terrain type to *not* be explicitly indicated. If a propulsion type is not listed, we assume that the MHE is diesel powered. The normal height profile and standard terrain capability are the default characteristics when low-profile or rough terrain are not stated.

In contrast with MHE, CESE vehicle types are not activity-specific. Only vehicle type identifies a CESE vehicle. The possible CESE types considered in this model are light cargo trucks (CUCV), cargo (stake) trucks, truck tractors (Figure 3), break-bulk trailers, and special Lowbed "low boy" trailers designed to carry loads weighing up to 35 tons. Requirements for unit personnel movement and local area cargo delivery dictate the number of CESE vehicles needed by a personnel-only unit. CESE vehicles may be necessary to move unit personnel from their living areas to their particular work site. Local area cargo delivery, usually for distances less than 20 kilometers, may also be required in order to move cargo from a receiving area such as a seaport or airfield to a warehouse facility. The cargo (stake) truck shown in Figure 4 is used for both personnel movement and local area cargo delivery.

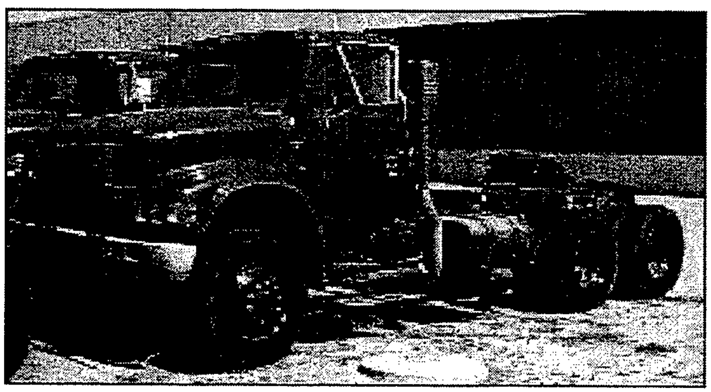

Figure 3: Truck Tractor [Ref. 7]. Truck Tractors pull break-bulk or special lowboy trailers.

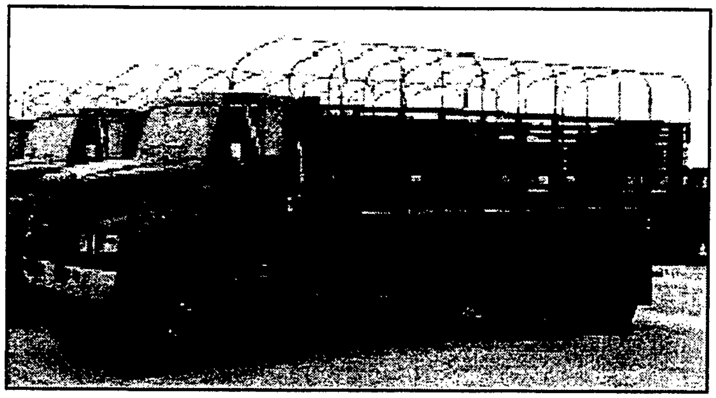

Figure 4: Cargo (stake) Truck [Ref. 7]. Cargo (stake) Trucks provide both personnel movement and local area cargo delivery.

3. Planning Factors

Each of the personnel-only units requires one or more equipment packages designed to handle the relevant type of cargo at the type of facility where the personnel-only unit is operating. Naval Expeditionary Logistics Support Force (NAVELSF) planners have assembled general requirements as to what combination of material handling equipment and civil engineering support equipment vehicles should be used by a T-series personnel-only unit as a function of the cargo type being handled and the type of facility being used. NAVELSF has also specified the minimum required number of MHE and CESE vehicles needed for each personnel-only unit to efficiently use assigned personnel. The model uses a working copy of these recommendations. The recommendations have not been formally approved and should *not* be considered official. However, they are adequate for the purposes of this research. Appendix B includes the NAVELSF equipment package requirements provided. Determining the number of equipment pieces and the specific equipment types best suited for a personnel-only unit depends on several considerations, known as *planning factors*. Planning factors link equipment packages with personnel-only units.

Cargo type and type of facility are the planning factors used to determine the kind of material handling equipment and CESE vehicles required for a Freight Terminal Company, Warehouse Company, or Mobile Mail Company personnel-only unit. The selection of equipment packages for Navy Cargo Handling Battalions requires the consideration of three additional planning factors: the type of NHCB needed, the type of cargo handling operation to be performed, and the number of ships that must be simultaneously serviced. Because of the additional planning factors, NCHBs are treated separately within the model.

To illustrate the concept of planning factors, consider a scenario in which a Warehouse Company, operating in an expeditionary environment and handling break-bulk cargo, is assigned to an OPLAN. The Warehouse Company requires CESE vehicles to move arriving cargo from the seaport to its warehouse facility (local area cargo delivery) and to transport unit personnel from distant living quarters to the work site (personnel movement). The minimum number of MHE and CESE vehicles is provided so each personnel-only unit is efficiently utilized. Table 3 lists the NAVELSF-required equipment package combination for this scenario.

Task	Required MHE	Required CESE Vehicles
Cargo loading and unloading	4 - 4,000-lb capacity, DED, standard profile, rough-terrain forklifts 1 - 10,000-lb capacity, DED, standard profile, rough-terrain forklift 1 –16,000-lb capacity, DED, standard profile, rough-terrain forklift	N/A
Local area cargo delivery	N/A	2 – Light cargo trucks (CUCV) 2 – Cargo (stake) trucks
Personnel movement	N/A	1 – Light cargo truck (CUCV) 1 – Cargo (stake) truck
Minimum required number of MHE and cargo transportation vehicles	6	2

Table 3: Recommended MHE and CESE vehicles for a Warehouse Company operating in an expeditionary environment and handling break-bulk cargo. The Warehouse Company requires CESE vehicles to move arriving cargo from the seaport to its warehouse facility (local area cargo delivery) and to transport unit personnel from distant living quarters to the work site (personnel movement). The minimum number of MHE and CESE vehicles is provided so each personnel-only unit is efficiently utilized.

C. MODEL PRESENTATION

There are two major data requirements in the formulation: (1) the NAVELSF-required combination of MHE and CESE vehicles for each type of personnel-only unit, handling a specific type of cargo at a particular facility type, i.e., the MHE and CESE vehicle requirements with respect to the mission to be accomplished, and (2) the minimum number of MHE pieces required by a personnel-only unit to ensure that no equipment operators are idle, i.e., the MHE requirements with respect to guaranteeing that every equipment operator on each work shift has a piece of equipment to operate. This data is given on a *per unit* basis, where the "unit" refers to one Warehouse Company, Freight Terminal Company, or Mobile Mail Company handling a given cargo type at a particular type of facility. Additional data is necessary for Navy Cargo Handling Battalions because the NAVELSF recommendations for NCHBs reflect the minimum amount of MHE and CESE vehicles required for *each ship* serviced by one NCHB. The product of the minimum number of MHE and CESE vehicles required per ship and the parameter *NumShips,* that specifies how many ships each type of NCHB must simultaneously unload, ensures that adequate MHE and CESE vehicles are available to support the given number of ships.

The capability to provide local area cargo delivery and personnel movement vehicles may not be required for every Freight Terminal Company, Warehouse Company or Mobile Mail Company. To account for this possibility, binary data indicates whether local area cargo delivery vehicles and/or personnel movement vehicles are needed. For example, if the capability to provide local area cargo delivery is required for all

Warehouse Companies, then the binary data element *LocDel* will equal one, otherwise *LocDel* is zero.

Given this data, we present an integer linear programming model, which determines the minimum number and type of material handling equipment and CESE vehicles required for a given number of Warehouse Companies, Freight Terminal Companies, Mobile Mail Companies, and Navy Cargo Handling Battalions. The integer decision variables of the model represent the numbers of specific types of material handling equipment and CESE vehicles required for the given personnel-only units. MHE is characterized by weight-handling class, engine type, height profile, and the type of terrain over which the MHE is designed to operate. CESE vehicles are identified by vehicle type only.

The linear constraints of the model ensure that the minimum MHE and CESE vehicle requirements, applicable to a given personnel-only unit handling a specific type of cargo at a particular facility type, are met for both NCHB and non-NCHB (Freight Terminal Companies, Warehouse Companies, and Mobile Mail Companies) personnel-only units. When NCHBs are involved, the constraints also account for the type of cargo handling operation and the number of ships that must be simultaneously serviced. Finally, the constraints guarantee that there are no idle MHE or CESE vehicle operators.

1. Formulation

Note: Compound index sets are only defined for existing combinations.
Data units indicated in brackets.

