SEALIFT OR AIRLIFT FOR GLOBAL MOBILITY?

Tyler T. Prevett, Joint Operational Support Airlift Center, USTRANSCOM,
Scott AFB, IL, 62225, tyler.prevett@ustranscom.mil, 618-220-1695

Bradley E. Anderson, Air Force Institute of Technology, 2950 Hobson Way, Wright-Patterson
AFB, OH, bradley.anderson@afit.edu, 937-255-3636 x4538

ABSTRACT

This research builds a decision model to choose between sealift and airlift for global mobility. Data is gathered through a literature review and through open ended interviews with experts in the mobility field. These factors are combined to form an Analytic Network Process (ANP) model of the strategic mobility decision.

Keywords: sealift, airlift, ANP, modal choice, global mobility

SEALIFT OR AIRLIFT FOR GLOBAL MOBILITY?

In a press conference, the Air Force Chief of Staff, and the Secretary of the Air Force emphasized that the Air Force is on the road to transform into a more “lean, lethal and agile force”, and that this includes using better business management and lean tools to “husband resources” (Wynne, 2005:1). Later in his introduction he emphasized that the many advancements over the past 15 years allow the military the chance to reexamine their processes to extract more efficiency and effectiveness out of the current force structure. Effectiveness and efficiency have many aspects, but for the purpose of the present research, effectiveness will mean getting the required equipment to its destination at the required time. Efficiency will mean maximizing the use of airlift and sealift assets in a manner that results in minimum total cost. Airlift is an extremely limited resource for transportation, and it’s extremely expensive when compared to sealift. Overall transportation effectiveness is intricately related to using limited assets in the most efficient manner possible. By using transportation efficiency, we increase the effectiveness of transportation resources. Choosing sealift or airlift for global transportation requirements is a complex decision. Generally, sealift is slower, but more cost-effective, while airlift is faster and more expensive. There comes a point in our transportation system when the decision is made to move something by air or sea, and this decision is influenced not only by technical limitations, but also by human sentiments. This seemingly simple decision is complicated by a myriad of influential factors. How is a decision made for which mode is used for strategic lift? What are the critical factors to making this decision? What are the complicating factors, and how can they be addressed?

Most of the attention to our transportation system has focused on measurable metrics that address such factors as how much something costs to move, whether the cargo arrived on time, the volume of cargo moved, or the number if items moved. Optimizing and comparing these metrics is apropos, but neglects to consider the elements of the decision that aren’t dependent on numbers. Some examples of these ‘human’ factors might be: How much is pressure from public opinion influencing the choice? How critical is the required material to troop survival? How important is it that a political message of commitment is relayed to coalition partners? There has yet to be a systematic examination of the human sentiments in the military strategic transportation arena. These human sentiments influence the decision together with the systematic limitations and advantages of each mode. This research attempts to formulate a model that combines the human and technical factors together in a single decision model for choosing sealift or airlift for global mobility requirements.

SCOPE OF RESEARCH

This study will look at the strategic modality decision from an integrated qualitative and quantitative perspective in order to identify the factors that must be considered by members of the United States Transportation Command (USTRANSCOM) as a strategic lift provider, and by customers of the strategic lift system. Service providers are defined as the members of USTRANSCOM that act in a supporting relationship to arrange the strategic transportation for combatant commanders. Customers of this transportation service include individuals who request movement of materials on behalf of the combatant commander and the troops who ultimately require the material. Strategic lift mode choice is a decision of how to move cargo from the United States to overseas locations. The scope will be limited to strategic moves of materials for initial deployment and long term sustainment, which could include contingency operations, humanitarian relief efforts, or any other movement of material in support of vital national interests. In each case, material is delivered to a particular geographic region under the command of a single combatant commander.

TRANSPORTATION OPTIONS

It is critical that the military evaluate ways to become more efficient at strategic logistics. Rolled into this requirement is a need to understand the current options for mobility. There are 5 major modes of transportation currently employed for transportation: airlift, sealift, rail, motor carrier, and pipeline (Coyle, Bardi, and Novack, 2006). Moving material from the U.S. to overseas locations requires a choice between sealift and airlift for the strategic transoceanic leg. The other modes of transportation can be used before and after the strategic leg, but practicality limits their consideration to continental movements.

Strategic lift provided by USTRANSCOM is seen as a triad of capabilities (JP 4-01.2, 2005). Together, sealift, airlift and prepositioning of materials close to anticipated areas of conflict makeup what is known doctrinally as the “Strategic Triad” as seen in the figure below.

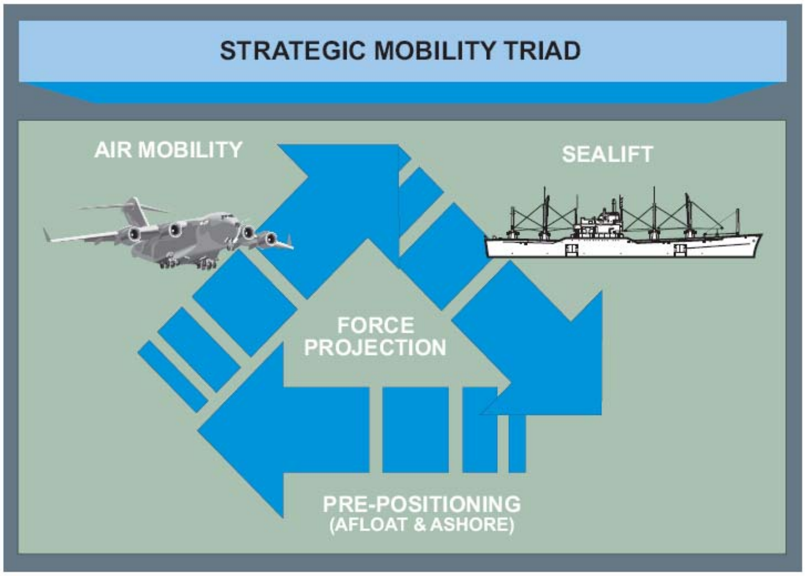

FIGURE 1. THE STRATEGIC TRIAD (JP 4-01.2, 2005)

