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Analysis of Mission and Design Concepts For a Logistic Ship**

*by Franz A. P. Frisch and W. Donald Weir**

SUMMARY

Methods being used by the U.S. Navy in acquiring the Fast Deployment Logistic (FDL) ship differ from previous practices in several respects. The methods include program phases known as concept formulation and contact definition. A major objective of the former is determination of system mission and performance envelopes.

System studies which addressed some of the problems of defining such envelopes for the FDL ship were performed by The Center for Naval Analyses (CNA). A comprehensive description of the analytical approach employed by CNA is presented here to provide an overview of the structuring of the studies and interrelationships among their essential elements.

As a first step in studies of this type, the mission area must be identified. For the FDL, it was defined as large-scale, rapid-deployment of military forces. Objectives to be accomplished in this mission can be determined from scenarios for the locations of interest. Combat and support force requirements can be expressed as cargo destinations, tonnages, and dates by which deliveries are required.

Deployment means must also be identified. In addition to sealift systems, airlift and prepositioning systems will be of interest for this mission. Each system must be described with respect to its performance capabilities, usage constraints, and costs.

There are many combinations of these systems which will give a force meeting mission objectives. The method used by CNA in determining the most efficient combination of systems is a fixed-effectiveness, least-cost type which took advantage of the availability of a computerized, linear programming model developed by the Research Analysis Corporation (RAC).

The "least-cost" force mix determined in this manner is correct only if the model inputs for systems and requirements are valid. To investigate the effects of changing model inputs on total force cost and composition, sensitivity analyses were conducted and a number of least-cost forces were found. Among the inputs varied were tonnage delivery requirements and systems performance, costs, and usage constraints. Thus, the desirability of paying the additional cost required for a five knot increase in ship speed, for example, could be examined.

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**This paper does not necessarily represent the views of The Center for Naval Analyses or of the U. S. Navy

The primary measure of preference available in these particular analyses is total force cost. If the difference in this measure between alternatives does not exceed some threshold, say 5-10 percent for the example mentioned above, it may not provide an adequate basis for determining a preference.

One reason for this is that all inputs used were point values, but there is uncertainty associated with the system performance and cost estimates. In addition, there may be other measures important to the determination of preference which have not been identified or quantified.

These considerations suggest that the most appropriate use of these types of analyses is to identify during concept formulation, those system elements whose variation has the greatest impact on overall force results, and the boundaries, or limiting values for those elements, within which more detailed examinations should be carried out. Determination of these limits may involve exogenous factors in some cases.

This kind of information can provide the basis for better direction in the work of contract definition which is the phase of most programs when industry first assumes a major role. Areas of high potential payoff can be examined more thoroughly, particularly in terms of better quantification of existing options and identification of options not already considered. While such an emphasis for contract definition seems desirable, it should not exclude consideration of other elements of the system not satisfactorily examined previously.

The type of analysis described here is being given a trial application in the FDL Ship Project. Among the considerations which will have to be taken into account before deciding to apply it to other ship types is an evaluation of the advantages and shortcomings experienced in this project.

INTRODUCTION

New methods are being used by the U.S. Navy in acquiring the Fast Deployment Logistic (FDL) ship. These methods involve a trial application of current Department of Defense (DoD) procedures for weapon system planning and definition.

The DoD procedures, which are based mainly on experience gained in procurement of aircraft and missile systems, call for increased industry participation in system design and award of a multi-year, series-production ship construction contract to one firm. It is hoped that the adaptation of these procedures to ship systems will result in lower average costs, increased standardization of ships, and improved shipbuilding techniques and facilities.

Two program phases, known as concept formulation and contract definition, are an integral part of the new methods. One of the principal differences from previous ship acquisition practices is in the work to be accomplished in these two phases. Among other purposes, these phases are intended to provide a more systematic approach to the examination of trade-offs between mission requirements and design characteristics.

Concept formulation has as a major objective the definition of mission and performance envelopes for the system. Those system elements whose variation has the greatest effect on results desired and their boundaries, or limiting values, are identified. Final "point designs" are not sought at this stage.

The specification of firm performance requirements and design characteristics for the system is an ultimate goal of contract definition. For most major weapon systems, the bulk of the work for this program phase will be carried out by two or more industrial organizations under competitive conditions.

The envelopes defined in concept formulation are the result of system studies. Such studies were conducted by The Center for Naval Analyses (CNA) for the FDL Ship Project, that element of the Navy charged with management of this program.

The primary purpose of this paper is to present a description of the analytical approach used by CNA in these studies. The treatment emphasizes practical considerations and will not go into detail for any particular area of the studies. Because of the nature of the subject and limitations of time and space, a comprehensive view of the overall structuring of a study effort of this type, giving attention to the interrelationships among its essential elements, seemed preferable.

