

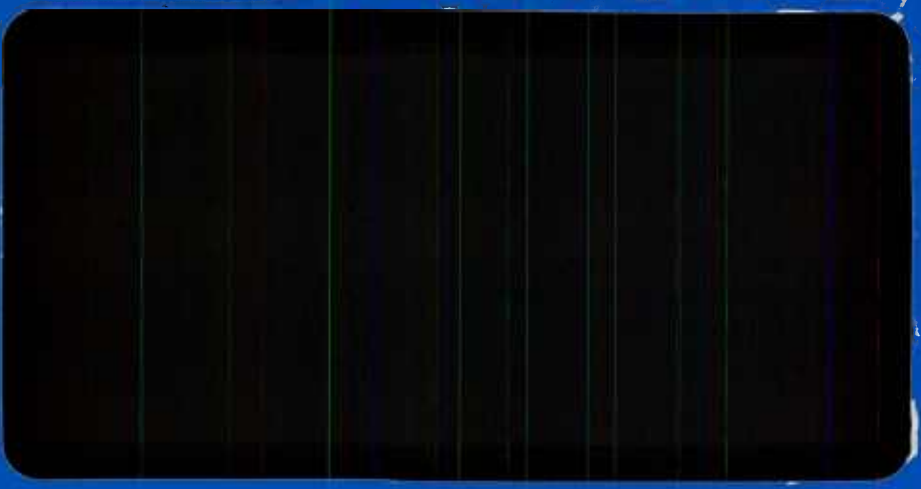
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1.

INTRODUCTION

The Analytic Sciences Corporation, under contract to the Office of Naval Research, has performed a preliminary analysis of the cost and feasibility of achieving efficient work load distribution in the shipbuilding industry through competitive allocation. This analysis has included a detailed investigation of the planning and procurement methodologies which are currently in use by the Navy and has considered the feasibility for the development of an analytic tool which would permit achievement of an efficient work load distribution in the shipbuilding industry. This analytic tool models the interaction between the shipbuilding industry and the Navy. It is anticipated that the use of a computer model will permit consideration of efficient labor utilization in the shipbuilding industry and its interaction with the Navy's budgeting, force planning, and procurement processes. It will provide decision makers with a tool permitting them to test for the predicted results of different shipbuilding decisions thereby permitting consideration of a greater range of options.

In the conduct of this contract TASC reviewed the literature on the subject in some depth -- literature pertaining specifically to the shipbuilding industry as well as more general economic literature which portends to describe the marketplace of the shipbuilding type. Extensive interviewing took place of Navy and other government officials, executives of shipbuilding firms and other researchers. As a result of these efforts, TASC has determined that a computer based modeling approach is feasible, and its use would be expected to significantly improve the Navy's long-range planning for shipbuilding and provide specific guidance in its acquisition policy on

a year-to-year and ship-to-ship basis with an objective of improved resource allocation.

This report, which presents the results of this six month study, demonstrates the feasibility of such an analytic approach to improved Navy planning through competitive allocation in the shipbuilding industry.

For the present study, "competitive allocation" is the allocation among shipyards of a Five Year Plan which uses the price benefits of competition and the stability benefits of allocation to result in a shipbuilding program which costs the Navy the least, given other objectives and constraints such as suitable quality of products, attainment of schedules, and maintenance of industry capacity.

To demonstrate the feasibility of modeling competitive allocation, a preliminary model was designed. This model is based on the comparative efficiencies of individual shipyards and on their behavior in the marketplace. When fully developed, it will be a tool to inform the Navy of:

- The desired competitive allocation for Five Year and longer term Plans
  - which distribution of work among yards costs the Navy the least?
- The acquisition methods needed to implement the competitive allocation
  - which yards are appropriate participants in competitions staged by the Navy?
  - which yards are appropriate candidates for allocations of ships?

Previous studies and interviews with people associated with the shipbuilding industry revealed that, while there is

much agreement on what are the factors which affect the costs and delivery times of ships such as employment level and stability, and quality of labor, the interrelationships between these factors and relative magnitudes of their impacts are not explicitly defined. Thus, the model was developed so that historical data would test the magnitude of each factor's impact and the functional interrelationships of the factors.

The basic modeling approach uses three modules. The first module is the estimation of the relative cost of production in different yards. The second uses these relative costs, and information on the market strategies of the yards, to estimate prices and price sensitivity of the Five Year Plan which costs the Navy the least. The third is an executive module which controls the program, incorporates competitive effects and Navy decision criteria, and makes the least cost allocation.

The cost estimation part of the model is an adjustment of the Navy's estimate of the basic cost to build a ship, as it would vary with individual yards. The specific variables, such as labor quality and supervisory experience, were revealed by interviews and previous studies. The model was designed so that the weight of each factor will be determined by historical data.

The price estimation module is based on the yards' relative costs, as revealed by the cost estimation; on the price benefits of competition; on the objective, needs, and constraints of the Navy; and on the objectives of the yards and their gaming, or strategic behavior (as revealed by interviews, annual reports, etc). These aspects will be combined to find the allocation of work which will cost the Navy the least, and to show which yards are appropriate candidates for competitions for ships, and which yards are appropriate candidates for allocations of ships.

2.