This triad serves as the tool for U.S. to achieve its responsibility to react quickly to conflict anywhere in the world. Within this concept, strategic mobility is the result of all 3 methods of delivery working together to accomplish the overall strategic mobility requirements. Air Mobility Command (AMC) is responsible to USTRANSCOM to provide airlift, while the Military Sealift Command (MSC) is responsible for providing strategic sealift. Prepositioning of materials close to an area of anticipated conflict can occur via either method, but normally consists of ships moving cargo to predetermine afloat or ashore locations. The next few sections will describe and examine the capabilities and characteristics of airlift and sealift.

MODE CHOICE COMPARISONS

The characteristics, capabilities, and platforms available for strategic movements can be compared along performance criteria to get a basic understanding of their relative merits. The criteria listed in this section are prescribed by doctrine for combatant commanders and USTRANSCOM service providers to consider when making a mode choice for strategic transportation.

Capacity

Individual ships can carry a tremendous amount of cargo. On a comparative basis, a single ship can carry 100-300 times as much cargo as the biggest airlift transport. This also translates to the overall delivery of cargo in any major operation; sealift accounts for 95% of the materials to arrive at the destination of a major conflict (Matthews and Holt, 2003). The decision to use airlift instead of sealift is of even greater importance because airlift capacity is less than required. Current airlift capacity amounts to only about 44.7 MTMs per day - a shortfall of 9.8 MTM from the 54.4 MTMs required by the National Military Strategy (Bartlett, 2004). The current logistics requirements in Operations Iraqi Freedom and Enduring Freedom are second only to the Berlin Airlift, and future lift requirements place great emphasis on using airlift efficiently (Bartlett, 2004). The following table gives a synopsis of the major strategic transportation modes and their relative capacities.

SEALIFT / AIRLIFT LOAD EQUIVALENCY (planning capacity in short tons)

	AVG TOTAL SQFT	AVG SQFT (* Stow Factor)	S-tons	# C-5 equivalent		# C-17 equivalent	
Planning Factors:		**75%**		61	S-tons per C-5	45	S-tons per C-17
Fast Sealift Ship	202,627	151,970	7,599	125		169	
LMSR (surge)	360,108	270,081	13,504	221		300	
LMSR (new bld)	387,622	290,717	14,536	238		323	
RRF RO/ROs	157,367	118,025	5,901	97		131	

TABLE 1. SEALIFT/AIRLIFT PLANNED LOAD EQUIVALENCY (USTRANSCOM, 2005)

The planning factor in this table is a limiting factor which transportation providers typically use when determining how much cargo can be loaded on the associated platform. For instance, planners only plan to use 75% of the carrying capacity of ships, while airlift planners only plan on using 61 and 45 S-Tons of capacity on C-5s and C-17s respectively. The reason for this limitation is that cargo oddities, shape, volume, density, etc. typically limit the amount of cargo that can physically fit on the platform. Table 3 shows the relative amount of strategic lift aircraft it would take to match the carrying capacity of various ships after these planning factors have been taken into account.

Speed

Another striking difference between the modalities is speed. A FSS is has the highest maintainable speed of sealift, and can achieve speeds of up to 27 knots (30 MPH) over the duration of the journey (JP 4-01 2003). In contrast, C-17 and C-5 cruising speeds are in excess of 450 knots (500 MPH) (AMC, 2006). It's a broad generalization that airlift is faster for cargo transit. In fact, Coyle and others (2006:167) point out that overall transit time for cargo can also be dependant on the total distance traveled. In the shorter distances of movement, other modes of transportation such as trucking can be faster than airlift due to accessibility, transloading, volume of cargo moved, and handling issues. This tradeoff is also apparent in the airlift vs. sealift comparison. In 2003, the United States Government Accountability Office (GAO) published a report to congress considering the strategic deployment of army Stryker brigades (GAO-03-801, 2003). This report stated that airlift resources were not sufficient to achieve the required 4-day delivery of a Stryker brigade, and that a combination of airlift and sealift would be necessary to achieve the fastest delivery times. Depending on the location of pick-up and the location of delivery, the GAO actually forecast that strategic sealift could be *faster* than airlift (GAO-03-801, 2003). Sealift, when prepositioned close to the theater, can result in a relative advantage with respect to speed due to the huge volume of material it can deliver in a relatively short time.