The main topics to be covered and their order of discussion are as follows:

- Mission requirements
- Deployment system options
- FDL ship initial design
- Force-mix analysis
- Measures of preference and ship system envelopes

This order coincides with the general sequence of analysis followed in the studies, but it should be emphasized that the process, in general, is iterative.

MISSION REQUIREMENTS

A study task which must be undertaken early is to define the mission requirements. In the case of this study, a number of missions were considered. While most were similar in that they were of the logistics support type, the system capabilities needed to meet all the requirements covered a wide range of ship performance characteristics.

Among the possible missions explored were use 1) as a forward floating warehouse; 2) in rapid-response deployment of selected ground force cargo; 3) as a part-troop, part-equipment carrier; 4) as a helicopter transport; and 5) as a small-craft tender. These missions are not mutually exclusive and it is quite likely that the FDL ship will serve in most, if not all, of these roles during its lifetime. However, a ship designed to be equally capable of meeting the requirements of several missions will be different from one with a more narrowly defined mission.

The primary mission which led to the requirements for the FDL was seaborne, rapid deployment. Other missions were not excluded, but were considered of secondary importance in the system studies. The primary reason for this decision was that it resulted in an emphasis in the program consistent with higher level planning studies of deployment force composition and size.

The mission area selected as being of primary importance for this ship comes under the general heading of strategic mobility. This problem has recently been the subject of extensive analysis in the defense community of the United States. In these studies different aspects of the problems of large-scale, rapid-deployment of military forces have been emphasized.

Some of the studies concentrated on determination of the most desirable force mix. Others addressed questions of individual system characteristics. Both types are desirable in the concept formulation process. They are related and their assumptions must be consistent if their results are to be valid.

No matter what the orientation in prior studies, results obtained were consistent only when the ground rules and system performance and cost estimates used were similar. Where there were inconsistencies in the results, they were usually because of differences in these factors. This is especially true with respect to mission requirements.

While there are no authorized scenarios for strategic mobility, there have been studies which identify combat and support force requirements for a number of theaters of interest. For each theater, a range of possible situations is usually presented with a "most likely" situation identified. These force requirements can be translated into tonnage delivery requirements.

These tonnages can be distinguished by type. For example, the amounts of vehicular cargo for combat elements and support units can be identified. Quantities of resupply needed can be determined for each of the five standard classes. In addition to the weight, the area and volume characteristics of each type can be specified.

Delivery requirements can also be related to the time when needed. Combat vehicles and some initial supplies are needed first. Support vehicles and additional resupply follow. The type and amount of cargo required will shift with time. In deployments of the type studied here, very large movements are required in relatively short times.

The problem examined here is also defined to include deliveries from origins and to destinations which require some overland movement on both ends of the ocean shipment. While these segments of the problem may appear to have little direct effect on the ship system, they do strongly influence its design through the increased need for integration of its uses with those of other forms of transportation, particularly the C5A aircraft in this case.

Ship design is also influenced by the conditions under which loading and discharging are effected. For example, the expected availability of piers is an important consideration in design of the ship. A survey of port conditions in theaters of likely interest showed the need for the FDL to be capable of unloading over the beach.

There are many possible ways of meeting this requirement. During the course of the studies, ship unloading was found a fertile area for trade-off analyses. For each option investigated, it was necessary to identify the constraints to the total flow process, so that the effect on ship use as part of an overall deployment force could be seen.

DEPLOYMENT SYSTEM OPTIONS

When examining feasible means of meeting the mission requirements, airlift and prepositioning systems must also be considered. As mentioned previously, the uses of each kind of system will influence the design of the others.

Different combinations of these systems to meet the requirements are possible, varying from forces which are rich in either airlift or sealift to a balanced mix. The candidate systems will include several types of aircraft and ships. Some will be in inventories, others just phasing into operation, and a few in the conceptual phase. Before analyzing force mixes, each system must be described in terms of its performance capabilities, usage constraints, and costs.

Basic performance and cost information for systems other than the FDL ship was available from a variety of sources. Figures for existing aircraft and ships were based on operating experience. Development and test information was used for systems phasing into inventories. The estimates for conceptual aircraft, such as the C5A, were based on other studies. To apply this information in the CNA studies, it was necessary to convert it to a different form.

The cargo capacities of the various systems had to be determined under a number of different conditions. Planning factors developed in defining mission requirements, which identified cargo weight and area characteristics, were not sufficient. Vehicle loading practices will allow for such considerations as lengths of flight legs, stacking trailers, leaving passageways, and putting resupply in trucks. Template loadings were needed, especially for the new systems, including each deck of the FDL ship.

Effective vehicle speeds had to be determined for a number of routes. All origins and destinations of potential interest were taken into account. In addition, it was necessary to provide for such delays enroute as refueling and for other constraints on the use of each system. Where alternative systems were used jointly to make a delivery, allowance had to be made for cargo flow timing adjustments between one system and another.