Indices:

Material Handling Equipment:

c	weight-handling class	{4K, 6K, 10K, 16K, 30K}
e	engine type	{electric, diesel}
p	height profile	{normal, low}
t	terrain type	{standard, rough}

Civil Engineering Support Equipment:

i vehicle type {light cargo truck, stake truck, tractor and break-bulk/container trailer, tractor and lowboy trailer}

Navy Cargo Handling Battalions:

a	NCHB type	{active, reserve}
s	NCHB operations type	{offload only; offload and pier-clearing; offload, pier-clearing and marshal yard}

Miscellaneous indices:

f	facility type	{existing, expeditionary}
m	type of cargo being handled	{break-bulk cargo, break-bulk ammo, 20-foot containers, vehicles, all-purpose}
u	personnel-only unit type	{freight terminal company, warehouse company, mobile mail company}

Sets:

$\Gamma^{M}_{m,f}$ set of all c, e, p, and t type equipment appropriate for handling type m cargo at a type f facility for non-NCHB units

$\Gamma^{N}_{m,f,s}$ set of all c, e, p, and t type equipment appropriate for handling type m cargo, at a type f facility during a NCHB type s operation

$\Theta^{M}_{m,f}$ set of all civil engineering support equipment vehicles i appropriate for handling type m cargo at a type f facility for non-NCHB units

$\Theta^{N}_{m,f,s}$ set of all civil engineering support equipment vehicles i appropriate for handling type m cargo at a type f facility during a NCHB type s operation

Data:

$NumAssets_{u,m,f}$	given number of type *u* personnel-only units (excluding NCHBs) handling type *m* cargo, at a type *f* facility [unit]
$MinVehic_{u,m,f}$	minimum total number of civil engineering support equipment vehicles (including personnel movement vehicles) that one type *u* personnel-only unit, handling type *m* cargo, at a type *f* facility, requires to efficiently operate [vehicles/unit]
$MinMHE_{u,m,f}$	minimum total number of material handling equipment pieces that one type *u* personnel-only unit, handling type *m* cargo, at a type *f* facility, requires to efficiently operate [pieces of MHE/unit]
$MHE_{c,e,p,t,u,m,f}$	required number of MHE with weight-handling class *c*, engine type *e*, height profile *p*, and terrain type *t*, for one type *u* personnel-only unit, handling type *m* cargo, at a type *f* facility [pieces of MHE/unit]
$Vehicles_{i,u,m,f}$	required number of type *i* civil engineering support equipment vehicles for one type *u* personnel-only unit, handling type *m* cargo, at a type *f* facility [vehicles/unit]
$DelVeh_{i,u,m,f}$	required number of type *i* civil engineering support equipment vehicles for one type *u* personnel-only unit, handling type *m* cargo, at a type *f* facility for local area cargo delivery [vehicles/unit]
$PersVeh_{i,u}$	required number of type *i* civil engineering support equipment vehicles for one type *u* personnel-only unit for personnel movement [vehicles/unit]
$LocDel_u$	equals 1 if local area cargo delivery vehicles are required for a type u personnel-only unit; 0 otherwise
$PersMove_u$	equals 1 if personnel movement vehicles are required for a type *u* personnel-only unit; 0 otherwise
$NumShips_{a,s}$	number of ships for which one type *a* NCHB is required to conduct simultaneous type *s* operations [ship]

$NumNCHB_{a,m,f,s}$ required number of type *a* NCHBs handling type *m* cargo, at a type *f* facility while conducting a type *s* operation [NCHB]

$NCHBminMHE_{a,m,f,s}$ minimum total amount of material handling equipment per NCHB per ship that one type *a* NCHB, handling type *m* cargo, at a type *f* facility, while conducting a type *s* operation, requires to efficiently operate [pieces of MHE/NCHB/ship]

$NCHB\_MHE_{c,e,p,t,a,m,f,s}$ amount of MHE required per ship with weight-handling class *c*, engine type *e*, height profile *p*, and terrain type *t*, required for a type *a* NCHB handling type *m* cargo at a type *f* facility while conducting a type *s* operation [pieces of MHE/NCHB/ship]

$NCHBminVeh_{a,m,f,s}$ minimum total number of civil engineering support equipment vehicles, including personnel movement vehicles, per ship that one type *a* NCHB, handling type *m* cargo, at a type *f* facility, conducting a type *s* operation, requires to efficiently operate [vehicles/NCHB/ship]

$NCHB\_Veh_{i,m,f,s}$ number of type *i* civil engineering support equipment vehicles required per ship to handle the expected volume of type *m* cargo at a type *f* facility during a type *s* operation [vehicles/NCHB/ship]

Decision variables:

$X_{c,e,p,t}$ total number of MHE with weight-handling class *c*, engine type *e*, height profile *p*, and terrain type *t* required for the specified personnel-only units and NCHBs [pieces of MHE]

V_i total number of type *i* civil engineering support equipment vehicles required to meet the cargo transportation and personnel movement needs of the specified personnel-only units and NCHBs [vehicles]

Formulation:

Minimize

(1) $$\sum_c \sum_e \sum_p \sum_t X_{c,e,p,t} + \sum_i V_i$$

Subject to:

(2) $$\sum_{(c,e,p,t)\,\varepsilon\,\Gamma^M_{m,f}} X_{c,e,p,t} \geq \sum_u MinMHE_{u,m,f} * NumAssets_{u,m,f} \quad \forall\, m,f$$

(3) $$X_{c,e,p,t} \geq \sum_u \sum_m \sum_f MHE_{c,e,p,t,u,m,f} * NumAssets_{u,m,f} + \sum_a \sum_m \sum_f \sum_s NumShips_{a,s} * NCHB\_MHE_{c,e,p,t,a,m,f,s} * NumNCHB_{a,m,f,s} \quad \forall\, c, e, p, t$$

(4) $$\sum_{i\,\varepsilon\,\Theta^M_{m,f}} V_i \geq \sum_u MinVehic_{u,m,f} * NumAssest_{u,m,f} \quad \forall\, m,f$$

(5) $$V_i \geq \sum_u \sum_m \sum_f [Vehicles_{i,u,m,f} + DelVeh_{i,u,m,f} * LocDel_u + PersVeh_{i,u} * PersMove_u] * NumAssets_{u,m,f} + \sum_a \sum_m \sum_f \sum_s NumShips_{a,s} * NCHB\_Veh_{i,m,f,s} * NumNCHB_{a,m,f,s} \quad \forall\, i$$

(6) $$\sum_{(c,e,p,t)\,\varepsilon\,\Gamma^N_{m,f,s}} X_{c,e,p,t} \geq \sum_a NumShips_{a,s} * NCHBminMHE_{a,m,f,s} * NumNCHB_{a,m,f,s} \quad \forall\, m,f,s$$

(7) $$\sum_{i\,\varepsilon\,\Theta^N_{m,f,s}} V_i \geq \sum_a NumShips_{a,s} * NCHBminVeh_{a,m,f} * NumNCHB_{a,m,f,s} \quad \forall\, m,f,s$$

(8) $X_{c,e,p,t} \geq 0$ and integer, $\forall\, c, e, p, t$; $V_i \geq 0$ and integer $\forall\, i$

2. Additional Notes

Objective function explanation:

(1) Expresses the total number of MHE with weight-handling class c, engine type e, height profile p, and terrain type t plus the total number of type i CESE vehicles necessary to meet the MHE and CESE vehicle requirements for the given personnel-only units.

Constraint explanations:

(2) For a given type of cargo at a specific facility, all types of appropriate MHE must be greater than or equal to the minimum number of MHE pieces that the given personnel-only units, excluding NCHBs, require to efficiently operate times the given number of personnel-only units, excluding NCHBs. That is, Equation 2 ensures that no MHE operators for the non-NCHB personnel-only units are idle.

(3) For a given type of MHE, the total number of each MHE type must be greater than or equal to the minimum required amount of each MHE type for the given personnel-only units handling a given type of cargo at a specific facility, times the given number of personnel-only units, excluding NCHBs, plus the number of ships each NCHB type must simultaneously unload times the minimum required amount of each applicable MHE type for the given NCHBs handling a given type of cargo at a specific facility during a particular type of operation multiplied by the given number of NCHBs. That is, Equation 3 ensures that the NAVELSF minimum MHE requirements are met for the given personnel-only units.

(4) For a given cargo type at a specific facility, all types of appropriate CESE vehicles must be greater than or equal to the minimum number of all types of CESE vehicles that the given personnel-only units, excluding NCHBs, require to efficiently operate times the given number of personnel-only units, excluding NHCBs. That is, Equation 4 ensures that no CESE vehicle operators for the non-NCHB personnel-only units are idle.

(5) For a given CESE vehicle type, the total number of each CESE vehicle type must be greater than or equal to the minimum required number of CESE vehicles, local area cargo delivery vehicles, as necessary, and personnel movement vehicles, if required, times the given number of personnel-only units, excluding NCHBs, plus the number of ships the given NCHBs must service times the minimum required number of CESE vehicle types necessary per ship multiplied by the given number NCHBs. CESE vehicle requirements for local area cargo delivery and personnel movement are considered separately because not every personnel-only unit may require the personnel movement and/or local area cargo delivery capability. Equation 5 ensures that all the minimum CESE vehicle requirements are met for the given personnel-only units.