Cost

Another area of sealift/airlift comparison that merits examination is cost. Computing the cost of transportation is a complicated process. The cost structure was presented in the previous sections on airlift and sealift, and general notion is that airlift is much more expensive than sealift for strategic movements (CBO, 1997). Actual rates can be computed with several references made available by USTRANSCOM (USTC/J8, 2006). In both cases, cost can be expressed in dollars per ton/mile – that is the cost to transport one ton of cargo one mile. Another dimension of the cost of airlift vs. sealift can be made in terms of cost structure. Airlift cost is highly variable and very dependent on how much cargo is moved, how far it is traveling, and what infrastructure is required to support the airlift. On the other hand, the costs associated with sealift are much more fixed. This means that the weight of the cargo has little impact on the overall cost of the ship making the strategic movement. The majority of the relative difference in cost is attributable to fuel costs, and somewhat to labor costs (Coyle and others, 2006). When comparing total expenditures, airlift accounts for almost 50% of the Transportation Working Capital Fund expenditures for transportation services (Fleming, 2005), while only delivering on the order of 5% of total transportation capacity as noted in the previous section.

Security

Yet a third area of concern and comparison is security. This is of particular interest in military strategic mobility due to the criticality of the cargo. Pilferage or loss of personnel and cargo can literally result in risking the entire supported military operation. In the enroute structure, shipping is highly vulnerable to attack from other surface-born vessels (JP 04-01.2, 2005). In addition, a large number of sealift vessels gathered to load and deploy a significant force "is an obvious indication that a convoy or major operation is being planned" (JP 04-01.2, 2005) and can cue adversaries to take action. Enroute airlift tends to be out of reach as a potential target, and will depart and arrive in terminals that are appropriately protected. In current operations in Iraq, there is great concern over the safety of truck convoys, and airlift is used to mitigate the danger of transporting people and equipment over dangerous roads. In fact, one metric tracked the Defense Logistics Agency (DLA) is the number of dangerous truck convoys averted by airlifting the cargo and personnel in Operation Iraqi Freedom.

Accessibility

A critical difference between sealift and airlift is their relative accessibility to deliver to the point of effect. Sealift is bound by the confines of deep berth ports and waterways, whereas airlift can transcend geography and deliver directly to the required location, or extremely close to required location. While airlift is unencumbered by the topography of land, it must consider the sovereign rights of any landmass it seeks to fly over, while sea lanes are recognized international territory. In most cases, both modes of transportation require some form of infrastructure at the departure end, and at the receiving end. The relatively recent development of Contingency Response Groups (CRG) and Logistics Over-the-Shore (LOTS) (JP 04-01.2, 2005) capabilities are characteristic of efforts to allow airlift and sealift to access areas without existing infrastructure.

SUMMARY OF ADVANTAGES

Military doctrine considers airlift advantages based on the capability they provide to the combatant commanders to create desired effects in their operations. The primary advantage of airlift is speed, and other advantages include flexibility, range, responsiveness, capability, accessibility, and reliability (JP 4-01.1, 1996).

The disadvantages are easily identifiable as well. Airlift is the most expensive mode of transportation, and compared to sealift, is extremely limited in the capacity it can deliver. The expense of air transportation makes it critical that users of this mode evaluate their choice in terms of cost and the ability to get the required amount of freight delivered at the required time. As stated previously, military users are much more focused on the time/capacity function of airlift rather than the cost. The following figure summarizes the advantages and disadvantages of airlift and sealift.

ADVANTAGES AND DISADVANTAGES OF ELEMENTS OF THE STRATEGIC MOBILITY TRIAD

ADVANTAGES	DISADVANTAGES
AIR MOBILITY	
• Rapid deployment of combat and supporting units • Flexibility of employment • Direct delivery capability to the warfighter, i.e. "factory to foxhole" without transload requirements	• Limited delivery capacity • Air lane dependent • May require overflight rights • Dependent on availability of airfields • Requires cooperation of foreign governments
PRE-POSITIONING (Ashore)	
• Rapid deployment of heavy combat and supporting units • Reduces movements required for deployment and redeployment • Reduces deployment timeline	• Lacks flexibility • Airlift dependent • Fixed sites may be easily targeted for attack • Requires cooperation of foreign governments • Finite capability
PRE-POSITIONING (Afloat)	
• Rapid deployment of heavy combat and supporting units • Reduces movements required for deployment and redeployment • Flexibility of employment • Reduces deployment timeline	• Dependent upon suitability of port facilities and debarkation locations • Sea lane dependent • Airlift dependent
SEALIFT	
• Sustained delivery of heavy combat and supporting units and their sustainment • Flexibility of employment	• Seaport dependent (less Afloat Pre-positioning Force) • Speed • Sea lane dependent

FIGURE 2. ADV/DISAD OF THE STRATEGIC TRIAD (JP 04-01.2, 2005)

The choice between airlift and sealift in civil organizations is primarily based on deciding what delivery time is acceptable for a given cost. However, cost is less important to military transportation customers due to budgeting, price structure, and perceived criticality of the cargo. Price insensitivity serves to make the decision even more complex. In the absence of an important cost consideration and an effective priority system, the modal decision becomes very fluid and depends on the multitude of other factors that influence the decision.

METHODOLOGY

ANP was chosen as a decision model for the present research because of its ability to include qualitative and quantitative inputs to a decision, as well as their interaction with each other. ANP represents an opportunity to evaluate the global mobility decision in an appropriate framework which considers multiple alternatives, criteria, and interactions among elements. While the mathematical formulation of the model can prove to be quite complex, easy-to-use *SuperDecisions 1.6.0* software will be utilized for this research, where the pairwise judgments and synthesis are performed via graphical user interface (Super Decisions, 2006). The software interface is presented in this section along with describing the 3 phases of ANP modeling. There are 3 basic steps to modeling a decision using AHP: decomposition, comparative judgment, and synthesis (Saaty, 1990; Büyükyazici and Sucu, 2003).