INDUSTRY OVERVIEW

After several years of relative prosperity, the shipbuilding and repair industry at the present time appears to be entering a period of decline. During the decade from 1967 through 1978 the shipbuilding and repair industry has seen the value of work done increase from \$2.5 billion to \$7.7 billion with total employment increasing from 139,000 to 193,000 persons. This growth has been steady with each year showing an increase in both value of work done and employment over the previous year. At the present time, however, the projections for the future are not so promising. The anticipated new construction for both Naval and commercial purposes show a decrease over the next few years. The medium term employment decline is anticipated to be in the tens of thousands with different sources showing different anticipated drop-offs. The Shipbuilders Council estimates an employment decline of 45,000, while the U.S. Maritime Administration (MARAD) estimates somewhat less.

Despite the industry's recent relative prosperity, the distribution among firms has been very uneven. Firms in the shipbuilding industry tend to operate in a boom or bust cycle, and firm sales and employment over periods of time show very large excursions. These instabilities lead to inefficient production through the use of inexperienced work forces and the inefficiencies associated with frequent hiring and termination. Over the near term, these problems are expected to be exaggerated, as firms complete current backlog without new orders arriving to take their place. The medium term outlook is not promising and is particularly gloomy for some of the firms. There is speculation that four yards will close in the

next three years. It is generally recognized that a relatively stable five year procurement schedule and a better job of Navy planning with a more careful consideration of the industrial base, would permit a minimization of the inefficiencies which have historically taken place and specifically those which will occur in the near term as the industry production shrinks.

Certain characteristics of the shipbuilding industry should be particularly noted when one is considering the planning problem for this industry. These characteristics make it difficult to plan, as well as increasing the need for good planning. The first of these is the fact that the industry is inherently a construction industry in contrast to a production industry. This distinction, recently advanced by Dr. Franz Frisch, is important to consider when one plans for the shipbuilding industry. Production lines, characteristic of repetitive manufacturing processes, are simply not pertinent to shipbuilding. Ships tend to be lumpy products with a manufacturing character more like that of a building than of a factory produced product. As such it is important that planning methods recognize that construction has certain unpredictable characteristics about it which must be considered in the planning process. Even for a construction industry, shipbuilding presents a particularly difficult planning problem in certain further aspects. Shipbuilding is characterized by very long lead times with final delivery sometimes taking place a decade after initial requirements. These very long lead times complicate planning processes for individual production items due to the uncertainties associated with inflation, availability of materials, technological change, etc. This complicates the costing problem, making it very difficult to estimate costs.



In addition, of course, the whole shipbuilding problem is one which is made more complex because of the complicated design of modern naval vessels. The entire package of subsystems associated with naval vessels is becoming increasingly complicated, thereby complicating the total design and construction processes. This makes planning for shipbuilding inherently difficult and subject to uncertainties.

Another characteristic of the shipbuilding industry deserves special note. In recent years most shipbuilding firms have become operating units of conglomerates. This change in the fundamental ownership and management of shipbuilding firms has had a significant impact on the shipbuilding industry. Firms are no longer entirely dependent on shipbuilding for the viability of the firm. This gives the firm increased financial and other resources, while at the same time decreasing the importance of shipbuilding to the firm's health as a whole. The resulting effects can be both positive and negative. The availability of financial resources makes the firms less dependent upon near term production. On the other hand the conglomerate may be much more likely to divest itself of its shipbuilding operations if it deems them unprofitable within the planning horizon of the firm. This more stringent financial control of conglomerates would be expected to have particular impact during the current period of sales decline.

All of these factors put together indicate that the Navy has a particularly difficult planning problem over the next few years due to the decreased number of ships required and the general decline in the industry. It is important that the decline takes place smoothly, in a manner to cause the least disruption to local economies and individual firms. This is in the interests of the workers, the firms, the Navy and the Nation. It may be that all firms currently in the

shipbuilding industry cannot be expected to survive this decline, in which case it is important that the Navy emerge from this period of decline with a strong industry with the most efficient producers still viable for later potentially increased requirements, while at the same time insuring that sufficient capacity exists for potential surge in shipbuilding in this country.

All of these problems are the specific concerns of the Navy, because the Navy is the largest single customer of the shipbuilding industry. However, industry does enjoy substantial sales in commercial production, and the Navy must consider the commercial production interaction in its consideration of the shipbuilding industry. Despite this, the Navy is, and is likely to remain, the predominant customer for the industry. More careful planning of the Navy shipbuilding programs from an industry viewpoint would be expected to have significant positive impact in terms of cost and delivery time through the minimization of the instabilities which have historically taken place in this industry, particularly since past planning has largely been done in the absence of specific consideration of the overall industry impact as a compendium of firms.

A planning model, of course, will do nothing about the expected near term decline in the shipbuilding industry. A planning model can, however, facilitate the ability of the Navy and the industry to accommodate this decline without severe disruption in industry efficiency and capacity. This would take place by permitting the Navy to plan its program in a way to prevent undue instability effects of employment and sales by individual firms. It is presumed that more stable employment in yards will result in a more productive work force, contributing to a lower cost of production while maintaining stability in production. In addition, the planning

tool will permit the Navy to identify those yards which are in a position to be the least cost producers for any particular ship at any specific time, incorporating in the costing the effects of current backlog and employment levels. The tool should inform the Navy which yards are suitable competitors for given programs and which are the most efficient for purposes of allocation.

3. REVIEW OF THE LITERATURE ON THE  
SHIPBUILDING INDUSTRY\*

Much of what has been written on the U.S. shipbuilding industry has been descriptive of the opinions of researchers and those more closely involved with the industry. The literature is replete with assertions about the industry such as "high labor turnover is a major cause of inefficiency", or "skilled labor shortages contribute significantly to shipbuilding industry inefficiency."

