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FORWARD POSITIONING AND CONSOLIDATION OF STRATEGIC INVENTORIES

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ABSTRACT

The forward positioning of strategic inventory in the supply chain has an impact on transportation times and is important for sensitive demand profiles. Consolidation of stocks creates pooling effects and minimizes costs. This study analyzes a current military case where forward consolidation of equipment is considered using optimization, and payback periods are calculated for the cost of consolidating inventory at one of six locations. Results indicate that forward positioning and consolidation reduces time and cost, and also creates savings in reverse logistics flows. The study has implications for geographically diverse supply chains such as humanitarian aid and emergency response operations.

INTRODUCTION

The forward placement of inventory in the supply chain in order to save time and cost in "anticipation" of future demand is a strategic decision, which can save delivery time, and also cut transportation costs. *, ** Similarly, the consolidation of inventory creates pooling effects, improves standardization, and can increase control and visibility of key stocks. But how should this type of consolidation be made in an existing logistics network and what sort of metric should be used to measure the efficiency of such a consolidation of strategic inventory? These are questions which managers must understand as they consider forward positioning strategic inventory in the supply chain, especially in the face of uncertain demand with extremely high stockout costs, as exist in wartime, humanitarian aid operations, and other emergency response environments. This decision to forward position inventory in the supply chain may also help support critical maintenance activities necessary to sustain geographically isolated operations or to protect valuable personnel and resources when the unavailability of such inventory poses significant risk and costs.

The U.S. military faces the problem of deciding how and where to pre-position such anticipation inventory in the face of uncertain demand and is also highly sensitive to shipping time and stockout costs. In one particular problem, the U.S. Air Force at Randolph Air Force Base Texas is responsible for the management of a variety of Security Force's' War Readiness Material (WRM) equipment

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packages that are shipped overseas for conflicts. This equipment is divided into several different Unit Tasking Codes (UTCs) and the packages are positioned at twelve Air Force bases in the U.S. As a result of this decentralized storage, inconsistencies in management of the assets often exist and the timeliness of their deployment to overseas locations is often lacking. How and where to best manage this inventory prior to shipment overseas is a question whose answer may provide efficiencies and increased savings for the military. Additionally, the methods used in this study and the similar forward positioning of strategic inventories in the supply chain may hold similar advantages and savings in other logistics operations where delivery time is critical.

LITERATURE REVIEW

Although the elimination of inventory has the potential to achieve significant cost savings, the need for strategic inventory buffers is still an accepted practice to account for variability in demand, even in "lean" supply chains (Womack and Jones, 1996; Christopher and Towill, 2000). The concept of advanced placement of inventory in the supply chain has been considered in a handful of previous studies (Sampson et al., 1985; Teulings and van der Vlist, 2001). More recently, the advanced or forward placement or pre-positioning of such inventories referred to as "floating stock" has been studied by Dekker et al. (2009). They showed that using intermodal rail terminals as pre-positioning points in the supply chain can result in lower inventory costs as well as shorter customer lead times. These results are similarly consistent with expected results of the forward placement or "logistics speculation" of inventory in the supply chain, as discussed by Pagh and Cooper (1998). Related research has also shown that inventory consolidation may create efficiencies and pooling effects (Zinn, Levy and Bowersox, 1989; Evers and Beier, 1998) leading to decreased logistics costs for transshipments (Evers, 1999, and Minner 2003) and as achieved by the square-root rule (Croxton and Zinn, 2005 and Shapiro& Wagner, 2009). These studies all examine the efficiencies and inventory cost savings associated with pooling and consolidation.

This study, however, contains more of a supply chain focus that looks at the impact of transportation, inventory and other relevant costs when making decisions about where to pre-position inventory in the supply chain (Vanteddu et al, 2007, and Dekker et al, 2009). Similarly, studies of service-sensitive demand including deployable military equipment have shown there may be important cost and time savings realized from the consolidation of equipment at one or more locations in the supply chain (Ho and Perl, 1995; Amouzegar, Tripp, and Galway, 2005; and Ghanmi and Shaw, 2008). One internal Air Force study, entitled, "Evaluation of the Recent Deployments of Expeditionary Medical Assets" highlights the advantages of consolidating and forward placing military equipment prior to overseas shipments (AFLMA, 2003). Similarly, a study of humanitarian logistics by Oloruntoba and Gray (2006) looks at the need to decouple the humanitarian supply chain with strategic inventory, but does not attempt to model the decision or to look at the costs of such an effort. Additionally, no known study has looked at the payback period for forward positioning strategic inventory in an existing network while simultaneously consolidating inventory in anticipation of demand.