For each route, the speed and payload of each system were related and expressed as a vehicle productivity. The information resulting from this process was expressed in a form which stated, for example, that it will take 10 C5A aircraft to deliver 1,000 tons of vehicular cargo from the East Coast of the U. S. to Europe in a specified eight-hour period, or it will take .2 FDL ships to deliver 1,000 tons of resupply from Hawaii to Korea in 10 days. Of course, the numbers in these examples are for illustrative purposes and are only representative of values used in the studies.

The other essential element in describing the systems is cost. The types of cost which are pertinent must be determined and should cover supporting systems and operations as well as the primary systems.

The three basic cost categories generally used are R&D, investment, and operations. Since the lift systems are in different stages of usage or development in this case, questions of inherited assets and residual value were important.

For this analysis, investment costs of existing systems were treated as sunk. R&D for new systems on which a development decision had not been made were included. No provision was made for residual value in the basic calculations, although this was examined in sensitivity analyses.

The residual value question is related to the length of the operating period used, which is also influenced by the system effectiveness measures used in the analysis. In these studies, a ten-year period was used. This period is not advocated as a preferred measure for all analyses, but was considered the most valid measure for this analysis. Other studies have used five-year, seven-year or other length operating periods. The decision must be made on a case-by-case basis, as is true for many of the costing ground rules in this type of analyses.

To describe each of the deployment force systems in the above manner, their physical characteristics and performance capabilities had to be known. As mentioned previously, for systems other than the FDL this information was obtained from other sources. In the CNA studies this information was used primarily in determining the effect of other systems on design of the FDL ship.

Before such analysis could proceed, however, the same type of information as was available for the other systems had to be developed for the FDL. This type of ship was different in many respects from any in the fleet. A preliminary design was needed, therefore, which would provide an initial measure of physical characteristics and performance capabilities, and serve as a point of departure for subsequent design efforts.

FDL SHIP INITIAL DESIGN

Before discussing requirements for the initial FDL design, a brief description will be given of a general technique used to facilitate examination of relationships between mission requirements and feasible design responses for the ship. The first step in this technique is to define the applicable mission and design elements.

Mission Elements

A ship's mission can be defined by the following four elements:

(1) the type of mission (T)
(2) the military load for such mission (L)
(3) the speed connected with the mission (V)
(4) the necessary endurance for such mission (E)

The mission type determines the objectives of the ship; e.g., tanker, aircraft carrier, or transport. Closely related to the mission type is the military load, which may be tons of fuel to be carried in the tanker; the number of aircraft carried by the carrier; or the number of troops embarked on the amphibious transport; etc. After the mission type and military load have been defined, speeds appropriate for the mission must be considered. Finally, it is necessary to determine endurance. Basically, endurance is the distance over which variations will be examined for a certain military load at a certain speed. For this discussion, however, the meaning of endurance will be extended to include all elements which are related directly or indirectly, such as the relationship between speed and vulnerability, the operating cycle, and ship availability.

Design Elements

The definitions of the design elements agree with conventional naval architectural practices, and include:

(5) FOC—fuel oil and consumables
(6) LSW—light ship weight
(7) DWT—total dead weight
(8) W_h—hull weight
(9) W_o—outfit weight
(10) W_e—engine weight
(11) SHP—shaft horsepower
(12) Δ—displacement

Interplay Between Mission and Design Elements

Theoretically, any combination of values for the mission elements can be selected. In selecting these, there will be certain trade-off points between the mission and the efficiency of a particular design. However, once values have been determined for the four mission elements, the remaining question is how to design a ship satisfying the mission requirements.

To assist in arriving at an understanding of the relationship between the mission and design elements, table 1 has been prepared.

The elements of the rows and the columns are identical. The table can be read by entering at any row or column. For example, item 6 is related to items 8, 9, 10, and 12.

The nature of the relationship has not been stated. Within the subgroup of mission elements and within the subgroup of design elements there will be a trade-off. There will also be a trade-off between elements across the subgroups. The degree to which such across-the-board trade-offs can be used depends upon the constraints on the mission.

An interrelationship of the elements has been indicated with a "1". The mission elements in the block at the left hand side have no influence on each other with regard to design. However, the mission elements will exert a certain direct influence over design elements 5 to 12. Each of these design elements will in turn indirectly influence the other design elements.