(6) For a given type of cargo, facility type, and type of operation, all types of appropriate MHE for a given NCHB must be greater than or equal to the number of ships each NCHB type must simultaneously unload times the minimum number of MHE that all given NCHBs require to efficiently operate multiplied by the given number of NCHBs. That is, Equation 6 ensures that no NCHB MHE operators are idle.

(7) For a given type of cargo, facility type, and type of operation, the total number of each appropriate CESE vehicle type must be greater than or equal to the number of ships each NCHB type must simultaneously unload times the minimum number of all CESE vehicle types that the given NCHBs require to efficiently operate, multiplied by the given number of NCHBs. That is, Constraint 7 ensures that no NCHB CESE vehicle operators are idle.

(8) All decision variables must be greater than or equal to zero and integer.

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III. RESULTS

A. SCENARIO DESCRIPTIONS

This thesis tests five hypothetical operational scenarios involving selected T-series ABFCs. Each scenario involves a plausible combination of personnel-only units handling different types of cargo at both existing and expeditionary facilities. Because the capability to move unit personnel from their living area to the work site is extremely important in an operational environment, all of the personnel-only units in the test scenarios require a personnel movement capability. Local area cargo delivery requirements vary from scenario to scenario.

Each Freight Terminal Company and Warehouse Company is assumed to have six qualified material handling equipment operators for each shift; each Mobile Mail Company has three qualified operators per shift. The number of MHE operators required for a Navy Cargo Handling Battalion varies depending on the operation performed. All MHE operators must have a piece of equipment to operate to ensure efficient unit operation, so each personnel-only unit must have a minimum number of MHE assigned. If any type of T-series ABFC does not require dedicated CESE vehicles for personnel movement from living quarters to the work site, the model assigns two light cargo trucks to the personnel-only units for transportation needs between potentially geographically dispersed work sites. NCHBs always require two light cargo trucks and two cargo (stake) trucks, per ship, for personnel movement. NCHBs never require local area cargo delivery vehicles, because local area cargo delivery is not a NCHB responsibility.

Tables 3 through 7 list the personnel-only units selected for the test scenarios. Each table illustrates the unit types chosen for the scenario, the cargo type applicable for each unit, the type of facility at which the unit is operating, and any requirements for personnel movement and/or local cargo area cargo delivery vehicles. For the Navy Cargo Handling Battalions, the tables indicate the type of NCHB, the type of cargo being handled, the type of operating facility, and the type of operation performed.

Scenario 1, shown in Table 4, is a small-scale deployment of two T-series personnel-only units to provide cargo handling and warehouse services. The reserve NCHB is working around-the-clock unloading break-bulk cargo from one ship at an existing port facility and is conducting an offload and pier-clearing operation. The Warehouse Company provides storage for the break-bulk cargo and local area cargo delivery services. The Warehouse Company requires personnel movement vehicles. Scenario 1 is an example of how ABFCs might be used in a small-scale operation such as providing disaster relief following a natural disaster. The *N/A* annotations in Table 4 indicate that the column heading is not applicable to the particular personnel-only unit. For example, *Local cargo delivery* is listed as N/A for the NCHB, because local area cargo delivery is not a NCHB responsibility. A *Y* indicates that the personnel-only unit requires that particular capability, while an *N* implies that the unit does not require the capability listed in that column. All of the tables found later in this thesis follow this convention.

Personnel-only unit type	Cargo	Facility type	Personnel Movement	Local cargo delivery	NCHB operation type
Reserve NCHB	Break-bulk	Existing	N/A	N/A	Offload and pier-clearing
Warehouse Co.	Break-bulk	Existing	Y	Y	N/A

Table 4: Scenario 1 Description. The reserve NCHB is working around-the-clock unloading break-bulk cargo from one ship at an existing port facility and is conducting an offload and pier-clearing operation. The Warehouse Company provides storage for the break-bulk cargo and local area cargo delivery services. The Warehouse Company requires personnel movement vehicles. Scenario 1 is an example of how ABFCs might be used in a small-scale operation such as providing disaster relief following a natural disaster.

Scenarios 2 and 3 involve six personnel-only units all handling break-bulk cargo but operating at different types of facilities. These two scenarios illustrate how ABFCs might be used to provide cargo handling, freight terminal, and warehouse support from existing or expeditionary facilities for a peace-keeping operation. In Scenario 2, displayed in Table 5, the ABFCs deploy to existing facilities, while in Scenario 3, shown in Table 6, the personnel-only units operate at expeditionary facilities. The two reserve NCHBs each unload one ship and conduct pier-clearing and marshal yard operations. The Freight Terminal Companies and Warehouse Companies require personnel movement vehicles but do not provide local area cargo delivery services. Scenarios 2 and 3 are designed to illustrate the relationship between the facility type and the cost of the material handling equipment needed to support the mission.

Personnel-only unit type	Cargo	Facility type	Personnel Movement	Local cargo delivery	NCHB operation type
Reserve NCHB	Break-bulk	Existing	N/A	N/A	Offload and pier-clearing
Reserve NCHB	Break-bulk	Existing	N/A	N/A	Offload and pier-clearing
Freight Terminal Co.	Break-bulk	Existing	Y	N	N/A
Freight Terminal Co.	Break-bulk	Existing	Y	N	N/A
Warehouse Co.	Break-bulk	Existing	Y	N	N/A
Warehouse Co.	Break-bulk	Existing	Y	N	N/A

Table 5: Scenario 2 Description. All units operate at existing facilities. The two reserve NCHBs each unload one ship and conduct pier-clearing and marshal yard operations. The Freight Terminal Companies and Warehouse Companies require personnel movement vehicles but do not provide local area cargo delivery services.

Personnel-only unit type	Cargo	Facility type	Personnel Movement	Local cargo delivery	NCHB operation type
Reserve NCHB	Break-bulk	Expeditionary	N/A	N/A	Offload and pier-clearing
Reserve NCHB	Break-bulk	Expeditionary	N/A	N/A	Offload and pier-clearing
Freight Terminal Co.	Break-bulk	Expeditionary	Y	N	N/A
Freight Terminal Co.	Break-bulk	Expeditionary	Y	N	N/A
Warehouse Co.	Break-bulk	Expeditionary	Y	N	N/A
Warehouse Co.	Break-bulk	Expeditionary	Y	N	N/A

Table 6: Scenario 3 Description. All units operate at expeditionary facilities. The two reserve NCHBs each unload one ship and conduct pier-clearing and marshal yard operations. The Freight Terminal Companies and Warehouse Companies require personnel movement vehicles but do not provide local area cargo delivery services.

Scenarios 1 through 3 are relatively small-scale ABFC deployments such as disaster relief or peace-keeping operations. Scenario 4 represents a possible T-series ABFC deployment for a two major theater war scenario occurring in Southwest Asia and Korea. All of the units in this scenario operate at existing facilities. Six of the twelve reserve NCHBs provide cargo handling support at various seaports and Naval Weapons Stations. Scenario 4 does not involve NAVCHAPGRU. The reserve NCHBs provide cargo handling services for a variety of cargo including break-bulk, 20-foot containers, break-bulk ammunition, and vehicles. The three NCHBs performing offload-only operations are equipped to work continuously on two ships each. The remaining three NCHBs work on one ship each. Two of the four Freight Terminal Companies and two of the four Warehouse Companies are required for reception, staging, and storage of cargo unloaded by the NCHBs. Only one of the two Mobile Mail Companies is necessary to provide mail handling and distribution services. The Freight Terminal Companies, Warehouse Companies and the Mobile Mail Company all require personnel movement vehicles and local area cargo delivery capability. Table 7 summarizes Scenario 4.

Personnel-only unit type	Cargo	Facility type	Personnel Movement	Local cargo delivery	NCHB operation type
Reserve NCHB	Break-bulk	Existing	N/A	N/A	Offload, pier-clearing, and marshal yard
Reserve NCHB	Containers	Existing	N/A	N/A	Offload only
Reserve NCHB	Containers	Existing	N/A	N/A	Offload and pier-clearing
Reserve NCHB	Break-bulk ammo	Existing	N/A	N/A	Offload only
Reserve NCHB	Break-bulk ammo	Existing	N/A	N/A	Offload only
Reserve NCHB	Vehicles	Existing	N/A	N/A	Offload, pier-clearing and marshal yard
Mobile Mail Co.	Break-bulk	Existing	Y	Y	N/A
Freight Terminal Co.	Break-bulk	Existing	Y	Y	N/A
Freight Terminal Co.	Containers	Existing	Y	Y	N/A
Warehouse Co.	Containers	Existing	Y	Y	N/A
Warehouse Co.	Break-bulk	Existing	Y	Y	N/A

Table 7: Scenario 4 Description. All units operate at existing facilities during a two MTW scenario. Six NCHBs deploy and handle a variety of cargo types. The three NCHBs performing offload-only operations are equipped to work continuously on two ships each. The remaining three NCHBs work on one ship each. The Freight Terminal Companies, Warehouse Companies and the Mobile Mail Company all require personnel movement vehicles and local area cargo delivery capability.