Given the above studies, the Air Force Institute of Technology conducted an independent analysis on the advantages and disadvantages of Security Forces' equipment consolidation in the U.S. Air Force beginning in late 2008. The problem statement for this study was "What are the costs, benefits and investment payback for consolidating U.S. Air Force Security Forces' inventories at one or more locations in the continental U.S. This paper describes the objectives, methodology, results and conclusions of the study, the theoretical implications and future planned research.

OBJECTIVE

The objective of this study is to evaluate the possible forward positioning and consolidation of security forces' equipment UTCs, at either a single location or dual locations, at or near predetermined Aerial Ports of Embarkation (APOEs) in the continental U.S. where Air Force cargo aircraft depart to overseas locations. A description of these UTCs and the typical number contained in a wartime tasking is provided in Table 1. The study aims to provide insight, including benefits and limitations, regarding whether to move forward with consolidation. A secondary objective of the study is to provide the Air Force with a decision model that can determine the minimum transportation cost of moving Security Force UTCs from the existing twelve bases to the forward consolidation point during a deployment. This will still be useful even if consolidation is not immediately implemented by the Air Force.

TABLE 1
DESCRIPTION OF A TYPICAL UTC WARTIME TASKING

UTC	Number	Description
QFE42	9	Air base defense equipment
QFE4F	4	.50 Caliber team equipment
QFE4S	2	Leadership support equipment
QFEBJ	1	MK-19, grenade launcher
QFEBR	5	Dog team equipment
QFEBX	4	Sniper equipment
QFETS	8	Tactical automation sensor

METHODOLOGY

Data about inventory quantities, transportation costs, and warehousing standards for the UTCs were compiled and collected from the Security Forces squadrons at each of the twelve Air Force Bases for the study from the period February 1st-March 30th, 2009. After the data had been collected and reviewed it was evident that significant variability existed in almost every category. This served to reinforce the Air Force's initial concern that management of this equipment at the separate bases lacked standardization. First, all UTCs should be palletized and ready for shipment though some bases reported that this was not the case. This potentially affects the square footage needed for storing the equipment, as well as the time required to deploy since pallets would need to be obtained and configured before any movement could be initiated. Second, the frequency of and time required to complete equipment inspections and the personnel doing them were noticeably different from base to base. Third, the majority of bases lacked historical data regarding the number and cost of deployments to overseas locations over the last five years. Since an accurate demand (deployment) history was not available, the research team worked with the Air Force research sponsor to develop a standard deployment package to serve as the unit of demand in the study (Table 1). According to U.S. Air Force subject matter experts, this package represents the essential equipment UTCs required to stand up a small to medium size base overseas during a deployment. It is meant to be representative of the equipment necessary to support a base with no additional support from the Army, Navy or the host nation. This requirement would be both situation and location dependent.

Finally, two assumptions had to be made regarding movement of UTCs to different locations in order to evaluate consolidation costs. One being that the transportation costs (Table 2), obtained from the Langley AFB, Virginia and Wright-Patterson AFB, Ohio, Traffic Management Offices, are point-in-time estimates for moving a single aircraft pallet weighing approximately 7500 pounds from origin to the particular destination Air Force Base in the U.S. These costs can vary appreciably depending on when the shipment occurs, potential for a return shipment for the transportation company, and total number of pallets being shipped. Second, in a two location scenario, UTCs have to be allocated as evenly as possible among the two coasts, in a manner that minimizes the total cost of movement.

Optimization Model

In order to find the least cost consolidation point, the transportation costs for a single site location were analyzed using optimization. The problem is a classic transportation problem (Beasley, 1993; Daskin, 1995; Adlakha and Kowalski, 2009) where the cost to move equipment UTCs from the current storage locations at twelve bases to each of the potential consolidation points is determined. The study is also related to facility location problems (Efroymson and Ray, 1966; Akinc and Khumawala, 1977; Geoffrion and Powers, 1995; Drezner 1995), which have been used in previous military studies (Dawson et al. 2007, Overholts et al., 2009) since a minimum cost location is being selected from a number of alternative candidate sites. In this study, the number of consolidation points was restricted to either one single location or two locations (East Coast and West Coast of the U.S). The single-site decision model built to generate solutions for this study was created using linear programming within Microsoft Excel. The optimization model was created to determine which UTCs to ship from each of the current twelve bases to a single APOE consolidation point to minimize cost while tasking enough UTCs to meet the needs of a standard demand for a deployment as determined by the Air Force.