The table can be divided into three typical fields. Field 1 is the mission

TABLE OF MISSION AND DESIGN RELATIONSHIPS

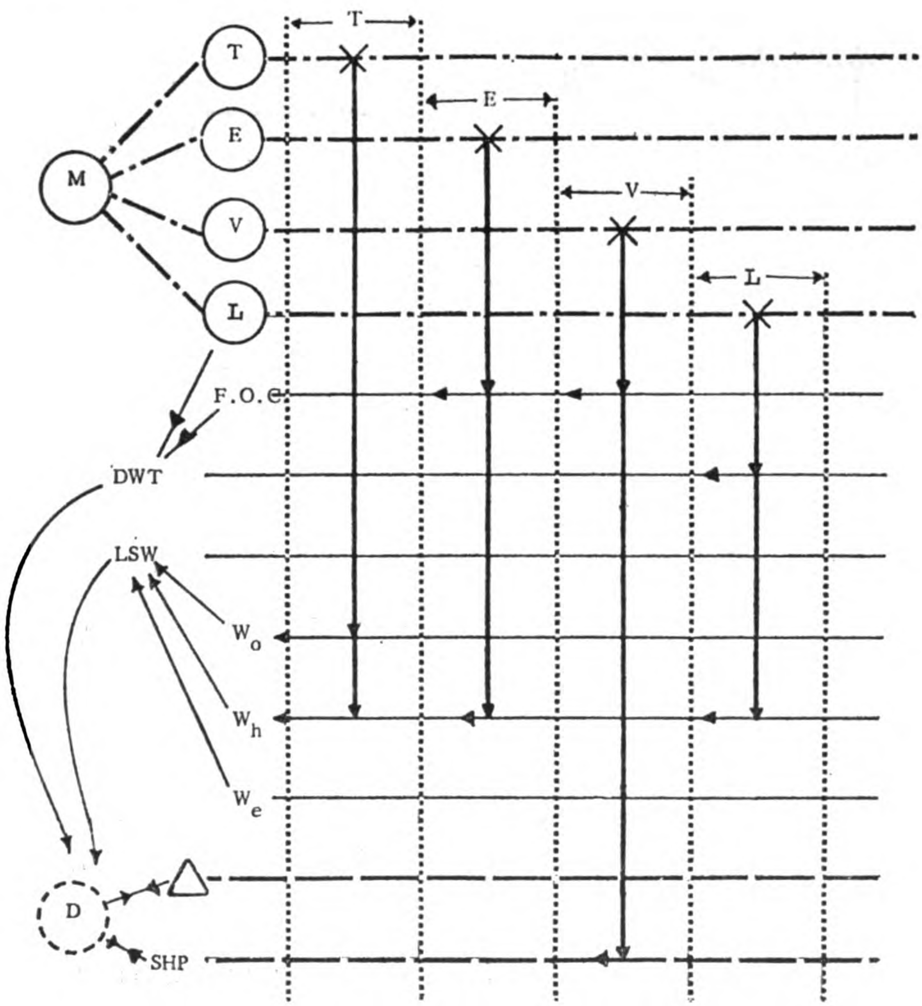
		T	E	V	L	FOC	LSW	DWT	W_h	W_o	W_e	SHP	Δ
		1	2	3	4	5	6	7	8	9	10	11	12
T	1	///							I	I			
E	2		///			I			I				
V	3			///		I						I	
L	4				///			I	I				
FOC	5		I	I		///		I					
LSW	6						///		I	I	I		I
DWT	7				I	I		///					I
W_h	8	I	I		I		I		///				
W_o	9	I					I			///			
W_e	10						I				///	I	
SHP	11			I							I	///	I
Δ	12						I	I				I	///

T - type of mission
E - necessary endurance for such a mission
V - speed connected with the mission
L - military load for such mission
FOC - fuel oil and consumables
LSW - light ship weight
DWT - total dead weight
W_h - hull weight
W_o - outfit weight
W_e - engine weight
SHP - shaft horsepower
Δ - displacement
M - mission
D - design response