Decomposition

Decomposition of the decision problem is very similar between ANP and AHP. Since ANP breaks down the traditional one-way influence of the hierarchy, it is graphically represented differently as seen in the following figure as adapted from Büyükyazici and Sucu (2003).

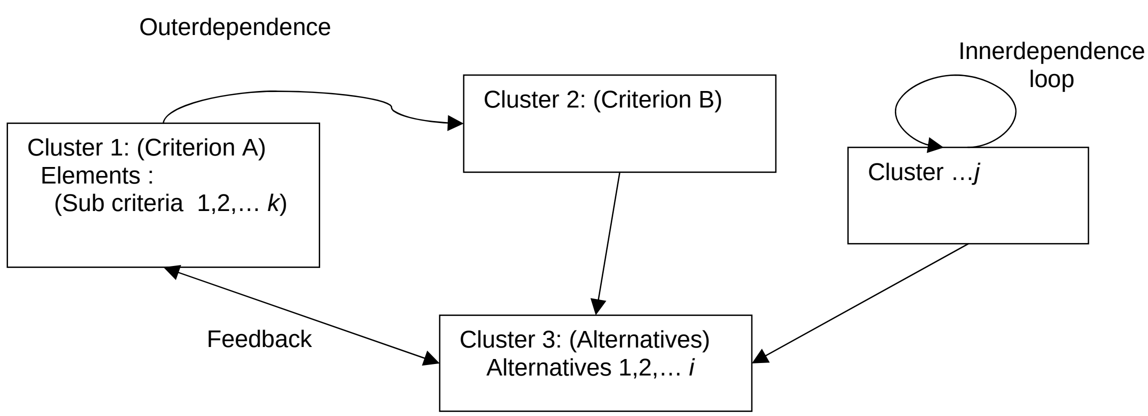

FIGURE 3. ANP MODEL REPRESENTATION

There are several important differences in this ANP network model. The first is terminology. The criteria and the alternatives depicted in the model are represented by *clusters* and the sub-criterion are called *elements.* When an element within a cluster influences another element within the same cluster, this relationship is called *innerdependence* and is represented by the arrow looping back to the same cluster as in criterion B as shown above. Similarly, when an element from one cluster influences an element from another cluster, this relationship is called *outerdependence* and is represented by the arrows between clusters. When the characteristics of one of the alternatives influences a criterion or sub-criterion, this relationship is called *feedback* and is represented by an arrow moving from the alternatives cluster to a criterion cluster. In this way, the importance of the criteria and their sub-criteria not only influence the priority of the alternatives, but also influence the priority of the various criteria and other elements within the model.

This powerful network model can also represent extremely complex decision making by including as many clusters and elements as required for the objective, and each cluster can also entirely contain sub networks of criteria. The depth and complexity of the network model is limited only by the needs of the decision maker. The network model can also be expanded to incorporate different dimensions of the decision, each of which corresponds to a given preference for an alternative based on an overall environment. For example, one might evaluate different alternatives based on the Risk, Opportunity, Costs, or Benefits each alternative presents (Saaty, 2003). These higher level dimensions are called *control hierarchies*, and represent a separate network of the same criteria for each dimension being considered (Saaty, 1999).

In the present research, data will be drawn from interviews with subject experts in the military distribution system, and it will be compiled to determine appropriate criteria to include in the model. Decomposition of the decision through interviews was used by many researchers as represented in the review of the literature. Bolis and Maggi (2003) demonstrate that acceptable fidelity is achievable with as few as 4 interviews of appropriate subjects.

Comparative Judgment

The comparative judgment phase of ANP is essentially the same as AHP. Each cluster is compared in a pairwise fashion relative to its importance to the objective. Similarly, pairwise comparisons of each element within a cluster are also constructed using the same qualitative and quantitative methods as described with AHP models in the previous section.

Relative comparisons for all of the information in the decision can be interpreted as pairwise judgments and included in the overall decision model. In Saaty's *SuperDecisions 1.6.0* software, this pairwise comparison can be made by pie chart, bar chart, questionnaire, or input directly into a pairwise comparison matrix (Super Decisions, 2006). The following figures represent the same pairwise comparison in each style.

These 4 graphical interfaces represent the same pairwise comparison. In this particular example, they indicate that the type of cargo being transported "very strongly" favors the use of sealift. The reason for the strength of the pairwise comparison might be that the commodity is extremely dense or heavy, and might not be able to be transported by air. Within the software, a similar comparison is accomplished for each sub-criterion with respect to the alternatives.