Such ideas have a good deal of common sense appeal, but an analytic demonstration of their validity and their degree of importance would significantly contribute to the ability of both policy makers and shipbuilders to solve the problems facing today's shipbuilding industry. A deficiency in shipbuilding research is that all too often studies are descriptive and general; too many use, without careful analysis, commonly held assumptions about the industry to arrive at recommendations which, if implemented, would alter the status quo significantly. While discussions of industry problems and solutions based on these assumptions certainly do raise questions worth considering, and take less time and effort than more detailed, basic analysis, there has been a void in the area of the shipbuilding industry.

The literature provides a knowledge of the issues which are of concern to those involved in the shipbuilding industry. This knowledge, combined with an understanding of

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\*This chapter summarizes the key points revealed by the literature search. Reviews of individual studies particularly relevant to this study and a bibliography of other shipbuilding industry studies are included in Appendix A.

how the industry works (obtained from interviews with Navy and industry personnel) was used to develop a model which will reflect the industry structure and the nature of the market for ships and which will test with historical data the relative importance of recognized factors of efficiency.

To summarize the literature: labor factors critically affect efficiency. These factors include the importance of not overemploying or underemploying yards to avoid either overcrowding or insufficiently spreading fixed costs. Other critical labor factors of concern were skill levels, experience levels, and turnover. Demand stability was thought to reduce labor inefficiencies.

Another theme of the literature is that shipbuilding is a high risk industry due to the nature of the product. Difficulties in cost estimation of ships, long lead times, and complex designs contribute to the risk, as well as the fact that a ship is manufactured by construction processes and not by repetitious production processes. A number of studies emphasized that different contract types should be used in different situations to divide risk fairly. While the use of appropriate contracts would reduce the risk which the shipbuilder faces due to the nature of the product, it is important to note that long-term demand stability would also reduce the risk which a shipbuilder faces due to planning and forecasting difficulties.

The literature also provides information on the extent of industry concentration. Factors such as the presence of public shipyards, the Navy's interest in maintaining industry capability, the many voices of government and the segmentation of the market by ship-type provide added complexity to the simple characterization of the market as a monopsony facing an oligopoly.

4. ECONOMICS OF THE INDUSTRY

In many ways the shipbuilding industry is unique. The uniqueness of the industry must be captured when building a model to be used for decisions with respect to this industry. No generally acceptable economic model can completely capture the essential elements of the shipbuilding industry as it exists at this time. Despite this we can learn from a consideration of different viewpoints which are commonly in use, and these can be adapted for our use as we represent the economics of the shipbuilding industry.

One of the prime economic phenomenon in the shipbuilding industry is its highly concentrated character. While this is not unique to American industry, the shipbuilding industry is not always recognized as having this character. Approximately 70% of the total sales and employment are enjoyed by three yards: Electric Boat Division of General Dynamics, Newport News Shipbuilding of Tenneco, and the Ingalls Shipbuilding Division of Litton. The remaining percentage of business is shared among some ten companies and the shipbuilding divisions of several of these companies are in questionable financial straits at this time. The highly concentrated nature of this industry must be considered when this market is viewed in an economic sense. Economic perspectives (which assume that there are multiple competitors with a classic economic marketplace determining price) are simply not applicable in an industry where concentration has achieved a level such as in the shipbuilding industry. Most government procurement practices are actually based upon such a free market model.

Our consideration of concentration in the industry can be taken a step farther. While the industry as a whole is very oligopolistic in nature, certain segments of this market actually have achieved a level of monopoly. The shipbuilding industry is not really an industry in which all of the competitors can produce all of the products. The product mix is actually highly segmented by technical level from an extremely complex nuclear aircraft carrier to a relatively simple supply ship. The segmentation of the market and the number of competitors in a position to bid for a given production contract vary as the complexity of the ship is considered. The marketplace for nuclear aircraft carriers is currently a monopoly -- Newport News, which will engage in bilateral negotiations with a monopsony, the U.S. Navy. The nuclear powered ship industry in general is not much richer in suppliers because at the present time only two yards enjoy nuclear qualification -- Newport News and Electric Boat. When one considers medium size fighting ships, the market becomes a bit broader and would include Bath, Todd, and Ingalls. Others occasionally can attempt to enter this marketplace. Thus, the market must be recognized as even more concentrated than is apparent from the overall statistics.

These considerations of high concentration and market segmentation lead to the conclusion that for the purposes of modeling the economic behavior of this marketplace, individual yards must be considered. The small number of yards involved and the few ships planned do not permit general models of economic behavior to be made and then applied to the industry as a whole with any confidence. Rather, the behavior of the individual market segments must be considered and behavior of the individual yards in this marketplace must be represented. Similarly, concepts involving "market share" cannot be used and each ship must be modeled individually.

Implicit in many views is that the industry is characterized by a monopsony, i.e., the Navy is the sole customer for the products and will behave in a relatively consistent fashion. This characterization, which has been treated in the economic literature, is not totally valid to this industry. In the first instance, the Navy is not entirely monopsonistic. Many of the producers in the industry have at least some volume of their business which is devoted to the commercial market. Indeed, there are still a few producers of ships who produce entirely for the commercial market. Second, the Navy is not only a buyer, but also a producer of the product. At least a residual capacity exists to produce ships in the Navy yards. In the repair and conversion segment of the market, the Navy yards operate in more or less direct competition with private industry. The Navy thus is in the position of having mixed motives with respect to its role as a buyer. Another characteristic of the monopsony, that it acts in a uniform predictable fashion on the industry, is not applicable. The many pressures on government procurement of such visible items do not permit the Navy to act with one voice. Other levels of administration and Congress act to remove the monopsony image. Unfortunately, in many ways the government regulations, as they exist at this time, do not permit the Navy to use acquisition policies, which permit it to operate in its own best interest as seen in this perspective. The result is that monopsony models are of limited use and are not directly applicable.