TABLE 2
TRANSPORTATION COSTS OF A SINGLE AIRCRAFT PALLET

	Altus	Colum	Good	Kees	Lack	Laugh	Luke	Max	Rand	Shep	Tynd	Vance
Charleston	1900	2100	1900	1200	1400	1400	2200	1400	1400	1400	1200	1500
Dover	2300	3693	2100	1500	1900	1900	2100	1900	1900	1900	1400	1900
Kelly	800	1200	800	1000	0	700	1300	1200	700	800	1200	900
McGuire	2100	2100	2100	2200	2500	2200	1500	2200	2300	2100	2500	2200
McChord	2500	1900	1400	1100	1400	1400	2100	1400	1400	1400	1400	1600
Travis	2400	2100	1900	1500	2100	1900	1100	2100	2000	1900	2100	1900

Assumptions and Limitations

Several additional assumptions were made in the model in order to determine the correct scope of the problem and to meet time and resource requirements of the study. They are:

- All currently positioned Security Forces' equipment UTCs are properly configured and meet the requirements to be deployed
- Demand for any one UTC is equally important as demand for any other UTC; therefore no weighting or preference was given to one UTC over another in the models created for the study
- Under the current policy, all UTCs deployed overseas from the twelve current bases will also be redeployed to the original bases and a return transportation cost is considered a relevant part of the analysis
- No consumption of UTCs or equipment occurs while deployed, and therefore there is no reduction in transportation costs for the returned assets or any purchasing costs for replacement assets included in the study
- Any manning and support equipment used to inspect or maintain UTCs at the current warehouse locations is available to be transferred to one or more consolidation points
- Current warehousing space will be obtainable from the owning installation of any potential consolidation point, or land will be made available on the site for the construction of a warehouse facility at an existing military installation
- No damage, loss or theft of any assets will occur during transportation, or it is assumed to be covered by the insurance of the carrier
- Transportation costs are fixed and no "time-value-of-money", inflation, or other financial adjustments have been made to the analysis of the cost of future deployments in the study and all costs are given based in 2009 dollars.

This study is limited to seven specific Security Forces' UTCs identified by codes: QFE42, QFE4F, QFE4S, QFEBJ, QFEBR, QFEBX, and QFETS; currently positioned at 12 U.S. Air Forces Bases controlled by the Headquarters at Randolph AFB, Texas. Also, the potential set of consolidation points is limited to a single site (either Charleston, Dover, Kelly, McChord, McGuire, or Travis Air Force Bases) or to two sites with one on the east coast and one on the west coast of the U.S. The two site consolidation problem does not consider Kelly, Texas; therefore, there are six combinations of east-west coast locations (Charleston/McChord, Dover/McChord, McGuire/McChord, Charleston/Travis, Dover/Travis, and McGuire/Travis).

Formulation of Problem

The problem studied in this research can be most closely associated with the traditional transportation problem which has been studied in previous operations management and logistics studies. The formulation of Daskin (1995) is used here and is modified to be a multi-item version of the formulation since there are multiple equipment UTCs in this study. The problem formulation is:

Minimize $$Z = \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{l} c_{ijk} x_{ijk} \quad (1)$$

Subject to:

$$\sum_{j=1}^{n} x_{ijk} \le s_{ik} \quad \text{for i} = 1, 2, \ldots, \text{m and k} = 1, 2, \ldots, l \quad (2)$$

$$\sum_{i=1}^{m} x_{ijk} = d_{jk} \quad \text{for } j = 1, 2, \ldots, \text{n and } k = 1, 2, \ldots, l \quad (3)$$

Where:

Z= total transportation cost

x_{ijk} =number of unit type codes (UTCs) of equipment of type k to be transported from supply location i to demand location j

c_{ijk}=cost to transport a UTC of equipment of type k from supply location i to demand location j

s_{ik} =number of UTCs of equipment of type k available at supply location i
d_{jk}=number of UTCs of equipment of type k demanded at demand location j