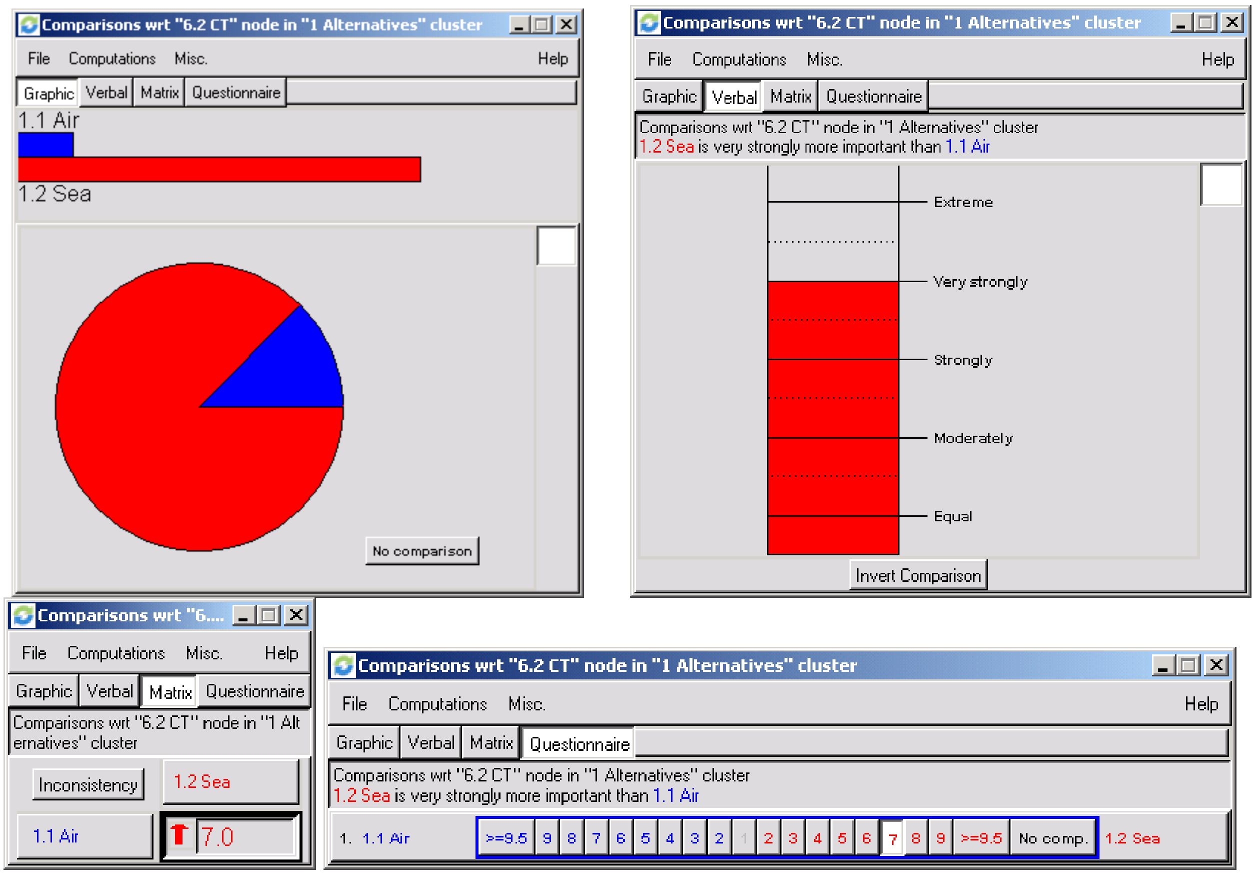

FIGURE 4. PAIRWISE PREFERENCES IN SUPERDECISIONS 1.6.0 SOFTWARE.

Synthesis

The synthesis phase of ANP is much different than an AHP. In ANP, a *supermatrix* of the pairwise comparisons is constructed. This supermatrix consists of several partitions or sub-matrices of which take into account the impact of elements on each other (Büyükyazici and Sucu, 2003). The supermatrix is organized with each element of the model occupying a column and a row. These columns and rows are grouped by their parent cluster. In this way, there is a representation for how much each element of the model influences every other element of the model. Of course, elements can also exert no influence on each other, and a '0' is entered in the matrix where these two elements intersect. The intersection of two clusters of elements represents a single pairwise comparison matrix, and the supermatrix represents the compilation of all the priorities derived from pairwise matrices (Büyükyazici and Sucu, 2003). An important point is that the supermatrix must be *column stochastic* (Saaty, 1999). This means that the sum of each column within the supermatrix must sum to one so that the supermatrix converges to when raised to an acceptably large power (Büyükyazici and Sucu, 2003). This can be done by multiplying the values within the sub-matrix by the relative weight of their interaction. Saaty (1999) represents the supermatrix by the following notation:

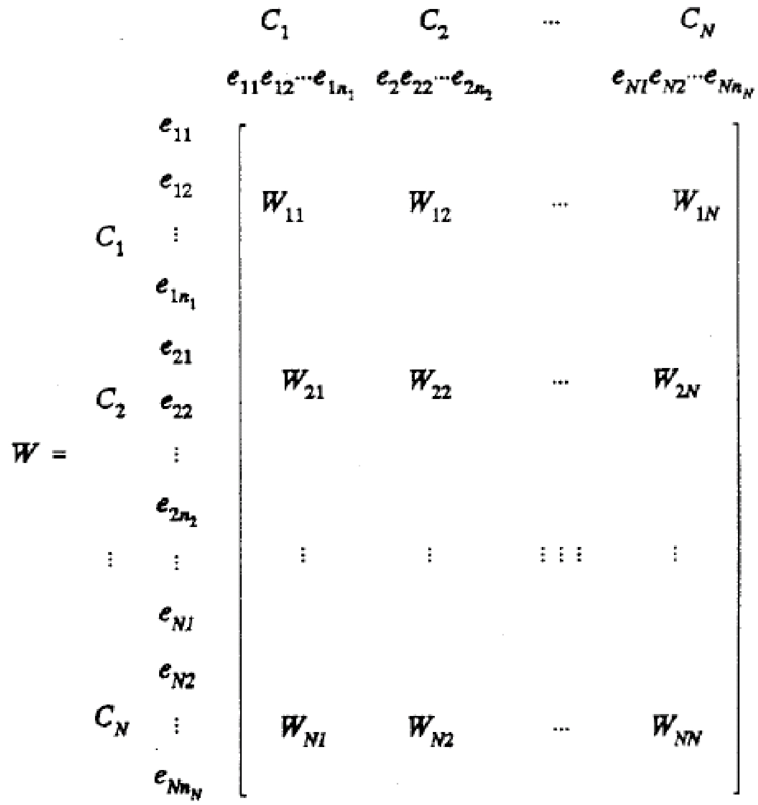

FIGURE 5. SUPERMATRIX FORMULATION (SAATY, 1999)

In this figure, W is the supermatrix, N represents the number of clusters, C_N represents each cluster, e_{Nn} represents each element of the model, and W_{Nn} represents the appropriate sub-matrix weight.