-·-·-·- MISSION-ELEMENTS
·········· DIRECT INFLUENCES
- - - - INDIRECT INFLUENCES

TABLE 1

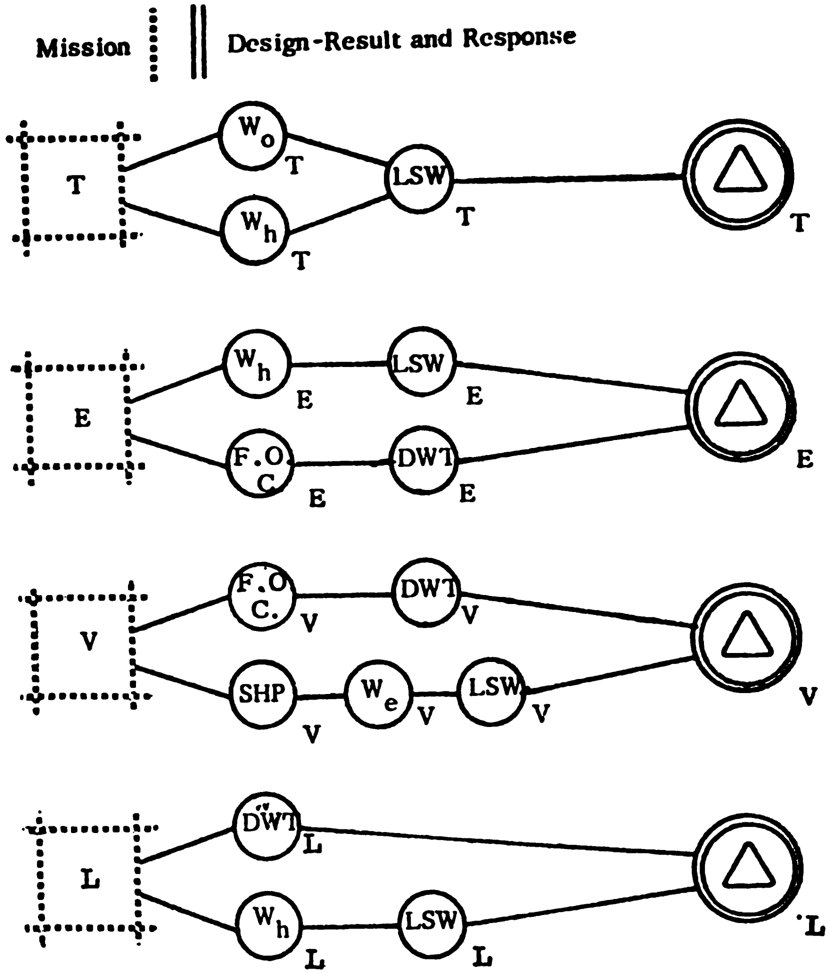
area with no interrelationship. Field 2 is the area of direct influence and Field 3 is the area of indirect influence. Figure 1 shows the method used to derive this table.



CHAIN OF FUNCTIONAL CONNECTIONS BETWEEN MISSION AND DESIGN

(See Table 1 for legend)

FIGURE 1



THE GENERIC INDIVIDUAL FUNCTIONAL CONNECTIONS

(See Table 1 for legend)

FIGURE 2

To find what influence each mission element exerts on the design, expressed as a combination of displacement and shaft horsepower, the chain of individual functions between each mission element and displacement has been singled out in figure 2. This shows, for example, that speed (V) directly influences fuel oil and consumables (FOC) and shaft horsepower (SHP) which in turn influence displacement ($\triangle$). Shaft horsepower (SHP) influences displacement ($\triangle$) via engine weight (W_e) and light ship weight (LSW). Fuel oil and consumables (FOC) influences displacement ($\triangle$) via total dead weight (DWT). Figure 2 also shows that mission type (T) and endurance (E) both directly influence hull weight (W_h), etc. This means that the mission as well as the designed endurance will influence hull weight. Of course, the influences shown in figure 2 will by no means be additive. However, they do have a joint influence over displacement ($\triangle$). Each relationship will have a different level of influence on the total result.

In figure 3, the mission elements, design elements and the total design response have been presented in a clockwise arrangement. Each of the elements is shown only once. However, each element has been connected with all others where an influence is exerted. No directions for the influence lines are indicated. This means that, within the circle of mission and design elements, there is freedom to choose entrance into the cycle or to select trade-offs due to design changes in any element, if the price of such a change is acceptable by modifying other elements. In the entire chain no element in itself is without at least a triple connection to the other elements in the group.