In addition to generating separate solutions to the transportation problem in (1) for a typical deployment tasking, this research aims to compare those optimized and therefore most efficient solutions to the cost of consolidating the entire amount of equipment one time at each of the potential consolidation locations. This can be thought of as a payback period as represented by:

$$Y = \text{Minimum of} \left[\frac{C_j}{Z_j} \right] \tag{4}$$

Where:
Y= the preferred consolidation point
Z_j= the minimum cost of potential consolidation point j from (1)
C_j= the cost to consolidate all inventory at potential consolidation point j

Since today's Air Force operations do not currently use optimization tools to select UTCs from the current twelve bases in the U.S. to support a deployment overseas, it is believed that the payback period represents a conservative lower bound for the length of time and number of deployments necessary to achieve a payback period. Future comparison of these payback periods to payback periods based on actual deployment costs would represent a more accurate estimate of the payback period and Air Force managers have started tracking those costs based on the recommendations from this study.

Generation of Solutions

The spreadsheet model used to generate solutions to the problem was built by first entering a cost matrix including the one-way transportation cost for an aircraft pallet from each of the twelve bases to each of the six potential consolidation points, Table 2. Next, a matrix of the current inventory of UTCs held at each base was entered into the model. Then a group of binary 'changing cells' were created to identify a feasible solution that would fill the requirements for a single package. These cells cannot task inventory that is not available in the inventory matrix, and they are multiplied by the cost matrix to identify a total shipping cost for the required pallets to the consolidation point, Figure 1.

In the model, the cost to ship the pallets was doubled to replicate the return of the pallets back to the original twelve bases from the APOE after the overseas deployment. As mentioned, this additional cost assumes no consumption of equipment in the overseas theater and represents a large potential savings not initially recognized by U.S. Air Force planners. The model's actual minimum cost solution is generated by solving the linear program using Excel's Solver Add-in. Finally, user inputs were added to the spreadsheet model to allow the selection of the number of required packages and the desired APOE prior to solving the model. The original Excel worksheet used to identify the current method for shipping UTCs from the twelve bases is referred to as "Baseline" in the Excel spreadsheet, and the consolidation solution for each APOE is saved in the spreadsheet as a separate worksheet. For example, "Baseline Dover", is the minimum cost solution to ship a single package of UTCs to Dover AFB from the twelve bases and then return the equipment to its origin following deployment.

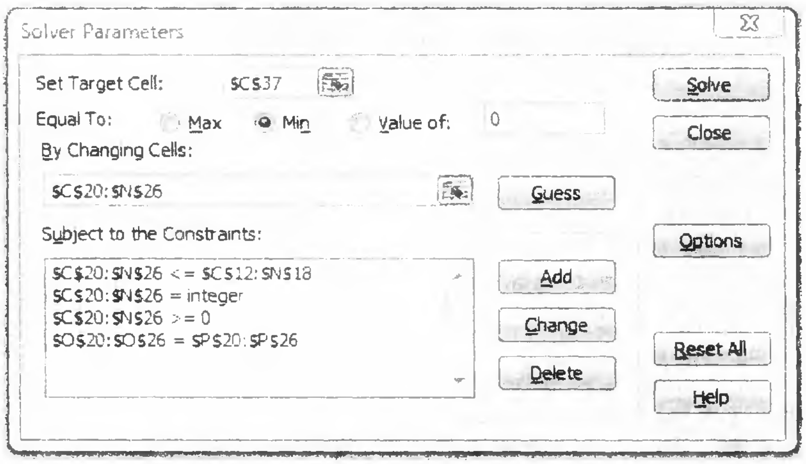
In addition to the baseline solutions, the model was also solved for the consolidation aspect of the study, where the model was used to determine the one-time cost to ship the entire inventory to each of the APOE locations. A separate consolidation worksheet was created for each solution. To create the two-site spreadsheet model, several