The desirability of an alternative can then be computed in a similar fashion to AHP while incorporating the effects of dependence between the elements of the model. While Saaty uses matrix representation for deriving the priority of alternatives, this process can also be represented mathematically. The following summation as adapted from Meade and Sarkis (1999) also represents the desirability of an alternative for a given control hierarchy.

$$D_i = \sum_{j=1}^{J} \sum_{k=1}^{K_j} P_j W^D{}_{kj} W^I{}_{kj} S_{ikj} \tag{1}$$

Where:

D_i is the desirability of alternative *i*.

P_j is the relative importance weight of the criterion *j* for the control hierarchy,

$W^D{}_{kj}$ is the relative importance weight for element *k* of criterion *j* for dependency between component levels of the model.

$W^I{}_{kj}$ is the stabilized relative importance weight as determined by the supermatrix for element *k* of criterion *j* for interdependency relationships between elements of the model.

S_{ikj} is the relative preference of alternative *i* with respect to element *k* under criterion *j*.

K_j is the index set of elements for criterion *j*, and *J* is the index set for all Criterion.

The synthesis step is accomplished seamlessly in the *SuperDecisions 1.6.0* software (Super Decisions, 2006). After entering all the pairwise comparisons, the user simply depresses the "syn" button on the tool menu, and the relative priority of the alternatives will be displayed graphically and in terms of the raw derived priorities.

The mode choice between sealift and airlift in the global mobility system can be modeled using the ANP methodology to account for qualitative and quantitative data that are specific to a particular transportation problem. Saaty's *SuperDecisions 1.6.0* software is easily adaptable to perform this task, and can be tailored to the specific criteria which are important to the decision.

RESULTS

This first step of an ANP evaluation involved 3 distinct subsets of problem identification (Forman and Selly, 2001). These elements of problem identification are: defining the problem, identifying alternatives and researching the alternatives. This first step in problem solving was accomplished by defining the research question. Sealift and airlift were identified as alternatives, and important background information was reviewed. ANP was chosen as the modeling methodology due to its capacity to incorporate complex interactions among criteria and to capture qualitative and quantitative variables. The global mobility decision was modeled using the following steps.

Building the Model

This phase of the research took data drawn from literature and personal interviews with transportation experts in different major commands. The interviews and literature were used to determine appropriate criterion to include in the decision model. The details of how the subjects were chosen and how data was decomposed are expanded below.

Subjects

Subjects for interview were gathered by contacting USTRANSCOM operations Directorate (J3) for experts in the matching of sealift or airlift assets to a movement request. Ten subject matter experts were interviewed. The subjects consisted of both service providers from USTRANSCOM and customers for 3 different Combatant Commands. Experience ranged from one subject who was a senior leader with 34 years of logistics experience in various commands and conflicts to a subject with 7 months experience in coordinating movement requests. All subjects had detailed knowledge of transportation functions and limitations, and had participated in movement requests and mode selection. Subjects consisted of transportation service providers and customers from all 4 service branches (Army, Air Force, Navy, and Marines). Subjects also had experience in all 9 of the United States Combatant Commands.

Data

Interviews were conducted with subject matter experts using an open ended interview. Interviews were recorded using a Sony ICD-BM1VTP voice recorder, and then subsequently transcribed to text. All subjects were advised that the interview would be recorded, and that their inputs would remain anonymous within the research. Each interview was decomposed into discrete statements of the criteria that influence the mode decision, and these 240+ individual statements were then reorganized into related concepts and groupings using an Affinity Diagramming procedure (Brassard, 1989). Each statement represented a specific criterion and element applicable to the mode choice, and could also indicate interaction with other elements. This procedure resulted in the identification of 6 main criteria and 28 sub-criteria for consideration in modal choice decisions. The following table summarizes the model elements:

Main Criteria	**Sub-Criteria (Elements)**	**Abbr.**
1.0 Alternatives	1.1 Airlift 1.2 Sealift	Air Sea
2.0 Costs	2.1 Monetary Considerations 2.2 Security Considerations	MC SC
3.0 Geography	3.1 Distance to be moved 3.2 Location of the Port 3.3 Weather Considerations	DM LP WC
4.0 Operational Requirements	4.1 HHQ taskings 4.2 Mission Type 4.3 Standard Operating Procedure 4.4 TPFDD layout	HT MT SO TL
5.0 Political Influences	5.1 Commander's Preferences 5.2 Host Nation Sensitivities 5.3 Inflated Requirements 5.4 Organizational Bias 5.5 System Knowledge 5.6 Trust 5.7 Visibility in the System	CP HN IR OB SK TR VS
6.0 System Limitations	6.1 Cargo Handling Limitations at the Port 6.2 Cargo Type 6.3 Load Efficiency 6.4 Platform Availability 6.5 Speed of Delivery 6.6 Volume of Cargo	CH CT LE PA SD VC
7.0 Time Available	7.1 Advanced Notice 7.2 Criticality 7.3 Emerging Requirements 7.4 Force Flow Model 7.5 Force Provider Availability 7.6 Late Requests	AN CC ER FF FA LR