This leads us to a consideration of the effect of the regulatory behavior (in a control not legal sense) of the Navy on this industry. Since the industry is highly oligopolistic and since the Navy is at least a principal buyer for the output of the industry, the behavior of the industry and the Navy is highly interactive and adaptive. Due to the relatively stronger power position of the government,



the industry is forced to be highly adaptive to the regulatory practices of the government. This concept is not generally recognized. It implies that the regulatory practices of the government's procurement should be formed in a way which recognizes the true characteristics of the industry and encourages the reaction of the industry in a manner which is both in the long range interests of the Navy and in the long range interests of the participants in this marketplace. Regulations based upon classical economics, in which there are multiple buyers and producers, simply are not applicable. The government, in its structuring of the procurement policy, and in its establishment of regulations for this marketplace, would be better served if its particular practices recognized the highly segmented characteristics of the industry, the relatively limited role at present of price competition, and the various complexities of the production process for this product. The approach to competitive allocation suggested by TASC recognizes the exigencies of this situation and adjusts the Navy's procurement practices in a way which permits a more positive and adaptive behavior on the part of the industry.

The model which best describes this behavior is actually a sort of gaming process. The marketplace is characterized by gaming on both sides, this gaming takes place within the bounds of the rules established by the procurement regulations. Pricing in the industry is largely established in response to the individual firms perception of the game in which they are engaged. Price is established from a consideration of two separate sets of information. The obvious one, but perhaps less important for a pricing decision, is the estimated cost of production. The second input which they must use is their perspective on what a winning price would be for this particular procurement and whether they want to build the ship in this price environment. The individual producer has almost perfect information at hand. They know relatively

well their cost of production and probably know with almost equal accuracy the cost of production of the competitors. They also have at hand the budgetary estimates for the Navy to procure the ship. Therefore, they have a good idea of the amount of resources which are currently planned to produce this particular vessel. Then they must game the behavior of the competition and the Navy. They must decide whether they should maximize profits in their bid for the competition, or perhaps even bid at a price which is beneath their expected cost of production in anticipation of "getting well" later with contract changes or follow-on business. It should be recognized that the firm's decision in this game is largely dependent upon its view of not only the auction taking place at the present time, but its abilities to manage and recover costs throughout the entire process.

The Navy participates in this game as well as the individual firm. The Navy in this particular practice should recognize that this marketplace is characterized more by gaming than by cost of production considerations. When establishing regulations, procurement practices and in managing the competitive allocation of purchases, the Navy should do so in a manner which is in its long range interests. Thus the decision on the acquisition of a particular ship, or even on a class of ships, or on the timing of a particular acquisition, etc. must all consider the overall impact on the shipbuilding industry and its long term efficiency -- this is rarely done today.

As a final comment on the price behavior of this marketplace, remember that new Naval ship construction is not the only product produced by the industry. The industry also participates in repair and conversion work for the Navy and in commercial ship production. In addition, certain yards may produce other products using whatever competitive advantage

they may have because of their abilities to handle ship production. These effects are relatively minor compared to the major Naval procurement. However, they must all be considered since, cumulatively, they can make a difference in the production cost and pricing behavior of the individual firm.

5.

INTERVIEW RESULTS

Interviews were conducted with shipbuilders, Navy and Maritime Administration personnel and researchers engaged in analysis of the shipbuilding industry. These interviews provided much very important background data on the nature of the industry and its current practices, which have not been recorded in the open literature. In addition, of course, they provided an opportunity to test our insights into the behavior of the industry with working practitioners. The results of these interviews have been incorporated into the model. The primary results are the identification of the important effects which determine the efficiency of this industry. There was consensus on the broad areas of importance but relatively little consensus on detailed levels of parameters. This lack of consensus does not seriously limit us because postulates can generally be tested by examination of the historical data base. Where this is not possible or inadequate data exists it may be necessary to use some more formal opinion gathering techniques to establish values on important parameters to be used in planning.

There was general agreement that labor issues are the predominant factors in shipbuilding efficiency at this time. While this general opinion is prevalent there is less consensus on the specific determinants of labor inefficiency and the levels at which efficient operation can be expected. It was true, however, that most people in the industry agree that the relative instability of employment in individual shipyards is a major contributor to high cost in the shipbuilding industry.

The concept of the "employment window" is generally accepted -- that is, there is a range of employment for any given yard, which permits that yard to operate close to optimum efficiencies. Employment in excess of this level will cause diseconomies of scale. On the other hand, as employment falls the labor base against which fixed costs can be applied causes a yard to become less efficient. While this concept is generally accepted, opinions on optimum employment levels in particular yards differ. Shipbuilders tended to estimate that their optimum employment level was somewhat above their current employment level. Some others thought that all shipyards would have an optimal employment range of 6,000 to 8,000, regardless of the variation among facilities, while others thought that the range of efficient employment was very dependent upon the facility. People generally seem to agree, however, that any yard could become too big on an absolute basis to handle the management problem of shipbuilding. There was some opinion that the larger yards today have exceeded the economies of scale which are inherent to this industry.