FIGURE 1
OPTIMIZATION SPREADSHEET AND SOLVER SETTINGS

	Altus	Columbus	Goodfellow	Keesler	Lackland	Laughlin	Luke	Maxwell	Randolph	Sheppard	Tyndall	Vance		
Transportation cost matrix														
Charleston	1900	2100	1900	1200	1400	1400	2200	1400	1400	1400	1200	1500		
Dover	2300	3693	2100	1500	1900	1900	2100	1900	1900	1900	1400	1900		
Kelly	800	1200	800	1000	0	700	1300	1200	700	800	1200	900		
McChord	2100	2100	2100	2200	2500	2200	1500	2200	2300	2100	2500	2200		
McGuire	2500	1900	1400	1100	1400	1400	2100	1400	1400	1400	1400	1600		
Travis	2400	2100	1900	1500	2100	1900	1100	2100	2000	1900	2100	1900		
													Total	
QFE42	3	0	2	4	10	0	3	3	3	3	3	0	34	
QFE4F	2	0	0	0	0	0	0	0	0	0	0	2	4	
QFE4S	1	1	0	2	3	1	1	2	0	0	1	2	14	
QFEBJ	0	0	0	0	0	0	0	1	0	0	0	0	1	
QFEBR	4	4	4	5	12	4	6	5	4	4	4	2	58	
QFEBX	1	1	1	1	1	1	1	0	1	1	0	1	10	
QFETS	1	0	1	1	5	1	2	1	2	1	1	0	16	
													Total	Total Req
QFE42	0	0	0	4	0	0	0	2	0	0	3	0	9	9
QFE4F	2	0	0	0	0	0	0	0	0	0	0	2	4	4
QFE4S	0	0	0	2	0	0	0	0	0	0	1	0	3	3
QFEBJ	0	0	0	0	0	0	0	1	0	0	0	0	1	1
QFEBR	0	0	0	5	0	0	0	0	0	0	0	0	5	5
QFEBX	0	0	0	1	1	1	0	0	0	1	0	0	4	4
QFETS	0	0	0	1	5	1	0	0	0	0	1	0	8	8
Total Pallets	2	0	0	13	6	2	0	3	0	1	5	2	34	
Cost per pallet to seleted APOE	$ 1,900.00	$ 2,100.00	$ 1,900.00	$ 1,200.00	$ 1,400.00	$ 1,400.00	$ 2,200.00	$ 1,400.00	$ 1,400.00	$ 1,400.00	$ 1,200.00	$ 1,500.00		
Total Cost from each location	$ 3,800.00	$ -	$	$ 15,600.00	$ 8,400.00	$ 2,800.00	$ -	$ 4,200.00	$ -	$ 1,400.00	$ 6,000.00	$ 3,000.00		

Selected APOE	Charleston
#deployments (standard packages)	1
time frame (years)	1
Total Outbound cost	$ 45,200.00
Total Backhaul cost	$ 45,200.00

[redacted]



modifications had to be made to the original spreadsheet model. First, two sets of 'changing cells', one for the east coast location and one for the west coast location, had to be created. Then the model's constraints had to be modified to ensure that the total inventory being tasked to the east and west coast from each of the twelve bases does not exceed the total inventory located at the base. The baseline solutions for the model were solved similarly to the single-site model with one standard package tasked to be shipped to both the east and west coast.

However, a problem was encountered and for two of the UTCs (QFE4F and QFEBJ) there was initially not enough inventory to complete two standard packages. Therefore, an assumption was made to give the east coast tasking priority and a full package was filled for the east coast and a reduced package, without those two UTCs, was filled for the west coast. For allocating inventory to either the east coast or west coast for consolidation purposes, approximately half the inventory was sent to each coast with minimum transportation distance being used as the basic rule for sending inventory from its current base to one of the two new consolidation points. Using these methods, a baseline and a consolidation solution were generated by Excel Solver for each feasible combination, and a payback analysis was conducted using equation (1) and (4) in the formulation section.

RESULTS AND ANALYSIS

The transportation cost was calculated for assembling one standard deployment package at each of the six consolidation locations by shipping the selected UTCs from the twelve Air Force bases using optimization. This cost was then doubled since any UTC shipped from a base would have to be returned to that base upon completion of the overseas deployment. This represents the state of current operations where the UTCs are stored at each base, although the Excel model used in the study optimizes which bases the UTCs should come from in order to minimize cost, which is not part of the current operating procedure. Table 3 shows the minimum transportation cost to ship a single package of UTCs to the six potential consolidation points.