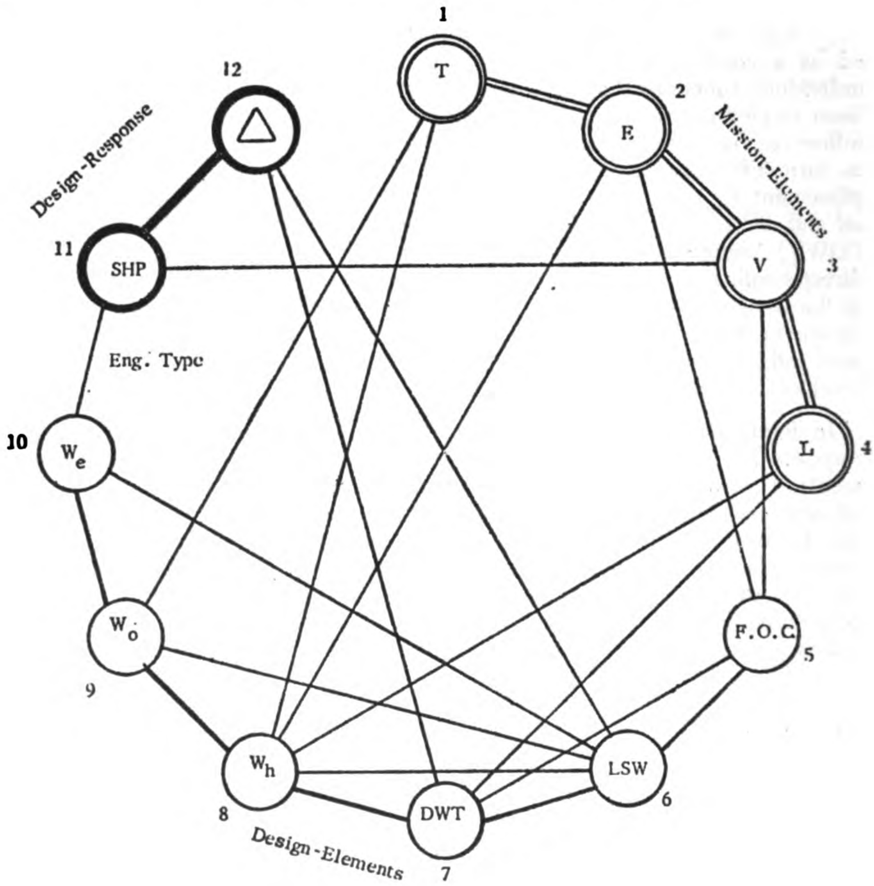
The picture is an extreme simplification of the standard design procedure for any hardware system where mission elements and design elements have to be reconciled. The definitions are peculiar to any design and are the result of multiple trial and error runs within the cycle of functional connections. If it is assumed that endurance (element E in figure 3) does not exist (as for nuclear propulsion), one may appreciate the degree to which the trial and error of design procedure can be simplified. Neither the direct influences on fuel oil and consumables (FOC) nor the direct influence on hull weight (W_h) exists, and consequently the influence chain to total dead weight (DWT), military load (L), and so forth up to the shaft horsepower (SHP) and displacement ($\triangle$) will be changed and simplified.

Initial Design Requirements

The purpose of this particular design effort is to respond to mission requirements developed for a seaborne logistic transportation system. The key requirements may be stated as follows:

- Rapid loading in CONUS
- High-speed transit between any two ports
- Rapid unloading, independent of port characteristics
- Ability to load any type of logistic cargo
- Ability to maintain logistic cargo during extended deployment.

These requirements must be translated into appropriate technical responses, as follows:



MULTIPLE FUNCTIONAL CONNECTION OF ELEMENTS

(See Table 1 for legend)

FIGURE 3

(a) Response to Rapid Loading Capability

In the present state-of-the-art, rapid loading for some non-bulk cargoes can be provided by:

- –Containerization
- –Roll-on/roll-off design

Vehicles cannot now be shipped in containers. Therefore, it is necessary to incorporate roll-on/roll-off features in the design of the ship.

(b) **Response to High-Speed Transit Capability**

The maximum distance between any two of the ports of interest can be determined. It is also possible to determine the distance between destination ports of interest and CONUS ports or U.S.-controlled prepositioned areas. Using this information, a ship endurance at a specific sustained speed was selected as reasonable for use in arriving at an initial design. It was recognized that neither the selected speed nor endurance are optimal; both were accepted only for a first approximation in the analysis.

The selected combination of endurance and sustained speed tends to determine the necessary length of the ship because of the resistance behavior of displacement ships. The specific power (HP/ton displacement) increases with increasing speed/length-ratio ($V/\sqrt{L}$, with V in knots and L in feet). Values for this ratio greater than 0.90 are uneconomical. Thus any ship with a $V/\sqrt{L} > 0.90$ will be penalized in cargo capacity because of tremendous fuel requirements.

This approximation is a simplification of a complex subject. But it describes in essence, trade-offs among speed, endurance, and ship size.

(c) **Response to Rapid Unloading Capability**

The way cargo is stowed in a ship will be a major determinant of the order and speed with which the cargo can be unloaded and made available. The methods of stowing cargo depend on the type of ship and the type of operation. Three types of military loading have been considered here.

—**Administrative Loading.** This type makes maximum use of troop and cargo spaces. No consideration is given to the tactical situation, unit integrity or priority of unloading.

—**Selective Loading.** Supplies and equipment are stowed to facilitate issue to designated units. Cargo is stowed so that it can be discharged and delivered on call.

—**Commodity Loading.** This is a method of loading where various types of cargo are stowed separately so that each can be discharged without disturbing other cargo. This method facilitates the issue of supplies and equipment to using troops.

Selective loading differs from commodity loading in that all classes of supplies required to support specified units are loaded and stowed so that the supplies can be discharged according to planned or anticipated requirements. Thus, if cargo is commodity loaded it can be selectively unloaded. However, if cargo is selectively loaded it does not necessarily follow that it can be commodity unloaded. The type of loading selected for a specific situation will depend mainly on the cargo to be carried at that time and unloading conditions at the destination.