Scenario 5 proposes a different two MTW scenario, which uses almost all of the established T-series ABFCs discussed in this thesis. Instead of the six reserve NCHBs required for cargo handling in Scenario 4, four reserve NCHBs and NAVCHAPGRU deploy for cargo handling missions in Scenario 5. NAVCHAPGRU is equipped to conduct an offload and pier-clearing operation on two ships simultaneously, while the two reserve NCHBs conducting offload, pier-clearing and marshal yard operations work on only one ship each. The two reserve NCHBs performing offload-only operations are equipped to work continuously on two ships each. Scenario 5 employs all of the Freight

Terminal Companies, Warehouse Companies, and Mobile Mail Companies, and all units require personnel movement and local area cargo delivery vehicles. Scenario 5, listed in Table 8, also requires some units to operate at expeditionary facilities and others to deploy with all-purpose equipment packages. Recall that the all-purpose cargo type requires a mix of MHE to handle both break-bulk and containerized cargo.

Personnel-only unit type	Cargo	Facility type	Personnel Movement	Local cargo delivery	NCHB operation type
NAVCHAPGRU	All-purpose	Existing	N/A	N/A	Offload and pier-clearing
Reserve NCHB	All-purpose	Existing	N/A	N/A	Offload, pier-clearing and marshal yard
Reserve NCHB	All-purpose	Existing	N/A	N/A	Offload, pier-clearing and marshal yard
Reserve NCHB	All-purpose	Existing	N/A	N/A	Offload only
Reserve NCHB	All-purpose	Existing	N/A	N/A	Offload only
Mobile Mail Co.	All-purpose	Expeditionary	Y	Y	N/A
Mobile Mail Co.	All-purpose	Expeditionary	Y	Y	N/A
Freight Terminal Co.	Break-bulk	Expeditionary	Y	Y	N/A
Freight Terminal Co.	Break-bulk	Expeditionary	Y	Y	N/A
Freight Terminal Co.	Containers	Existing	Y	Y	N/A
Freight Terminal Co.	Containers	Existing	Y	Y	N/A
Warehouse Co.	Containers	Existing	Y	Y	N/A
Warehouse Co.	Containers	Existing	Y	Y	N/A
Warehouse Co.	Break-bulk	Expeditionary	Y	Y	N/A
Warehouse Co.	Break-bulk	Expeditionary	Y	Y	N/A

Table 8: Scenario 5 Description. A two MTW scenario requiring ABFC units to operate in a variety of facility types and to handle different types of cargo. NAVCHAPGRU is equipped to conduct an offload and pier-clearing operation on two ships simultaneously, while the two reserve NCHBs conducting offload, pier-clearing and marshal yard operations work on only one ship each. The two reserve NCHBs performing offload-only operations are equipped to work continuously on two ships each. Scenario 5 employs all of the Freight Terminal Companies, Warehouse Companies, and Mobile Mail Companies and they all require personnel movement and local area cargo delivery vehicles.

B. SCENARIO RESULTS

The T-series Advanced Base Functional Components Equipment Package Optimization Model is implemented in GAMS version 2.50 [Ref. 8] using the XA linear integer programming solver, version 11.00 [Ref. 9]. All model runs and spreadsheet calculations are performed on a 400 MHz personal computer with a Pentium II processor. Each model run uses less than one second of processor time. Each scenario involves approximately 130 equations and 50 variables.

After each model run, we use a Microsoft Excel spreadsheet to calculate the total cost in fiscal year (FY) 2000 dollars of purchasing all of the material handling equipment and civil engineering support equipment vehicles required for the personnel-only units in the scenario. The Naval Expeditionary Logistics Support Force provided the cost data [Ref. 10]. The model does not consider equipment package cost in the optimization because each personnel-only unit requires a mix of specialized MHE and CESE vehicles to perform its mission. Simply choosing the least expensive piece of MHE does not meet the equipment specialization requirements of a particular scenario. Cost is used in the output analysis to demonstrate how much must be invested for the Navy to have its own stock of material handling equipment and CESE vehicles. This existing inventory of equipment would be considered "free" in the event that ABFCs deployed for a mission because the MHE and CESE vehicles need not be purchased.

Tables 9 through 13 display the results for each of the five scenarios. Specifically, the tables show the minimum number of MHE and CESE vehicle equipment packages for the personnel-only units assigned to each scenario. The tables list the ABFC equipment package number, a brief summary of the MHE or CESE vehicle characteristics, the equipment package cost in FY 2000 dollars, the required number of equipment packages, and the total cost of each equipment package. The final row of each table shows the total cost of all the MHE and CESE vehicle equipment packages required for the scenario. Deploying T-series personnel-only units can draw equipment packages from a small existing inventory of MHE and CESE vehicles, so in reality the actual cost to meet the equipment package requirement for each scenario is somewhat less than that presented in the following tables. Section C of this chapter contains an additional discussion regarding the existing equipment package inventory and how it affects the actual cost of purchasing the required equipment packages.

Table 9 lists the optimal number of equipment packages required for the personnel-only units in Scenario 1, which represents a small-scale deployment of ABFCs for disaster relief. The eight 6,000-lb. capacity, electric, low-profile forklifts are required because the NCHB requires four for the offload operation, while the Warehouse Company requires an additional four to fulfill its mission. The NCHB requires the six 6,000-lb. capacity, DED forklifts, one 10,000-lb. capacity, standard forklift, and one 16,000-lb. capacity, rough terrain forklift for the pier-clearing operation. The remaining two 10,000-lb. capacity, standard forklifts, and two 16,000-lb. capacity, rough terrain forklifts are required for the Warehouse Company. The Warehouse Company requires three light cargo trucks (one for personnel movement and two for local area cargo delivery) and three cargo (stake) trucks (one for personnel movement and two for local area cargo delivery). The balance of the light cargo trucks and cargo (stake) trucks are assigned to the NCHB. Even with the rather modest operational requirements for the ABFCs in this scenario, the MHE and CESE vehicle price tag is almost $1.3 million.

Equipment Package	Identification	Equipment Package Cost (FY00)	Optimal Number	Total Cost (FY 00)
T 40 HA	4,000-lb. capacity, low-profile, rough terrain forklift	$62,000	0	$0
T 40 HC	6,000-lb. capacity, electric, low-profile forklift	$24,000	8	$192,000
T 40 HB	6,000-lb. capacity, DED forklift	$24,000	6	$144,000
T 40 HH	10,000-lb. capacity, standard forklift	$44,000	3	$132,000
T 40 HD	10,000-lb. capacity, rough terrain forklift	$103,000	0	$0
T 40 HE	16,000-lb. capacity, rough terrain forklift	$120,000	3	$360,000
T 40 HF	30,000-lb. capacity, rough terrain, container handler (RTCH)	$180,000	0	$0
T 40 CA	Light Cargo Truck (CUCV)	$15,751	5	$78,755
T 40 CB	Cargo (Stake) Truck	$77,430	5	$387,150
T 40 CC	Truck Tractor	$74,650	0	$0
T 40 TH	Break-bulk Trailer	$20,000	0	$0
T 40 TL	Lowboy Trailer	$25,000	0	$0
		Grand Total	**30**	**$1,293,905**

Table 9: Optimal Number of Equipment Packages for Scenario 1. Scenario 1 represents a small-scale deployment of ABFCs for disaster relief.

The model results for Scenario 2 and Scenario 3 demonstrate how operating T-series ABFCs at expeditionary facilities significantly increases the total cost of the required equipment packages. Table 10 displays the model output for Scenario 2 where the ABFCs all operate at existing facilities. The Scenario 3 results, given in Table 11, show the equipment packages required for the same personnel-only units described in the previous scenario now operating exclusively at expeditionary facilities. The only equipment package change for the NCHBs between Scenarios 2 and 3 is the substitution of four 10,000-lb. capacity, rough-terrain forklifts in Scenario 3 for the four 10,000-lb.

capacity standard forklifts required in Scenario 2. The 10,000-lb. capacity, rough-terrain forklift costs $59,000 more than the 10,000-lb. capacity, standard forklift, increasing the total equipment package cost from approximately $3.2 million in Scenario 2 to over $4.4 million in Scenario 3. Note that there is no change to the CESE vehicle requirements when the units move from an existing facility to an expeditionary facility.