In Table 3, it can be observed that each location has a cost for shipping a single package in the range of $90K-$129K with the exception of Kelly, Texas. This is due to the fact that 23 out of the 34 pallets required for a single package are already positioned at nearby Lackland AFB, Texas; therefore it is dramatically less expensive to ship a single package to Kelly at this time. This point will be discussed further in later sections. The cost for a one-time move of the entire inventory of the Security Forces' UTCs located at the twelve bases to each of the consolidation locations was also calculated. This was done in the model by multiplying the shipping cost from the base to the consolidation point by the total number of pallets being transported from each base and then summing the results. This cost represents the one-time transportation cost to consolidate the entire current inventory at a single location. The results for all six potential consolidation points are listed in Table 4.

TABLE 3
SINGLE SITE PACKAGE SHIPPING COST

Charleston	$90,400.00
Dover	$114,600.00
Kelly	$17,800.00
McChord	$129,600.00
McGuire	$92,600.00
Travis	$106,400.00

In Table 4, it can be seen that the cost to consolidate the equipment at each of the six sites ranges from approximately $212K-$302K with the exception of Kelly which is again dramatically less due to the 31 pallets of equipment already located at nearby Lackland AFB. In general, it can be seen that the cost to consolidate at the other five bases is about double what it currently costs to ship a single package out and back to the APOE from the twelve bases. To understand this relationship further, the results were further compared by determining the payback period for each consolidation site. The cost of a one-time consolidation could be paid for over a period of time depending on the number of overseas deployments and tasked UTCs that are expected by the Air Force in the near future.

To understand this relationship, a "payback period" was calculated to understand how long it would take such a consolidation to pay for itself. For example, as shown in Table 3, the current cost to ship a single package of UTCs to Charleston and back is $90,400. The cost to do a one-time consolidation of all of the UTCs at Charleston costs $212,700 as shown in Table 4. Therefore, if consolidation occurs at Charleston, $90,400 in transportation costs could be saved each time a package is tasked for overseas shipment; and, the consolidation would pay for itself after 2.3 packages ($212,700/$90,400) are shipped

TABLE 4
SINGLE SITE ONE TIME MOVE COST

Charleston	$212,700.00
Dover	$270,358.00
Kelly	$103,700.00
McChord	$301,800.00
McGuire	$214,600.00
Travis	$262,000.00

TABLE 5
SINGLE SITE PAYBACK PERIOD

	Forward Site Transport Savings	Consolidation Cost	Payback Period (# packages)
Charleston	$90,400.00	$212,700.00	2.35
Dover	$114,600.00	$270,358.00	2.36
Kelly	$17,800.00	$103,700.00	5.83
McChord	$129,600.00	$301,800.00	2.33
McGuire	$92,600.00	$214,600.00	2.32
Travis	$106,400.00	$262,000.00	2.46

overseas. Therefore, if the Air Force expects to deploy a single package for each of the next three years, then the consolidation will pay for itself, however, since the demand for UTCs is relatively uncertain the exact payback period will only be measured by the number of packages. The payback period for each single base is calculated in Table 5.

From Table 5, it can be seen that for the current East and West Coast APOEs, an expected payback period of 2.32-2.46 packages can be expected. The results are significantly different for Kelly, since a large number of pallets are already located at nearby Lackland AFB. Assuming Kelly could be the APOE for all outbound shipments, the payback period for consolidation is 5.83 shipments. However, the initial consolidation cost for Kelly would be less than half that of any other potential location, and it is the only location in the central U.S. making it a more central location if a single consolidation location is selected.

Two-Site Consolidation

The cost for the two-site consolidation option was also calculated for assembling one standard deployment package at each of the two consolidation locations by shipping the necessary UTCs from the twelve bases. Again, this cost was doubled to account for the initial deployment and return from the consolidation locations. As previously stated, two complete packages cannot be created due to a current lack of equipment, so priority was given to the east coast and a partial package was assembled for the west coast. A modified version of the linear programming optimization model used for the single-site option was used to determine which UTCs to ship in order to minimize the transportation cost while obtaining all necessary UTCs to create a standard package at each consolidation location (minus shortages). The minimum cost for assembling one standard package at each of the two consolidation points is shown in Table 6.

TABLE 6
TWO SITE PACKAGE SHIPPING COST

	McChord	Travis
Charleston	$198,600.00	$179,400.00
Dover	$222,800.00	$206,800.00
McGuire	$200,800.00	$183,200.00

The cost for a one-time move of all UTCs to the pair of consolidation locations was also calculated. The same Excel linear programming model used for the two-site baseline was used for this, with the requirement that all UTCs be allocated evenly between the two locations by distance and that every UTC be sent to one of the two consolidation locations. The minimum cost for these one-time moves is shown in Table 7.