The conditions under which rapid unloading requirements may be encountered can be subdivided into:

—Rapid unloading with port facilities, and

—Rapid unloading without port facilities.

If sufficient port facilities are available, then rapid unloading can often be achieved (depending upon the type of cargo) by containerization, palletized cargo storage, or roll-on/roll-off design features.

If port facilities are not available rapid unloading can be achieved by ships with beaching capability (LST) or by ships with inherent transfer capability (LSD and LPD) or by other types of ships with beaching and/or transfer capability as an integrated design feature.

A study of theaters of potential interest has shown the necessity of an over-the-beach capability. Other investigations have shown that a large ship is indicated by the combined requirements of military load, endurance, and speed.

The combination of these results points to the need for a particular capability for unloading, namely that a ship is required with the following:

—Cargo transfer capability similar to that of the LSD.

(d) **Response to Loading of Any Kind of Logistic Cargo**

The response to the requirement for loading any kind of cargo can be achieved only by the provision of sufficient deck clearance to store any expected type of cargo.

To avoid waste of ship space, requirements for deck clearances were investigated, based on the characteristics of tactical units for non-assault operations. The result of this was confirmation of the desirability of varying deck heights. A combination of some of the requirements described before led to identification of the desirability of having a capability for continuous access between decks to provide internal cargo flow.

(e) **Response to Cargo Maintenance Requirement**

The requirement to maintain cargo results in a need for dehumidified areas for cargo sensitive to humidity, and enough ventilation to permit the operation of the vehicle aboard the vessel in preparation for offloading.

The mission requirements and corresponding technical responses are summarized in table II. Based on these requirements, an initial ship design was made.

FORCE MIX ANALYSES

Using system capabilities and costs previously determined, it is possible to analyze deployment force mix. The methods of performing such analysis have been discussed extensively elsewhere[1] and will be mentioned here only as necessary to facilitate description of the overall study process.

In general, the basic approach which can be used will be of either the fixed-cost, maximum-effectiveness type or the fixed-effectiveness, least-cost type. The model which describes the problem may be relatively simple or may use sophisticated mathematical techniques. Calculations can be by hand or by computer.

1 See for example the paper by Lynn in this volume.

TABLE II

INITIAL MISSION AND DESIGN RELATIONSHIPS

Mission Requirement	Technical Response
1. Rapid loading capability	Roll-on/roll-off feature
2. High-speed transit; selected speed and endurance	Speed/Length Ratio Below 0.90; therefore, large vessel
3. Rapid unloading independ. of port facilities	LSD—general features
4. Carry any kind of cargo	Sufficient deck clearance, in particular: varying deck heights
5. Combination of 3 and 4	Continuous access between decks
6. Cargo maintenance	Dehumidification and ventilation

All of these approaches were used in the CNA studies. Because there were many variables in the problem and some of the relationships were complex, it was very desirable to have a systematic and rapid method of examining alternatives. Therefore, much of the force mix analysis used a computerized, linear-programming model developed by the Research Analysis Corporation (RAC). Since this tool was being used by Office of the Assistant Secretary of Defense, System Analysis, (OASD-SA), it offered the additional advantage of being consistent with higher-level studies.

The model was of the fixed-effectiveness type and the output of the computer runs was a deployment force which was "least-cost" for the given input conditions. Not only were force size and composition specified, but system usage was identified in some cases. Since there was uncertainty in varying degrees associated with the model inputs, sensitivity analyses were conducted.

In the sensitivity analyses, variations from initial or "best" estimates were examined for mission tonnage delivery requirements and individual systems performance, costs, and usage constraints. Thus it was possible to examine force level and structure under a variety of "likely" conditions and determine a range of potential uses for the ship and other systems.

Since the primary emphasis in the CNA studies was on the ship system, relatively few variations from "best" estimates of other components of the force were examined. Rather, the variations examined addressed questions of whether, for example, it would be worth the estimated price of a five knot increase in speed. Two primary measures of required ship performance, speed and payload, were examined in this manner.

MEASURES OF PREFERENCE AND SHIP SYSTEM ENVELOPES

Total cost is the primary basis for determining a preference when using results of force mix analyses. This measure may not be sufficiently sensitive to permit precise determination of preferred characteristics of individual systems, such as ship speed or payload.

It has been pointed out that, at the conceptual stage of the program, there is considerable uncertainty associated with estimates of performance and cost. An attempt is made in the sensitivity analyses to determine the potential effects of this uncertainty. However, in the method used in these studies, each case run in the sensitivity analyses requires point values for the inputs. The primary measure of preference available in solving this particular logistic problem, total force cost, is a higher-level measure resulting from the interactions of many of these lower-level inputs that have varying degrees of uncertainty associated with them. Therefore, unless the difference in total force cost between alternatives exceeds some threshold, say 5-10 percent for changes in ship speed or payload, it probably does not provide an adequate basis by itself for determining a preference.