Equipment Package	Identification	Equipment Package Cost (FY00)	Optimal Number	Total Cost (FY 00)
T 40 HA	4,000-lb. capacity, low-profile, rough terrain forklift	$62,000	0	$0
T 40 HC	6,000-lb. capacity, electric, low-profile forklift	$24,000	24	$576,000
T 40 HB	6,000-lb. capacity, DED forklift	$24,000	12	$288,000
T 40 HH	10,000-lb. capacity, standard forklift	$44,000	10	$440,000
T 40 HD	10,000-lb. capacity, rough terrain forklift	$103,000	0	$0
T 40 HE	16,000-lb. capacity, rough terrain forklift	$120,000	10	$1,200,000
T 40 HF	30,000-lb. capacity, rough terrain, container handler (RTCH)	$180,000	0	$0
T 40 CA	Light Cargo Truck (CUCV)	$15,751	8	$126,008
T 40 CB	Cargo (Stake) Truck	$77,430	8	$619,440
T 40 CC	Truck Tractor	$74,650	0	$0
T 40 TH	Break-bulk Trailer	$20,000	0	$0
T 40 TL	Lowboy Trailer	$25,000	0	$0
		Grand Total	**72**	**$3,249,448**

Table 10: Optimal Number of Equipment Packages for Scenario 2. The ABFCs provide support to a peace-keeping operation from existing facilities.

Equipment Package	Identification	Equipment Package Cost (FY00)	Optimal Number	Total Cost (FY 00)
T 40 HA	4,000-lb. capacity, low-profile, rough terrain forklift	$62,000	16	$992,000
T 40 HC	6,000-lb. capacity, electric, low-profile forklift	$24,000	8	$192,000
T 40 HB	6,000-lb. capacity, DED forklift	$24,000	12	$288,000
T 40 HH	10,000-lb. capacity, standard forklift	$44,000	0	$0
T 40 HD	10,000-lb. capacity, rough terrain forklift	$103,000	10	$1,030,000
T 40 HE	16,000-lb. capacity, rough terrain forklift	$120,000	10	$1,200,000
T 40 HF	30,000-lb. capacity, rough terrain, container handler (RTCH)	$180,000	0	$0
T 40 CA	Light Cargo Truck (CUCV)	$15,751	8	$126,008
T 40 CB	Cargo (Stake) Truck	$77,430	8	$619,440
T 40 CC	Truck Tractor	$74,650	0	$0
T 40 TH	Break-bulk Trailer	$20,000	0	$0
T 40 TL	Lowboy Trailer	$25,000	0	$0
		Grand Total	**72**	**$4,447,448**

Table 11: Optimal Number of Equipment Packages for Scenario 3. The ABFCs provide support to a peace-keeping operation from existing facilities.

The first of the two possible dual MTW scenarios, Scenario 4, has an astronomical cost of over $10.4 million. Because more personnel-only units are required in Scenario 4, and, therefore, more equipment packages are necessary, the equipment package cost is greater than that of any previous scenario. Table 12 lists the minimum required number of equipment packages required for the personnel-only units in Scenario 4.

Equipment Package	Identification	Equipment Package Cost (FY00)	Optimal Number	Total Cost (FY 00)
T 40 HA	4,000-lb. capacity, low-profile, rough terrain forklift	$62,000	8	$496,000
T 40 HC	6,000-lb. capacity, electric, low-profile forklift	$24,000	32	$768,000
T 40 HB	6,000-lb. capacity, DED forklift	$24,000	10	$240,000
T 40 HH	10,000-lb. capacity, standard forklift	$44,000	15	$660,000
T 40 HD	10,000-lb. capacity, rough terrain forklift	$103,000	0	$0
T 40 HE	16,000-lb. capacity, rough terrain forklift	$120,000	14	$1,680,000
T 40 HF	30,000-lb. capacity, rough terrain, container handler (RTCH)	$180,000	7	$1,260,000
T 40 CA	Light Cargo Truck (CUCV)	$15,751	33	$519,783
T 40 CB	Cargo (Stake) Truck	$77,430	45	$3,484,350
T 40 CC	Truck Tractor	$74,650	14	$1,045,100
T 40 TH	Break-bulk Trailer	$20,000	12	$240,000
T 40 TL	Lowboy Trailer	$25,000	2	$50,000
		Grand Total	**192**	**$10,443,233**

Table 12: Optimal Number of Equipment Packages for Scenario 4. Scenario 4 represents possible T-series ABFC requirements for major theater wars in Southwest Asia and Korea.

Scenario 5, the second dual MTW scenario, has an even higher equipment package cost associated with it because of the following significant factors. First, in light of an assumed need for long-term ocean cargo handling operations in this scenario, NAVCHAPGRU is deployed. While bringing extensive cargo handling capabilities to the theater CINC, NAVCHAPGRU requires a large number of MHE and CESE vehicles. Second, the all-purpose equipment packages required for NAVCHAPGRU and many of the other personnel-only units in Scenario 5 add to the number of necessary equipment packages. Table 13 displays the detailed equipment requirements totaling over $20.4 million.

Equipment Package	Identification	Equipment Package Cost (FY00)	Optimal Number	Total Cost (FY 00)
T 40 HA	4,000-lb. capacity, low-profile, rough terrain forklift	$62,000	44	$2,728,000
T 40 HC	6,000-lb. capacity, electric, low-profile forklift	$24,000	32	$768,000
T 40 HB	6,000-lb. capacity, DED forklift	$24,000	12	$288,000
T 40 HH	10,000-lb. capacity, standard forklift	$44,000	16	$704,000
T 40 HD	10,000-lb. capacity, rough terrain forklift	$103,000	10	$1,030,000
T 40 HE	16,000-lb. capacity, rough terrain forklift	$120,000	26	$3,120,000
T 40 HF	30,000-lb. capacity, rough terrain, container handler (RTCH)	$180,000	24	$4,320,000
T 40 CA	Light Cargo Truck (CUCV)	$15,751	50	$787,550
T 40 CB	Cargo (Stake) Truck	$77,430	62	$4,800,660
T 40 CC	Truck Tractor	$74,650	20	$1,493,000
T 40 TH	Break-bulk Trailer	$20,000	16	$320,000
T 40 TL	Lowboy Trailer	$25,000	4	$100,000
		Grand Total	**316**	**$20,459,210**

Table 13: Optimal Number of Equipment Packages for Scenario 5. Scenario 5 represents possible T-series ABFC requirements and the deployment of NAVCHAPGRU for a two major theater war scenario.

C. ANALYSIS

The T-series ABFCs provide critical logistic support to deployed naval forces. However, in order to provide this support, the personnel-only units must have sufficient material handling equipment and CESE vehicles. The T-series ABFCs currently rely heavily upon Host Nation Support (HNS) to meet their equipment package requirements. HNS, which in this case involves material handling equipment or CESE vehicles provided by a host nation that has invited the United States to use the host nation's seaport facilities, airports, and transportation infrastructure, is critically important to accomplish current OPLANs. To illustrate this dependence on Host Nation Support, Table 14 lists the MHE and CESE vehicles currently available for the use of the T-series personnel-only units described in this thesis, while Table 15 displays the equipment package shortfalls for each scenario. NAVCHAPGRU material handling equipment and CESE vehicles are not included in Table 14 or Table 15 because NAVCHAPGRU is an active-duty unit with its own assigned equipment and does not draw equipment packages from the Table 14 inventory of existing MHE and CESE vehicles, i.e., it is assumed that NAVCHAPGRU has the necessary number of equipment packages available.

Equipment Package	Identification	Existing Inventory
T 40 HA	4,000-lb. capacity, low-profile, rough terrain forklift	8
T 40 HC	6,000-lb. capacity, electric, low-profile forklift	0
T 40 HB	6,000-lb. capacity, DED forklift	24
T 40 HH	10,000-lb. capacity, standard forklift	0
T 40 HD	10,000-lb. capacity, rough terrain forklift	0
T 40 HE	16,000-lb. capacity, rough terrain forklift	12
T 40 HF	30,000-lb. capacity, rough terrain, container handler (RTCH)	0
T 40 CA	Light Cargo Truck (CUCV)	26
T 40 CB	Cargo (Stake) Truck	10
T 40 CC	Truck Tractor	35
T 40 TH	Break-bulk Trailer	28
T 40 TL	Lowboy Trailer	13
	Total	**156**

Table 14: Existing T-series Equipment Package Inventory [Ref. 10]. Data does not include NAVCHAPGRU MHE or CESE vehicles.