TABLE 2. TABLE OF MODALITY DECISION CRITERIA

Criteria 1.0 represents the alternatives available to the decision maker, and criteria 2-6 represent elements of the decision. Throughout the interview process, it became apparent that criteria were indeed highly influential to each other. For example, the availability of airlift platforms was influenced to a high degree by worldwide global demand for strategic lift due to operational requirements. These various relationships are captured by including interdependence and outerdependence loops within the decision network. The interdependencies are presented in the following table:

Sub-Criterion	Is Influenced by:
2.1 Monetary Considerations	3.1 Distance to be moved 6.6 Volume of Cargo 7.1 Advanced Notice 7.5 Force Provider Availability
2.2 Security Considerations	6.5 Speed of Delivery
3.2 Location of the Port	6.2 Cargo Type
4.2 Mission Type	2.1 Monetary Considerations
4.3 Standard Operating Procedure	2.2 Security Considerations 3.2 Location of the Port 5.4 Organizational Bias 6.2 Cargo Type 7.2 Criticality
4.4 TPFDD layout	5.1 Commander's Preferences 6.5 Speed of Delivery 7.4 Force Flow Model 7.5 Force Provider Availability
5.1 Commander's Preferences	2.1 Monetary Considerations 4.2 Mission Type 4.3 Standard Operating Procedure 5.3 Inflated Requirements 5.4 Organizational Bias 5.5 System Knowledge 5.7 Visibility in the System 6.2 Cargo Type 6.5 Speed of Delivery 7.3 Emerging Requirements 7.5 Force Provider Availability
5.2 Host Nation Sensitivities	6.2 Cargo Type
5.3 Inflated Requirements	2.1 Monetary Considerations 5.1 Commander's Preferences 5.4 Organizational Bias 5.5 System Knowledge 5.6 Trust
5.4 Organizational Bias	3.2 Location of the Port 4.2 Mission Type 5.5 System Knowledge 6.2 Cargo Type 6.4 Platform Availability
5.5 System Knowledge	3.2 Location of the Port 4.3 Standard Operating Procedure
5.6 Trust	2.1 Monetary Considerations

	5.1 Commander's Preferences 5.4 Organizational Bias 5.5 System Knowledge 6.5 Speed of Delivery 6.6 Volume of Cargo
5.7 Visibility in the System	3.2 Location of the Port
6.1 Cargo Handling Limitations at the Port	3.2 Location of the Port 5.3 Inflated Requirements 5.5 System Knowledge
6.3 Load Efficiency	5.5 System Knowledge 6.4 Platform Availability
6.4 Platform Availability	2.2 Security Considerations 3.2 Location of the Port 3.3 Weather Considerations 5.2 Host Nation Sensitivities 5.3 Inflated Requirements 6.2 Cargo Type 6.3 Load Efficiency 6.6 Volume of Cargo 7.2 Criticality 7.3 Emerging Requirements 7.5 Force Provider Availability 7.6 Late Requests
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7.1 Advanced Notice	4.3 Standard Operating Procedure 5.6 Trust 6.4 Platform Availability 7.5 Force Provider Availability
7.2 Criticality	4.3 Standard Operating Procedure 5.1 Commander's Preferences 6.2 Cargo Type 7.3 Emerging Requirements 7.5 Force Provider Availability
7.3 Emerging Requirements	7.1 Advanced Notice

	7.2 Criticality
7.4 Force Flow Model	5.3 Inflated Requirements 6.2 Cargo Type 6.5 Speed of Delivery
7.5 Force Provider Availability	6.2 Cargo Type
7.6 Late Requests	7.5 Force Provider Availability

TABLE 3. SUB-CRITERIA INFLUENCE OTHER ELEMENTS

The table above shows that the subjects indicated a high degree of interaction among the elements of the model. The left most column indicates the element that had influence over the criteria to the right. Some elements such as Commander's Preferences and Platform Availability have a widespread influence over many other elements in the model. These criteria, sub-criteria, and their dependencies were all entered into *Super Decisions* 1.6.0 (Super Decisions, 2006) software to arrive at an overall network model.

This overall decision model can be used to represent the global mobility decision. As noted by Coulter and Sarkis (2005), the individual weight of each element within the model will change with the particular situation and the circumstances surrounding it. Each of the main criteria within the model forms a "cluster" of "nodes" where each node represents a sub-criteria or element of the model. For example, cluster 3, which represents the "Geography" criteria in the model is made up of nodes 3.1, 3.2, and 3.3, which represent the sub criteria: "Distance to be moved", "Location of the Port", and "Weather Considerations" respectively. This cluster is represented by the following figure:

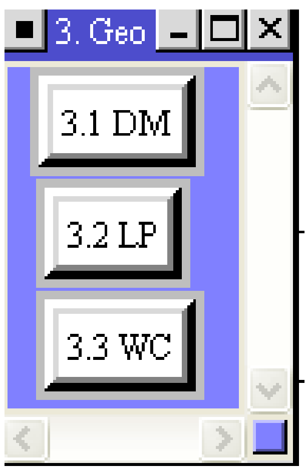

FIGURE 6. REPRESENTATION OF "GEOGRAPHY" CRITERIA AS A CLUSTER.