Opinions on several other labor factors also varied. Some people thought that a "learning curve" effect does exist in today's shipbuilding industry. Others tended to minimize its significance -- some thought the learning effect was small or negative and some thought it did not exist. In particular, several thought that the Guided Missile Frigate (FFG) was experiencing "negative learning", while others felt this program has a positive learning effect.

Other labor factors which were generally thought to affect shipbuilding productivity were turnover, training, and experience. There was little consensus on the importance of these factors. For example, some thought that high labor turnover significantly decreased productivity; others felt that if this were so, shipyards would have exerted greater

efforts to decrease labor turnover. Another opinion was that production labor turnover was not as important as foreman turnover; that it was in the foreman that the learning effect occurred. Another fundamental problem that was brought up was the question of the usefulness of the available labor turnover measures. The Bureau of Labor Statistics figures are from an industry sample which includes small repair yards along with the large construction yards, and are ten to twenty percent higher than the Navy turnover figures on specific major yards, when these figures are weighted in the same fashion as the BLS figures. Thus the accuracy of the statement "the shipbuilding industry suffers from high labor turnover" depends to some extent on which portion of the industry is under consideration. This particular problem is a good example of the variation among industry segments, which provide numerous opportunities for errors in analytic conclusions due to insufficient examination of yard-specific data.

One labor issue on which consistent agreement exists, is the importance of employment stability. Repeated and rapid build-ups (with subsequent dramatic slow-downs) are thought to be significantly detrimental to productivity. Whether rapid build-ups are inefficient because of the difficulty in maintaining the average skill level or because of inefficiencies inherent to instability is a question which has not been resolved.

The interview process revealed problems in the shipbuilding industry which are due to the nature of the product. A ship is manufactured by construction processes and not by a repetitious production process, and it can take several years to build. Thus, cost can only be estimated, and not calculated precisely. The long construction process of shipbuilding makes quantitative analysis of the industry particularly difficult. There has been very little analysis performed on

large system construction (with "lumpy" products). In addition, the non-repetitious construction process of building a ship, with the necessity to change plans often, means that analysis must be probabilistic, not deterministic.

Another aspect of the industry which was discussed is its structure. It is widely recognized that the industry is segmented along the lines of a yard's capabilities of building specific ship types. The yards exhibit their awareness of these segmentations by adjusting their bids for ships in a manner which takes their competition, if any, into account. For example, the FFG industry segment is now well defined, and both yards submit bids which are close enough to ensure they will get the business they want.

The effects of the acquisition of shipyards by conglomerates were also discussed. First, the shipyards state of financial health can be concealed by the incorporation of their accounts into the parent company's accounts. Second, the old style, shipyard-oriented managers have been replaced by modern mass-production-oriented managers with aerospace backgrounds. For example, after its acquisition by Litton Industries, Ingalls Shipbuilding and Drydock Company added an automated yard and modernized and expanded the existing yard.

This effect of conglomerate acquisition has almost made old-time shipbuilding a lost art. Managers now want to satisfy the objectives of the corporations more than they want to build ships. It has been said that since shipbuilding is not a production industry, the new management styles are inappropriate and are a cause of productivity problems. It is interesting to note that the Kaitz study, The Profitability of the U.S. Shipbuilding Industry, 1947-1976 found that the aerospace-oriented shipyards have fared much worse financially than the shipyards which have retained the old style management.

A third effect of the acquisition of shipyards by conglomerates is the increased availability of funds for the yards. While it has often been thought that this is beneficial to yards, the opinion was expressed that it has actually been detrimental. The availability of corporate funds, according to this opinion, allowed the shipyards to continue "business as usual" when they were first experiencing problems such as overruns in the 1960's. Had the shipyards not been able to borrow as much to continue with "business as usual", the problems would have come out in the open sooner, and would not have grown as they did to the claims problems of the 1970's.

Other management issues were discussed with on-site interviews with the managements of two shipyards. The yard's business objectives varied, one yard seeking to obtain a given return on investment and the other to pay off its loans. Support for a stable Navy Five Year Plan was expressed, since it takes several years to prepare a yard to build a new type of ship. Changes in productivity due to deviations from a range of optimal employment were believed to be important. Specifics about labor availability, how long it takes to hire, labor training, and state labor training programs were discussed. Work continuity was seen to be desirable. When employment fluctuates, productivity decreases due to the difficulties of hiring skilled labor or the tendency of labor to stretch work out when a slow-down is imminent. Issues of market planning were discussed. The two yards compete with each other for Navy business and it became clear from the interviews that they knew their competition well, and the cost of production of their competition, this knowledge allows the yards to game their bids, or use strategy to achieve the desired results.

Finally, interviews provided information about the shipyard data collected by the Navy. Apparently much detailed



data are collected, but retrieval of collected data will be difficult, since there is no centralized data storage and retrieval system. Relatively more effort will be required in data collection than originally anticipated.

6.

COMPETITIVE ALLOCATION

With respect to its allocation of shipbuilding construction across the industry, the Navy has certain objectives which it must keep in mind at all times. The primary Navy objective in the procurement of new ships is to minimize long term costs. During our interviews throughout the Navy we found no one who would explicitly state that the Navy's objective for procurement should be stated in any other way. In all cases, people recognized that there are constraints upon the Navy's abilities to satisfy this objective. These constraints are often stated as the product of various political forces within the country. However, many of the constraints which appear in this manner actually are based upon a rationale which can be expressed in the allocation process. An example of such an allocation constraint is the requirement to maintain some capacity for new ship construction on each of the coasts of the United States. Another constraint is that the Navy must allocate its work in a way that insures that the industry will have the capability to respond as necessary in times of unforeseen national emergency. Yet another constraint upon allocation is that the Navy will require specific delivery times for each vessel. Navy management of procurement problems recognizes the constraints and is ready to make a long term decision on procurement at variance with the minimum cost objective when these constraints are not met.