TABLE 7
TWO SITE ONE TIME MOVE COST

	McChord	Travis
Charleston	$229,500.00	$215,100.00
Dover	$259,200.00	$246,900.00
McGuire	$231,400.00	$218,300.00

Similar to the single-site analysis, a payback period for consolidation was calculated, as seen in Table 8.

Table 8 shows that shipping two packages (one east and one west) is almost the cost of consolidating the entire inventory of equipment at two consolidation sites. This payback period calculation is not equivalent to the single-site payback period calculation in that it compares the cost to ship two packages versus the cost to consolidate the inventory.

TABLE 8
TWO SITE PAYBACK PERIOD

	Forward Site Transport Savings	Consolidation Cost	Payback Period (# of two-package taskings)
Charleston-McChord	$198,600.00	$229,500.00	1.16
Dover-McChord	$ 222,800.00	$259,200.00	1.16
McGuire-McChord	$200,800.00	$231,400.00	1.15
Charleston-Travis	$179,400.00	$215,100.00	1.20
Dover-Travis	$206,800.00	$246,900.00	1.19
McGuire-Travis	$183,200.00	$218,300.00	1.19

Summary of Transportation Cost Findings

Costs to consolidate the security equipment at either one or two consolidation sites are not excessive in comparison to the one-time cost to ship a standard package. Overall, payback periods for the initial consolidation cost of all inventory, represent only a small number of deployments. With the current pace of military deployments, it is believed that such consolidation would pay for itself in only a few years. Also, the advantage of the reduction in transportation costs and relatively fast payback periods offer a significant advantage when compared to the potential tradeoffs with inventory and warehousing costs for the Air Force. First, it is expected that significant warehousing cost increases will not be expected since each potential consolidation point already houses military installations with available warehousing space. Also, any additional warehousing costs at the consolidation point would be offset by decreases in warehousing costs at the original twelve locations. Additionally inventory holding costs might also be reduced with expected efficiencies gained by inventory reduction from pooling effects. Overall, it is believed the potential reduction in transportation costs gained through forward positioning and consolidation offers a significant reduction in Air Force logistics costs as a whole.

Other Benefits and Issues

In addition to the transportation cost savings discussed above, there are several additional benefits to consolidating equipment. While some of these expected benefits are difficult to quantify, they can be of significant importance in the management and readiness of the equipment. The first benefit is the potential reduction in the manpower and number of hours required to inspect, maintain, and prepare the equipment for deployment. The twelve bases involved in this study report a total of 1248 hours per month required to inspect, maintain, and prepare the UTCs. Based on the estimates provided by the Air Force, at a consolidated location these same tasks could be accomplished in 402 hours, which translates into a cost savings of $416,000 per year. This savings alone would pay for consolidation at any of the potential locations. The second benefit in the consolidation options is the reaction time involved in deployment of the UTCs to overseas conflict locations. Currently, any UTC tasked requires a minimum of three days transit time, with an average of four, from the origin base to the APOE after notification of a tasking. When consolidated, this transit time is most likely reduced to half a day or less, as the equipment is already in a warehouse nearby to the APOE runway. Upon return from a deployment, the equipment is in transit the same four days from the APOE back to the base of origin, delaying reconstitution of the UTC and increasing transportation cost. Consolidation would reduce this time to .5 days as well, for a total savings of approximately 7 days. In addition, reduction in lead time variation also leads to reduced safety stock needed at the consolidation point, further reducing costs (Evers and Beier, 1998).

The third benefit in consolidation is standardization, both in inspection and in storage of equipment. As noted earlier, the twelve bases currently used report a wide range of inconsistency in equipment inspection. The primary purpose, and underlying assumption, of standard UTC packages is that each UTC will be the same regardless of origins. This is essential in the Air Force tasking process where equipment from one base may be matched with personnel from another at the overseas destination. The same assumption must be made for the readiness and inspection of the equipment at its storage location. In this case, inspections were reported as 'quarterly', 'monthly', 'random', and 'annual', with bases reporting different standards for the same UTC. Under consolidation, the inspection, maintenance, and readiness of the UTCs could be standardized, more closely monitored and managed with fewer personnel. Finally, the fourth benefit with consolidation is that there would be a greater ability to manage the total inventory for planning purposes. For example, given the current standard package requirement, only one complete package could be fielded due to the bottleneck of having only one QFEBJ type UTC. Also, while there are only enough QFE4Fs to field one package, there are enough QFEBRs to complete eleven packages. By managing the inventory at one or two consolidation points, inventory requirements could be set at a package level. Excess inventory of one type could be eliminated and others in short supply could be augmented, thus minimizing the total inventory held and increasing the number of available packages.