The uncertainty associated with trying to define mission requirements in the future compounds the problem. It is possible to produce a theoretically optimum design for specific requirements. The vehicle thus designed will not be optimal, however, when operating under off-design conditions. The results of force mix analyses are useful in showing how "flat" alternative design responses are under a variety of conditions, but are of little assistance in determining the extent to which "flatness" is desired.

It is not the intent here to suggest that force mix analyses are of little use in system design. They have a definite value, but their limitations must be recognized also. In some cases, they will indicate a clear preference for a certain design or operating characteristic; e.g., greater payload capability or forward-area stationing. For other characteristics, the results may be inconclusive between alternatives; e.g., "high" speed vs "low" speed. The results of force mix analysis have been found to be especially useful in assessing operating alternatives. Regardless of whether decision variables of this type indicate clear preferences or indifference, those factors not quantified or accounted for in the models used must be considered. Vulnerability is an example of such an exogenous factor which is not measured explicitly in this deployment problem model, although it would have been possible to do so.

By considering both the results of force mix analysis and exogenous factors, it is possible to come up with mission and performance envelopes. This type of result seems preferable to point designs in the conceptual phase of a program. In doing so, areas of high potential payoff can be identified and delimited for examination in greater depth in subsequent work. For example, contract definition might include better quantification of existing options, or identification of new options not already considered.

The ability to order the impact of requirements on design is another possible benefit of the concept formulation process which could aid in moving toward better definition of firm performance specifications and design characteristics. For example, requirements might be classified as primary, secondary, or ancillary. Examples of how previously identified requirements for the FDL ship might be ranked in order of design impact are shown in table III.

TABLE III

ORDER OF IMPACT

Design Features and/or Function	Type of Criteria			
	Prime	Second	Anc.	Notes
Roll-on/roll-off characteristic		X		
LSD or beaching characteristic	X			
Deck clearance and other configuration arrangements		X		
Maintenance functions		X		
Others, not listed before:				Ancillary capabilities have not yet been described.
deck storage for LCM			X	
flight deck			X	

Only one feature, or function, is designated as having primary impact: the beaching, LSD characteristic. This function originated from the requirements to "lift and land" the cargo. To land cargo without direct beaching of the ship, landing boats or similar equipment must be included in the basic design of the ship. These boats are now launched by a ship with a wet dock (LPD or LSD). To avoid the complications and displacement losses connected with such a design, the use of a dry well and ramp has been chosen.

Since amphibious vehicles such as BARC's and LARC's are normally carried as part of the Army divisional load, they were used as transfer vehicles in the studies. Such a selection gives the possibility of transferring the cargo not only to the beach but beyond it to the junction with local lines of communication. The use of BARC's and LARC's is acceptable because the combat characteristics of the LCU's and LCM's are not required for an unopposed (administrative) logistic cargo transfer from the ship to the beach (or port vicinity), and because few army vehicles have a fording capability.

Use of a ramp in designing for boat transfer would dominate the design and determine the underwater form of the ship. If such characteristics are not in the original design they probably cannot be incorporated later. Such a characteristic would have the primary impact on the design.

The secondary design criteria are the maintenance and roll-on/roll-off characteristics. Both characteristics can be specified for a design, but they do not influence the basic underwater design of the vessel. Normally they will be incorporated into the original ship layout, but this is not absolutely necessary. Practically any existing dry cargo ship, bulk ship, or tanker can be modified to both characteristics for a price, without changing the underwater form or engine arrangement. It should be emphasized that the roll-on/roll-off capability may be as important to fulfillment of the mission requirements as an over-the-beach capability, but it does not have the design impact.

Ancillary capabilities are: first, boat storage over the hatches; and second, the flight deck. If hatches are specified for the weather deck, stowing LCM-8's or other boats on top of them is largely a question of stability. If stability can be maintained, boat stowage is possible at little cost. The same holds true for flight deck: as soon as the roll-on/roll-off features are accepted (with or without connection of the ramp design) and the weather deck is not interrupted by hatch openings, a watertight deck desults. Such a deck can now be used with small additional cost as a flight deck. In other words, the features of the flight deck and boat storage are achieved with little additional cost as a result of other design characteristics.

By obtaining such results as definition of performance and mission envelopes based on analysis and an ordering of impact of mission requirements on design characteristics, it is hoped that concept formulation will lead to an improvement in the efficiency of contract definition. The ultimate objective is a ship better able to perform its mission for the money expended.

CONCLUSION

The type of analysis described here is being given a trial application in the FDL Ship Project. It will be some time before its successes and shortcomings can be properly evaluated. Whether the method is adaptable to other types of ships depends on a number of factors. This presentation is made in hopes of stimulating comments on such factors and how they might relate to improving the efficiency of future studies of this type.