The approach which we suggest in this study is that the Navy basically seek a minimum cost allocation of ship procurement with the results checked against these constraints in an explicit mathematical way. Where constraints are violated the solution algorithm would then seek the lowest cost suitable

solution. Therefore the constraints upon the allocation must be stated explicitly, that is, criteria must be set for the amount of shipbuilding which must take place on each coast, etc. Certain constraints probably cannot be foreseen and only after generation of a solution will people recognize that a certain solution violates some implied policy. In this case our solution must be sufficiently flexible to permit us to regenerate solutions based upon the feedback of executives in the Navy. The feasibility of such an approach is not in doubt, but it will require careful attention in the design of the executive control of the model.

The basic mechanism, which the Navy would use to manage the shipbuilding program in an optimum manner, would be to manage procurement based upon its knowledge of cost of production of its shipbuilding program in different yards. The model will find an optimum cost solution to this long range problem based upon cost of production, and an estimation of the prices which subsequently will be charged. This second aspect, i.e., the price charged as opposed to the cost of production, is a critical part of our competitive allocation model. The Navy recognizes that its price will be higher than the cost of production and indeed, a profitable industry is a necessary requirement for a viable industry.

In order to achieve this management of the market mechanism, the Navy will use a combination of allocation of ships and competition. Certain ship classes will receive both competition and allocation. The Navy would choose to allocate under several conditions.

- They would allocate when there is a significant production cost leader. It should be recognized that staging competitions when a price leader exists can tend to encourage the price leader to raise his prices to the level of the

next most efficient producer. The Navy could therefore expect that bilateral negotiations in an allocation process could give them a price advantage as opposed to staging competition. The Navy in conducting this negotiation will, of course, have a prediction on what the cost would be if it went to the next most efficient producer. Therefore, there is a level beyond which it would no longer be in the Navy's interest to carry on such a negotiation process.

- Another time at which the Navy would allocate is when there is sufficient technical justification to produce a ship at a given yard. Technical justifications would include the allocation of a lead ship to a yard which has had long experience in the design and production of that particular class of ship. Justification could also include the limitation upon the ability to produce because of nuclear qualification, subsurface vessel, etc. Another technical justification which would dictate allocation as opposed to competition, would be the physical capacity of a yard to produce the ships, either in terms of quantity of production or in size.

In all cases of technical justification, it should be recognized that there is an investment tradeoff. That is, a certain investment in almost any yard would give this yard the capacity to produce a given class of ships. There may be instances where it is in the Navy's long range best interest to develop this technical capacity in yards which do not currently have it. Examples of this could be, for example, the development of a second yard for production of nuclear ballistic submarines. Without prejudging the results of such analysis, the Navy should be aware of the long range cost of going with a monopoly supplier and be in a position to judge whether the Navy is better served by establishing alternative sources.

- In general, evidence indicates that alternative sources for procurement do lead to lower prices to the government due to the nature of the competitive environment. Thus, there will be instances when the Navy will choose to allocate ships to a second producer to establish this alternative source, with the expectation that this will lead to long term cost reduction.
- A final instance in which the Navy may choose to allocate as opposed to engaging in competition would be when the viability of a yard deemed essential to the Navy's long term interests are threatened. This could take place when, for instance, a yard does not have a sufficient backlog to carry it through a troublesome time, even though the Navy may recognize that it is in its long range interest to protect the capacity of this yard to produce a certain kind of ship.

On the other hand, the Navy will choose to engage in price competition, when the Navy is expected to benefit from the competitive process. Competition specifically would take place when the prediction for the cost of production or price in different yards is close. In these instances the Navy would be expected to benefit in both long and short terms from this price competition. It would also choose to compete when it perceives that staging a competition will reduce the price because the competitive behavior of the firms which are eligible would be expected to interact in a way to reduce the cost of production and potentially the fee charged. Through its more careful intervention in the competitive processes it can be expected that the long term result will be more frequent and more meaningful price competitions.

For given classes of ships or given buys, the Navy, of course, would choose to procure through a combination of competitive and allocation processes. This active interaction by

the Navy in the management of its acquisition problem would depend upon having a reasonably accurate prediction in the relative cost of production in different yards, and on understanding the nature of the specific competitive processes at work in this industry. The necessary analysis, which would supply these two requirements, is the subject of the next two chapters of this report.

7.

ANALYSIS MODEL

The analytic approach used by TASC in planning for competitive allocation in the shipbuilding industry is shown in Fig. 7-1. This analytic model is expected to be constructed in modular fashion with four separate modules. This phase of the program has emphasized the question of feasibility, consequently attention at this time has been devoted to the yard cost model and to the price, allocation estimator. The PARAIDE<sup>TM</sup> computer program is currently operational at TASC and would require little modification to handle our problem. Feasibility is not a question for the executive block which will be used to handle the overall management of the computer program and will seek the optimization solution.

The analytic model will use two separate types of input. The first and most often used will be the demand on the industry. This demand will be new naval ship requirement, an estimation of commercial production during the planning period, an estimate of the repair and conversion requirement, and the backlog position of the yards at the time of the analysis. It is expected that the model will be concerned primarily with the activity of the large yards which are capable of producing major Navy ships. Accordingly, the commercial and repair and conversion demand must be broken into those elements which will be satisfied by these thirteen or so yards capable of Navy construction. The estimates for repair and conversion and commercial production must be extracted from standard projections. The mechanism by which commercial production will be handled has not been resolved at

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PARAIDE is a trademark of The Analytic Sciences Corporation.