The existing equipment package inventory does not meet the MHE and CESE vehicle equipment package requirements for any of the scenarios presented in this thesis. For example, existing equipment packages cannot meet the equipment needs of Scenario 1, which involves just two T-series units. In Scenario 1, the equipment shortfall is eight 6,000-lb. capacity, electric, low-profile forklifts (equipment package T 40 HC). The optimization model does not consider equipment package substitutions. However, in reality, it might be possible for the 4,000-lb., low-profile, rough terrain forklifts (equipment package T 40 HA) to eliminate the shortfall. The decision to substitute equipment packages must be made by the logistics planner involved in the operation.

Equipment Package	Identification	Scenario 1 shortfall	Scenario 2 shortfall	Scenario 3 shortfall	Scenario 4 shortfall	Scenario 5 shortfall
T 40 HA	4,000-lb. capacity, low-profile, rough terrain forklift	Package not required	Package not required	8	0	36
T 40 HC	6,000-lb. capacity, electric, low-profile forklift	8	24	8	32	24
T 40 HB	6,000-lb. capacity, DED forklift	0	0	0	0	0
T 40 HH	10,000-lb. capacity, standard forklift	3	10	Package not required	15	12
T 40 HD	10,000-lb. capacity, rough terrain forklift	Package not required	Package not required	10	Package not required	10
T 40 HE	16,000-lb. capacity, rough terrain forklift	0	0	0	2	10
T 40 HF	30,000-lb. capacity, rough terrain, container handler (RTCH)	Package not required	Package not required	Package not required	7	18
T 40 CA	Light Cargo Truck (CUCV)	0	0	0	7	20
T 40 CB	Cargo (Stake) Truck	0	0	0	35	48
T 40 CC	Truck Tractor	Package not required	Package not required	Package not required	0	0
T 40 TH	Break-bulk Trailer	Package not required	Package not required	Package not required	0	0
T 40 TL	Lowboy Trailer	Package not required	Package not required	Package not required	0	0
	Total shortfall:	**11**	**34**	**26**	**98**	**178**

Table 15: Equipment Package Shortfalls for Scenarios 1 – 5. NAVCHAPGRU equipment package requirements are not included in Scenario 5 shortfalls.

The shortfall of 6,000-lb. capacity, electric, low-profile forklifts in Scenario 5, shown in Table 15, is determined by subtracting the existing inventory of 6,000-lb. capacity, electric forklifts found in Table 14 from the total number of 6,000-lb. capacity, electric, low-profile forklifts required for the scenario in Table 13, and then subtracting the number of 6,000-lb. capacity, electric forklift required by NAVCHAPGRU. Appendix B contains the NAVCHAPGRU MHE and CESE vehicle requirements. Notice that there is an adequate supply of 6,000-lb. capacity DED forklifts for all scenarios and enough 16,000-lb. capacity, rough terrain forklifts, light cargo trucks, and cargo (stake) trucks for Scenarios 1 through 3. The inventory of truck tractors and associated break-bulk or lowboy trailers is sufficient for all five scenarios. Scenarios 4 and 5 exhibit major shortfalls of MHE and light cargo trucks and cargo (stake) trucks. The lack of any 30,000-lb. capacity, rough terrain, container-handlers (equipment package T 40 HF) is cause for concern because of the trend towards military containerized cargo.

Table 16 displays the actual cost of purchasing MHE and CESE vehicles to overcome the equipment shortages found in Table 15. These figures account for the value of the MHE and CESE vehicles found in the existing inventory for each scenario and the value of the NAVCHAPGRU equipment packages (relevant only for Scenario 5). The value of the existing equipment package inventory and NAVCHAPGRU equipment, where applicable, is calculated using FY 00-equipment package purchase cost. Depreciation of the existing equipment inventory is not considered.

Scenario	Scenario Total MHE and CESE Vehicle Cost	Value of Existing Equipment Package Inventory and NAVCHAPGRU Equipment	Actual MHE and CESE Vehicle Purchase Cost To Overcome Shortfalls
1	$1,293,905	$969,905	$324,000
2	$3,249,448	$2,233,448	$1,016,00
3	$4,447,448	$2,729,448	$1,718,000
4	$10,443,233	$4,694,926	$5,748,307
5	$20,459,210	$7,621,550	$12,837,660

Table 16: Actual Cost of Purchasing MHE and CESE Vehicles to Overcome Equipment Shortages. The value of the existing equipment package inventory and NAVCHAPGRU equipment, where applicable, is calculated using FY 00-equipment package purchase cost. Depreciation of the existing equipment inventory is not considered.

IV. CONCLUSIONS

A. GENERAL

The T-series Advanced Base Functional Components Equipment Package Optimization Model presented in this thesis is an effective model that can be used to determine the minimum required equipment packages given a set of specific T-series personnel-only units. The model quickly and efficiently provides the user with the minimum required number of material handling equipment and CESE vehicles for Freight Terminal Companies, Warehouse Companies, Mobile Mail Companies, NAVCHAPGRU and the reserve NCHBs. Additional types of personnel-only units, equipment packages, cargo types, operating facilities, and cargo handling operations can be included.

The hypothetical operational scenarios presented in this thesis clearly show that the existing MHE and CESE vehicle inventory is not capable of supporting even the one NCHB and one Warehouse Company presented in Scenario 1. Host nation support, the purchase of equipment packages from commercial sources after a conflict begins, or equipment exchanges from other U.S. armed forces or government agencies are all possible methods of equipping the T-series personnel-only units. However, the U.S. Navy should not be completely dependent on commercial companies, foreign nations, or other government agencies to provide critical MHE and CESE vehicle support.

It is not difficult to imagine a situation in which a naval Advanced Logistics Support Site is needed at a secure, but severely damaged, seaport to support other deployed naval forces. Retreating enemy forces may have destroyed all cargo handling equipment and facilities and, consequently, the personnel-only units assigned to operate at the damaged seaport must bring all of their own equipment. If this scenario were to occur today, large amounts of MHE and CESE vehicles would need to be purchased or leased from commercial sources because the existing equipment package inventory cannot meet the operational needs of the personnel-only units.

ABFC program managers recognize the importance of MHE and CESE vehicles and a long-term equipment package acquisition plan does exist. However, the U.S. Navy must decide how to best utilize available funding. Acquiring and storing a complete inventory of MHE and CESE vehicles is not likely because of the expense of purchasing a stock of equipment that in all likelihood will simply sit in a storage lot waiting for a war to occur. Scarce funding might be better spent on weapons system and spare parts. However, a mighty bridge of ships and aircraft linking the United States to a war zone is useless if there is insufficient cargo handling equipment at the terminus of the bridge to unload the ships and aircraft.

B. AREAS FOR ADDITIONAL STUDY

Several modifications to this model are possible. The model could be expanded to include constraints that consider equipment package volume limitations in strategic sealift and airlift assets. It is also possible for the model to serve as a basis for a MHE and CESE vehicle acquisition model with the incorporation of, for example, budget and acquisition constraints. The model could also be modified to permit equipment package substitution when applicable, i.e., if a 4,000 lb.-capacity forklift already exists in the Navy's inventory and can handle the tasking of a 6,000-lb. capacity, DED, forklift then the model should allow the substitution.

Although the GAMS modeling language and the XA solver combination is extremely powerful, these software packages are expensive and not readily available to most Navy personnel. In order to facilitate use of the model by logistics planners, one might investigate the possibility of incorporating the model into an Excel spreadsheet application with the appropriate solver or program add-ins.

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APPENDIX A: DETAILED DESCRIPTION OF SELECTED T-SERIES ABFCS

This appendix is a compilation of information reflecting the new NAVELSF ABFC organization. References 11 and 12 are the sources of this information. The "Component" and "Title" information are provided by Reference 12. All other information is quoted directly from Reference 11. A complete revision of Reference 11 is proposed by OPNAV N412, so the details displayed here are subject to change. Note that specific unit details such as cargo throughput capabilities are deleted from this appendix to enable public distribution.

Component	Title
T22TP	**Supply Support Battalion Freight Terminal Company (FTC)**

1. **Mission Statement**: Provide personnel to function as surface cargo "freight forwarders" to provide commanders with ocean port capability to handle containerized or breakbulk cargo.

2. **Principal Taskings/Capabilities**: A FTC can operate a transshipment and routing facility capable of receiving, documenting, processing, routing and delivering surface breakbulk and containerized cargo including bulk mail. A FTC performs all of the missions outlined below at specified capacities. Required support equipment must be provided by host command/host nation support or one or more of the ABFC packages listed in paragraph 5.

a. Taskings. Provide personnel to:

(1) Sort, prioritize, package, and stage cargo received from ocean port operations.

(2) Prepare Transportation Control and Movement Documents (TCMDs) for surface cargo.

(3) Provide hazardous material shipment certification for surface cargo.

(4) Provide worldwide material documentation tracking support for surface cargo utilizing the Worldwide Port System (WPS) and WPS file servers at Fleet Industrial Supply Center (FISC) Pearl Harbor and Naval Station (NAVSTA) Keflavik via land lines or International Maritime Satellite (INMARSAT).