For simplicity, only innerdependence and outerdependence between the main criteria are shown in the overall Global Mobility Decision Model. The main objective "Sealift or Airlift for Global Mobility?" serves as the overall control hierarchy.

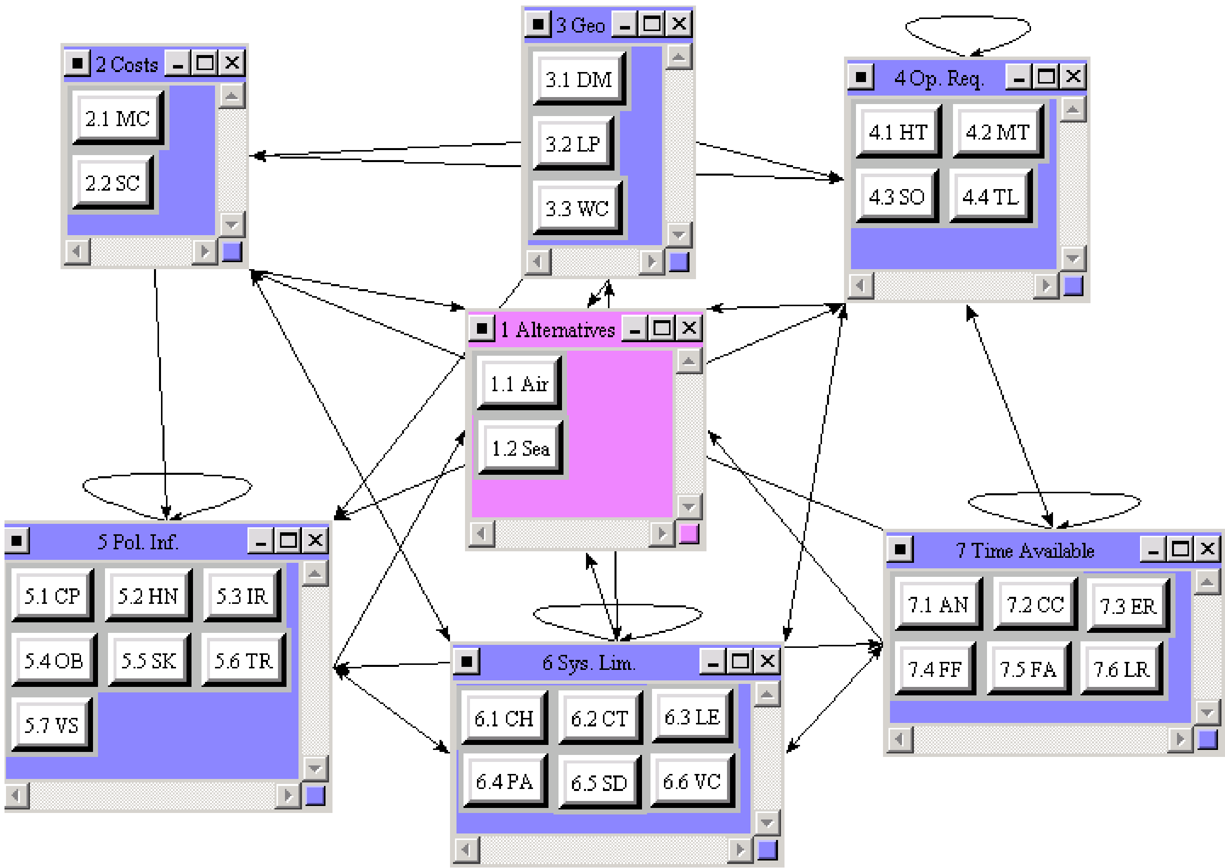

FIGURE 7. GLOBAL MOBILITY DECISION MODEL (GMDM)

The control hierarchy encompasses the entire model represented by the overall objective of "Sealift or Airlift for Global Mobility?" Cluster 1 consists of the two alternatives considered. Clusters 2-7 represent the 6 criteria identified earlier. Each of these contains the sub-criteria as specified earlier. It's obvious from the graphical picture of the decision network that the decision of which mode to use for a strategic move is extremely complicated. Each of the main criteria has sub-criteria that interact with the rest of the model. Four of the sub-criteria also demonstrate inner-dependence within the parent cluster as represented by the looping arrows above the cluster. Notice that the first cluster, 1, represents the alternatives available to the decision maker. In this case, nodes 1.1 and 1.2 correspond to airlift and sealift respectively.

Overall, the ability to examine relative influence of criteria and sub-criteria within the model allows the decision maker flexibility and power in their decisions while avoiding common decision errors.

FUTURE RESEARCH

The GMDM was built using the inputs of 10 experts in the mobility system. One area of future research that could add validity to the model is to evaluate the accuracy and completeness of the model through a case study or by using a Delphi Methodology. A case study would help validate the model, as would follow-up survey of all subjects, or examining the inputs of new experts. The survey could easily be built using *WebSurveyor Desktop 4.1*, and contain Likert scale ratings of each criteria and sub-criteria with respect to how frequently it impacts the modal choice, and how important it is to the modal choice.

SUMMARY

This research presents a decision model for mode choice using ANP. Tools such as this decision model and other initiatives serve to aid decision makers by allowing them to make more thoroughly informed decisions in a systematic way.

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