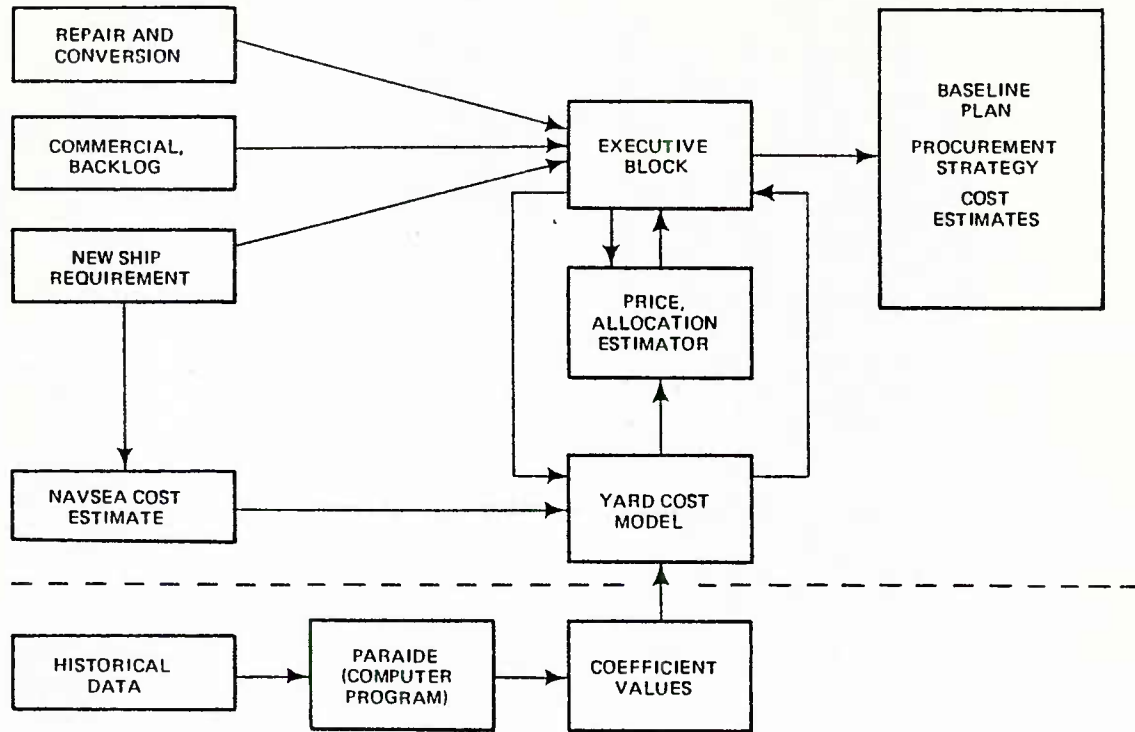


Figure 7-1 Analysis Model

this time. Commercial activity could be used in the same manner as the new Naval ship requirements as a part of the total demand on these yards. It is more likely, however, that commercial production will be allocated to individual yards and will form part of the presumed backlog. This allocation will be based upon MARAD projections available at the time of the operation of the model. Significant conversion activity, of the same order of magnitude as new ship construction, e.g., Service Life Extension Program (SLEP), would be handled in the same manner as the new ship requirements. The more normal repair and conversion activity has been handled historically as a leveling and filling device and would be expected to be treated in a similar manner in this model. An estimate must be made of the extent of this activity, particularly in terms of the labor requirement in these major yards.



The second major input required to operate the model is yard cost coefficient data. Historical data will be used to generate coefficients for comparative costing among the yards. This modeling approach will receive more attention later in this chapter. It should be noted at this time, however, that yard and ship specific data over the past few years must be collected in order to establish a data base, which can be used to predict cost in individual yards. This data base can be collected and evaluated separately from the day-to-day input required for model use.

The dotted line in Fig. 7-1 refers to the operation of the coefficient generating model, which will be handled separately from the major decision aspects of the model. It is anticipated that coefficient updating using a PARAIDE-type program would be performed on an annual basis, using an updated data base in each case. This would generate coefficients which would be used over the next year for purposes of yard cost estimation. The historical data base would be exercised through the TASC proprietary computer program PARAIDE to generate maximum likelihood values for the coefficients in the yard cost equations. The coefficient values which result from this analysis would then be used as input to the main analysis model. It is anticipated that these coefficient values would change relatively infrequently and would not be part of the normal input in the exercise of the model on a day-to-day basis.

The last input to the analysis model is the NAVSEA cost estimate for the ship under consideration. The best available NAVSEA cost estimate would be used and the yard cost model would have to be sufficiently flexible to handle the ship cost estimate in the various forms in which it is generated by NAVSEA. It is not anticipated that this model would interfere in any way with the cost estimating procedures of

NAVSEA -- rather, the philosophy of this modeling approach is to use the NAVSEA estimate in the form it is produced.

The main analysis model is comprised of three modules. The first, the yard cost model, will calculate the relative differences in production costs for producing a given ship at a given yard with consideration of the yard's backlog position and its labor situation. These estimates for yard cost are then fed into a price and allocation estimator, which will make an estimate of the price behavior which the market will produce, based upon yard production costs, the objectives of individual yard management, and the Navy's desires with respect to the industry as a whole. These modules will be controlled by the executive block, which will in addition seek an optimum solution and include such things as constraints upon individual procurements. This executive block would also process the solution for output.