(5) Process and document receipt and report transshipment of Depot Level Repairables (DLRs) and other retrograde via Streamlined Automated Logistics Transmission System (SALTS) or regular message traffic.

(6) Operate Material Handling Equipment (MHE) and vehicles for local delivery of surface cargo of less than 20 kilometers.

(7) Provide in-transit visibility to all classes of surface cargo for further transportation by land, sea, or air modes (using organic, automated data processing (ADP) equipment).

(8) Provide temporary storage for retrograde and frustrated surface cargo.

(9) As operational tempo permits, FTC personnel can assist in the buildup and breakdown of "463L" air cargo pallets and other palletized material, load and offload palletized cargo including stuffing and unstuffing of containerized cargo, and provide pierside support for cargo operations.

b. Capabilities. Capable of:

(1) Handling up to DELETED pounds of surface cargo and mail per day based on volume of cargo and number of containers received.

(2) Handling up to 50 Depot Level Repairable (DLR) and other retrograde transactions per day based on volume of arrivals.

(3) Performing local surface cargo deliveries not to exceed 20 kilometers in one direction. Number of deliveries per day will vary depending on road conditions, i.e., traffic congestion, dirt and/or potted roads, to and from the terminal area.

3. **Planning Data**:

a. **Basic Assumptions**:

(1) FTC is fundamentally a freight forwarder for breakbulk and containerized cargo. A FTC receives surface cargo from ship discharge by Navy Cargo Handling Battalion (NCHB) units and air cargo from aircraft unloaded by Navy Overseas Air Cargo Terminal (NOACT) units and prepares the cargo for transshipment to fleet and other units.

(2) FTC will operate two twelve-hour shifts on a 24-hour continuous basis.

(3) Line haul trucking of surface cargo farther than 20 kilometers is beyond the normal scope of a FTC and must be provided by host nation or other organic transportation capabilities.

Component	**Title**
T21WP	**Supply Support Battalion Warehouse Company**

1. **Mission Statement**: Provide personnel and administrative equipment for support and coordination of warehousing activities at an ALSS.

2. **Principal Taskings/Capabilities:** One SSB Warehouse Company can perform all of the missions outlined below at specified capacities. Required support equipment, in excess of unit organic equipment, must be provided by host command/host nation support.

a. Taskings. An SSB Warehouse Company as the warehouse support component at an ALSS provides personnel to:

(1) Handle receipt, storage, inventory and issue of material, including refrigerated stores, maintenance of related files, and provision of transportation assets for delivery of material.

(2) Operate assigned Material Handling Equipment (MHE) and Civil Engineering Support Equipment (CESE).

b. Capabilities. DELETED

3. **Planning Data**:

a. **Basic Assumptions:**

(1) SSB Warehouse Company can be deployed as an individual module or as a portion of a complete SSB.

(2) SSB Warehouse Company can operate two-twelve hour shifts on a 24-hour continuous basis.

(3) SSB Warehouse Company can serve as a Ready Supply Store (RSS) 224 account for receiving, stowing, and rapid issue of repair parts and supplies in the custody of the Supply Department Head.

(4) SSB Warehouse Company can provide local delivery support (less than 20 kilometers). Line haul of materials greater than 20 kilometers is beyond the normal scope of an SSB Warehouse Company and must be provided by host command/host nation support or other organic transportation capabilities.

Component	**Title**
T25MP	**Supply Support Battalion Mobile Mail Company (MMC)**

1. **Mission Statement**: Provide personnel for complete, fully functional, forward deployed mail capability through the establishment and operation of a postal facility including the processing and routing of mail and provision of limited financial services, such as stamp and money order sales.

2. **Principal Taskings/Capabilities**: One MMC can perform all of the missions outlined below at specified capacities. Required support equipment must be provided by host command/host nation support.

a. Taskings: Provide personnel to:

(1) Receive, distribute, consolidate, transfer, and dispatch military mail including registered mail.

(2) Prepare daily Mail on Hand (MOH) reports.

(3) Establish mail orderly and directory mail services.

(4) Liaison with serving air and surface mail terminals.

(5) Operate United States Postal Service equipment and calculators.

(6) Set up a Post Office, including cash sales of stamps, envelopes, post cards, parcel processing, and money orders.

(7) Order accountable paper (i.e., stamps, post cards).

b. Capabilities: Capable of:

(1) Handling the distribution of 20,000 pounds of mail per day.
(2) Handling approximately $1,000 of postal sales and $8,000 of money order business per day.

3. **Planning Data:**

a. **Basic Assumptions:**

(1) MMC can provide all mail service currently provided by an established Fleet Mail Center (FMC).

(2) MMCs operate three 8-hour shifts on a 24-hour continuous basis, however, the Post Office sales facility will operate only one 8-hour shift per 24-hour day.

(3) MMCs receive mail from Air Cargo Terminal or Ocean Terminal operations.

(4) A Fleet Post Office address including postal zip code has been assigned to each MMC in accordance with current military postal regulations.

(5) MMCs are familiar with host nation regulations pertaining to the handling of U.S. mail in overseas locations.

Component **Title**
T10NP **NCHB Staff and Surface Company**

Note: This information applies only to the Naval Reserve NCHBs. Reference 11 does not address NAVCHAPGRU.

1. **Mission Statement**: Provide a multi-mission capable unit of "combat stevedores" able to move quickly anywhere in the world to offload ships with containerized or breakbulk cargo.

2. **Principal Taskings/Capabilities:** The taskings and capabilities of a Navy Cargo Handling Battalion (NCHB) are classified in two major operational areas as follows:

a. Maritime Prepositioned Ships (MPS)/ Assault Follow-On Echelon (AFOE) Cargo Handling Operations:

(1) Taskings. Provide command and control, cargo handling and support personnel to:

(a) Discharge/load (pierside or in-stream) all classes of cargo, including hazardous materials (HAZMAT) and ammunition.

(b) Conduct port terminal operations in developed or undeveloped ports. Port terminal operations include discharge/load of containers, breakbulk cargo and vehicles from ships, and operation of shipboard heavy lift pedestal and gantry cranes, mobile hydraulic cranes, yard and stay rigs, and jumbo booms.

(3) Perform heavy lift crane operations in support of MPS squadrons, container ships, fast sealift ships (FSS or T-AKR) and auxiliary crane ships (T-ACS).

b. Expeditionary (Limited) Ocean Terminal Operations:

(1) Taskings. Provide managerial, clerical, and cargo handling personnel to:

(a) Operate a (limited) ocean terminal.

(b) Operate a transit warehouse for processing cargo identified by Transportation Control Numbers (TCNs).

(c) Perform the functions of documenting via Worldwide Port System (WPS), controlling and handling of ship discharging/

loading, pier operations, and delivery of material to/from a transit warehouse close to the pier.

(2) Caution. **Operating a terminal and/or a warehouse will result in a decrease in ship discharge/loading capabilities of a NCHB, since terminal operations divert personnel from cargo handling operations.**

(3) Capabilities. DELETED

3. **Planning Data**:

a. **Basic Assumptions**:

(1) NCHB organization provides a maximum of sixteen Hatch Teams (HTs) comprised of seven skilled cargo handlers. NCHB should be employed solely in ship discharge/loading operations. Maximum cargo throughput for a NCHB decreases as detachments/hatch teams are utilized for ocean terminal and other organic support duties.

(2) Each of the 16 hatch teams require augmentation by seven unskilled personnel (total of 112 augmentees) provided by the supported unit or activity, if projected discharge/loading time frames are to be met. **Without augmentation, productivity may be reduced by up to 50 per cent.**

(3) NCHB teams operate two-twelve hour shifts on a 24-hour continuous basis.

(4) Discharge/loading capabilities are estimated under optimum conditions of weather, sea state, equipment condition, available pier and related facilities (pierside operations), lighterage and related facilities (in-stream operations).

(5) The ship loading rate is approximately 60 percent of the discharge rate except for containers which have the same discharge/load rate.

APPENDIX B: RECOMMENDED EQUIPMENT PACKAGES

The following information is adapted from Reference 7. It has not been formally approved and should not be considered official. The optimization model, however, uses these guidelines when assigning equipment packages to the personnel-only units.