CONCLUSIONS, IMPLICATIONS AND FUTURE RESEARCH

The forward positioning of strategic inventory in the supply chain has an impact on transportation times and is important for sensitive demand profiles. Consolidation of stocks has the potential to create pooling effects and minimize costs. This study analyzes the forward consolidation of security equipment and uses optimization and payback periods to analyze the cost of consolidating inventory at one of six forward locations. Although there is great uncertainty about where military operations will occur overseas, there is very little uncertainty in how equipment will be shipped in the earliest part of the supply chain. This provides the opportunity to consolidate and create what Christopher and Towill (2000) call a de-coupling point. Results of the study further indicate that forward positioning and consolidation reduces time and cost, and also creates savings in reverse logistics flows from the consolidation point back to their origin bases. Essentially the initial steps and final steps of the supply chain are shortened.

Managerial Implications

The study has implications for geographically diverse supply chains such as humanitarian aid and emergency response operations (Oloruntoba and Gray, 2006). For example, similar forward positioning and consolidation of emergency supplies for earthquakes, hurricanes and other natural disasters has the potential for similar transportation cost savings and cycle time reductions. Similar to military operations, these operations also have sensitive demand profiles and heavy stockout costs which could include the loss of many lives if the supply chain is not responsive enough. Logistics planners should consider the techniques used here to possibly consolidate and forward position critical supplies needed for humanitarian relief efforts. Additionally, stocks needed in the supply chains of the medical industry for critical medical supplies may also have high uncertainty in terms of the demand locations where they will be needed. Forward consolidation of these stocks at shipping hubs has the potential to reduce lead times and minimize transportation costs. Similar uncertainties in rapidly changing retail goods and emergency services supply chains might also benefit greatly from consolidation and forward positioning of key stocks up to the natural decoupling points.

Based on the findings of this study, the Air Force will be able to implement the optimization model created during this study to determine the current sourcing of equipment UTCs for overseas deployments. This model will provide the minimum cost selection of UTCs to fulfill a particular tasking and can be adjusted if changes occur in shipping costs, number of UTCs available or required, or the number of standard packages required. Further, it is the recommendation of the study that the Air Force implement consolidation of security force UTCs at one or more of the consolidation locations. While there is an upfront cost associated with moving all the UTCs to a consolidation point(s), the payback period for transportation cost alone is less than three deployments in almost every case. When taking more of a total supply chain approach and considering manpower savings, reductions in shipping time, pooling effects and other benefits of consolidation, the payback is almost negligible.

Future Research

Future research should be conducted in several areas including the consequences of a natural disaster or terrorist strike at the consolidation point, since there is some risk associated with "putting all your eggs in one basket". When combining the theoretical implications of this research with those of supply chain risk studies (Manuj and Mentzer, 2008) it is thought that there may be a correct balance between forward positioning to minimize costs and cycle times, and ensuring the right amount of dispersion to avoid supply chain disruptions and costs associated with highly uncertain demand. Although in this study the reduction of transportation costs did not result in increased warehousing costs, similar research should be careful to analyze cost tradeoffs from consolidation and identify any diseconomies of scale from making consolidation points too large. Currently, it is believed the benefits achieved by consolidation of Air Force security equipment outweigh the potential risks; however, future research should also concentrate on the site specific details of each potential location such as the availability of resources, adequacy of security measures, and specific cargo handling and loading processes.

Additionally the results of this study have led the Air Force to launch a much larger study which includes the potential consolidation of all security forces equipment UTCs at over 70 installations across the U.S. The study will also analyze the potential for transshipment of stocks in transit in order to further reduce cost, and the reconfiguration of several UTCs thought to be obsolete. Finally, the actual planned consolidation of equipment will offer the potential to study post-implementation results in order to ensure forward positioning and consolidation have achieved the desired results.

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