Freight Terminal Company MHE and CESE Vehicle Requirements

	Cargo type			CESE Vehicles	
	20-foot containers	Break-bulk	All-purpose	Personnel movement	Local area cargo delivery
Exisiting facility	4-4,000-lb. capacity, low-profile, rough terrain forklift 1-10,000-lb. capacity, standard forklift 1-16,000-lb. capacity, rough terrain forklift 2-30,000-lb. capacity, rough terrain, container handler (RTCH)	4-6,000-lb. capacity, electric, low-profile forklift 2-10,000-lb. capacity, standard forklift 2-16,000-lb. capacity, rough terrain forklift	4-4,000-lb. capacity, low-profile, rough terrain forklift 4-6,000-lb. capacity, electric, low-profile forklift 2-10,000-lb. capacity, standard forklift 2-16,000-lb. capacity, rough terrain forklift 2-30,000-lb. capacity, rough terrain, container handler (RTCH) 2-Light Cargo Truck (CUCV) 2-Cargo (Stake) Truck 2-Truck Tractor 2-Break-bulk Trailer	1-Light Cargo Truck (CUCV) 1-Cargo (Stake) Truck	2-Light Cargo Truck (CUCV) 2-Cargo (Stake) Truck 2-Truck Tractor 2-Break-bulk Trailer
Expeditionary facility	4-4,000-lb. capacity, low-profile, rough terrain forklift 1-10,000-lb. capacity, rough terrain forklift 1-16,000-lb. capacity, rough terrain forklift 2-30,000-lb. capacity, rough terrain, container handler (RTCH)	4-4,000-lb. capacity, low-profile, rough terrain forklift 2-10,000-lb. capacity, rough terrain forklift 2-16,000-lb. capacity, rough terrain forklift	6-4,000-lb. capacity, low-profile, rough terrain forklift 2-10,000-lb. capacity, rough terrain forklift 2-16,000-lb. capacity, rough terrain forklift 2-30,000-lb. capacity, rough terrain, container handler (RTCH) 2-Light Cargo Truck (CUCV) 2-Cargo (Stake) Truck 2-Truck Tractor 2-Break-bulk Trailer	1-Light Cargo Truck (CUCV) 1-Cargo (Stake) Truck	2-Light Cargo Truck (CUCV) 2-Cargo (Stake) Truck 2-Truck Tractor 2-Break-bulk Trailer

Warehouse Company MHE and CESE Vehicle Requirements

	Cargo type			CESE Vehicles	
	20-foot containers	**Break-bulk**	**All-purpose**	**Personnel movement**	**Local area cargo delivery**
Exisiting facility	4-4,000-lb. capacity, low-profile, rough terrain forklift 1-10,000-lb. capacity, standard forklift 1-16,000-lb. capacity, rough terrain forklift 2-30,000-lb. capacity, rough terrain, container handler (RTCH)	4-6,000-lb. capacity, electric, low-profile forklift 1-10,000-lb. capacity, standard forklift 1-16,000-lb. capacity, rough terrain forklift	4-4,000-lb. capacity, low-profile, rough terrain forklift 4-6,000-lb. capacity, electric, low-profile forklift 1-10,000-lb. capacity, standard forklift 1-16,000-lb. capacity, rough terrain forklift 2-30,000-lb. capacity, rough terrain, container handler (RTCH) 2-Light Cargo Truck (CUCV) 2-Cargo (Stake) Truck	1-Light Cargo Truck (CUCV) 1-Cargo (Stake) Truck	2-Light Cargo Truck (CUCV) 2-Cargo (Stake) Truck
Expeditionary facility	4-4,000-lb. capacity, low-profile, rough terrain forklift 1-10,000-lb. capacity, rough terrain forklift 1-16,000-lb. capacity, rough terrain forklift 2-30,000-lb. capacity, rough terrain, container handler (RTCH)	4-4,000-lb. capacity, low-profile, rough terrain forklift 1-10,000-lb. capacity, rough terrain forklift 1-16,000-lb. capacity, rough terrain forklift	6-4,000-lb. capacity, low-profile, rough terrain forklift 1-10,000-lb. capacity, rough terrain forklift 1-16,000-lb. capacity, rough terrain forklift 2-30,000-lb. capacity, rough terrain, container handler (RTCH) 2-Light Cargo Truck (CUCV) 2-Cargo (Stake) Truck	1-Light Cargo Truck (CUCV) 1-Cargo (Stake) Truck	2-Light Cargo Truck (CUCV) 2-Cargo (Stake) Truck

Mobile Mail Company MHE and CESE Vehicle Requirements

	Cargo type			CESE Vehicles	
	20-foot containers	**Break-bulk**	**All-purpose**	**Personnel movement**	**Local area cargo delivery**
Exisiting facility	3-4,000-lb. capacity, low-profile, rough terrain forklift 2-10,000-lb. capacity, standard forklift 2-16,000-lb. capacity, rough terrain forklift	4-6,000-lb. capacity, electric, low-profile forklift 2-10,000-lb. capacity, standard forklift 2-16,000-lb. capacity, rough terrain forklift	3-4,000-lb. capacity, low-profile, rough terrain forklift 4-6,000-lb. capacity, electric, low-profile forklift 2-10,000-lb. capacity, standard forklift 2-16,000-lb. capacity, rough terrain forklift 2-Light Cargo Truck (CUCV) 2-Cargo (Stake) Truck	1-Light Cargo Truck (CUCV) 1-Cargo (Stake) Truck	2-Light Cargo Truck (CUCV) 2-Cargo (Stake) Truck
Expeditionary facility	3-4,000-lb. capacity, low-profile, rough terrain forklift 2-10,000-lb. capacity, rough terrain forklift 2-16,000-lb. capacity, rough terrain forklift	4-4,000-lb. capacity, low-profile, rough terrain forklift 2-10,000-lb. capacity, rough terrain forklift 2-16,000-lb. capacity, rough terrain forklift	6-4,000-lb. capacity, low-profile, rough terrain forklift 2-10,000-lb. capacity, rough terrain forklift 2-16,000-lb. capacity, rough terrain forklift 2-Light Cargo Truck (CUCV) 2-Cargo (Stake) Truck	1-Light Cargo Truck (CUCV) 1-Cargo (Stake) Truck	2-Light Cargo Truck (CUCV) 2-Cargo (Stake) Truck

Navy Cargo Handling Battalion MHE and CESE Vehicle Requirements

<table>
<tr><th rowspan="2"></th><th colspan="5">Cargo type</th></tr>
<tr><th>Break-bulk</th><th>Break-bulk Ammunition</th><th>20-ft containers</th><th>Vehicles</th><th>All-purpose</th></tr>
<tr><td>Load/unload only (Number required for each ship)</td><td>4-6,000-lb. capacity, electric, low-profile forklift</td><td>4-6,000-lb. capacity, electric, low-profile forklift</td><td>N/A</td><td>N/A</td><td>4-6,000-lb. capacity, electric, low-profile forklift</td></tr>
<tr><td>Pier-clearing and truck loading (Number required for each ship)</td><td>6-6,000-lb. capacity, DED forklift

2-16,000-lb. capacity, rough terrain forklift

[Existing facility only] 2-10,000-lb. capacity, standard forklift

[Expeditionary facility only] 2-10,000-lb. capacity, rough terrain forklift</td><td>6-6,000-lb. capacity, DED forklift</td><td>3-30,000-lb. capacity, rough terrain, container handler (RTCH)</td><td>2-16,000-lb. capacity, rough terrain forklift

[Existing facility only] 2-10,000-lb. capacity, standard forklift

[Expeditionary facility only] 2-10,000-lb. capacity, rough terrain forklift</td><td>6-6,000-lb. capacity, DED forklift

3-30,000-lb. capacity, rough terrain, container handler (RTCH)

2-16,000-lb. capacity, rough terrain forklift

[Existing facility only] 2-10,000-lb. capacity, standard forklift

[Expeditionary facility only] 2-10,000-lb. capacity, rough terrain forklift</td></tr>
<tr><td rowspan="2">Marshal Yard (Number required for each ship)</td><td>4-6,000-lb. capacity, DED forklift

2-16,000-lb. capacity, rough terrain forklift

[Existing facility only] 2-10,000-lb. capacity, standard forklift

[Expeditionary facility only] 2-10,000-lb. capacity, rough terrain forklift</td><td>4-6,000-lb. capacity, DED forklift</td><td>2-30,000-lb. capacity, rough terrain, container handler (RTCH)</td><td>2-16,000-lb. capacity, rough terrain forklift

2-Truck Tractor

2-Lowboy Trailer

[Existing facility only] 2-10,000-lb. capacity, standard forklift

[Expeditionary facility only] 2-10,000-lb. capacity, rough terrain forklift</td><td>2-30,000-lb. capacity, rough terrain, container handler (RTCH)

2-16,000-lb. capacity, rough terrain forklift

2-Truck Tractor

2-Lowboy Trailer

[Existing facility only] 2-10,000-lb. capacity, standard forklift

[Expeditionary facility only] 2-10,000-lb. capacity, rough terrain forklift</td></tr>
<tr><td colspan="5">4-Truck Tractor
4-Break-bulk Trailer
6-Cargo (Stake) Truck</td></tr>
<tr><td>Personnel Movement (Number required for each ship)</td><td colspan="5">2-Light Cargo Truck (CUCV)

2-Cargo (Stake) Truck</td></tr>
</table>

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