At this time the output would be expected to be shown in terms of the baseline plan for the Navy in its handling of the five-year program. This plan would allocate individual ships to individual yards and give cost and labor estimates of this total program, broken down by ship and yard. In addition, it would indicate a suggested procurement strategy. It would indicate which vessels should be allocated and which vessels would be the subject of price competition. The output would indicate those yards which would be expected to compete in such price competition and would make a prediction on the expected outcome. The baseline plan in its gross features, would be expected to be more accurate than these detailed allocations. It is anticipated that the plan would be frequently updated, based upon individual procurement actions as each new ship passes through the procurement process. Specific detail follows on the modeling approach which is used in the yard cost model and in the price allocation estimator.

## 7.1 MODELING THE COST OF SHIPS

### 7.1.1 Introduction

The following approach develops quantitative relationships which determine the price of ships. Pricing is modeled in a two-stage process, wherein an estimate is first made of the cost to a given shipyard for building a ship, and this cost is then used in a separate module to estimate the price which will be acceptable to that yard for the ship. This second stage involves game theoretic considerations and as such is of a different nature from the first stage, which is a direct cost estimation.

The functional relationships between variables are tentatively formulated and are expected to change, based on later analysis with real data. Certain parameters given in the model are to be evaluated by a statistical package (PARAIDE) designed to permit testing of alternative functional representations to achieve the maximum likelihood fit to the data base.

The overall cost for a ship will be represented as the sum of costs, to the Navy and the shipbuilders.

$$C_{ij} = D_{ij} + O_{ij} + P_{ij} + G_j + U_j \quad (7.1-1)$$

where:

$C_{ij}$  = total cost to the purchaser of building  $j$  ship in yard  $i$ , in terms of dollars as expended (not constant dollars).  
This figure may include "cost overruns"

$D_{ij}$  = direct cost to yard  $i$  of building ship  $j$ , in terms of dollars as expended

$O_{ij}$  = overhead of yard  $i$  attributed to building ship of type  $j$

$P_{ij}$  = actual profit or fee accruing to yard  
i, in dollars, in the manufacture of  
ship of type j

$G_j$  = cost of operational equipment furnished  
by purchaser (GFE, when purchaser is  
government)

$U_j$  = costs to purchaser not directly related  
to building process (administrative,  
testing, etc.)

$G_j$  and  $U_j$  will be taken as given quantities, for the  
present year. The only expressions concerning their values  
are:

$$G_j = G_j^0(1+I_g)^{t_1} \quad (7.1-2)$$

$$U_j = U_j^0(1+I_u)^{t_2} \quad (7.1-3)$$

where:

$G_j^0$  = estimate of  $G_j$  if built at the present  
time

$U_j^0$  = estimate of  $U_j$  if done at the present  
time

$I_{g,u}$  = inflation rate of this cost category

$\{t_k\}$  = times at which costs are actually incurred

Provision is made in the model for differential  
inflation rates. The best available inflation rate will be  
used for each cost component.

$P_j$  will, of course, be dependent on the price stipu-  
lations in the contract between purchaser and builder. It is  
estimated in the second module.

$D_{ij}$  and  $O_{ij}$  are dependent on yard operation and may be related to the conditions within a given yard, as applied to the ship under consideration. These relations are now developed.

7.1.2 Relations for  $D_{ij}$  and  $O_{ij}$

Consider first the overhead  $O_{ij}$ , which is easier to formulate. We will express this as

$$O_{ij} = \dot{O}_{ij}D_{ij} + F_{ij} \quad (7.1-4)$$

where:

$\dot{O}_{ij}$  = overhead rate for yard  $i$  at the time of building ship of type  $j$

$F_{ij}$  = exceptional fixed investment, if any, for ship of type  $j$  by yard  $i$

$F_{ij}$  represents any fixed investment which must be made in yard  $i$  when a ship of type  $j$  is to be built there for the first time. This cost is allocated completely to the first ship rather than being spread over several ships of the same type. If the ship is to be built early in a plan period, the fixed investment will probably be written off over the plan period. If the ship is to be built later, then this costing procedure may cause an overestimation (if, in fact, more ships of type  $j$  are to be built after the five-year period) but it is anticipated that this error will be self-correcting by changes in later yearly replanning allocations.

We may write

$$F_{ij} = F_{ij}^0(1+I_f)^t \quad (7.1-5)$$

where:

$F_{ij}^0$  = estimate of  $F_{ij}$  in the present year for yard i and ship j

$I_f$  = inflation rate for capital investments

t = projected time at which special equipment will be expensed

The equation for overhead rate  $\dot{O}_{ij}$  will be based on historical observation of its relation to yard conditions and is given as

$$\begin{aligned} \dot{O}_{ij} = & \alpha_{1i} + \alpha_{2i} B_i + \alpha_{3i} \left( \frac{R_{ij}}{R_{ij} + V_{ij} + L_{ij}} \right) \\ & + \alpha_{4i} \left( \frac{V_{ij}}{R_{ij} + V_{ij} + L_{ij}} \right) + \alpha_{5i} S_i \end{aligned} \quad (7.1-6)$$

where:

$B_{ij}$  = backlog of yard i at the time when ship j is being constructed, not yet completed but under contract

$R_{ij}$  = initial estimate of present cost of material supplied by shipyard i for ship j

$V_{ij}$  = initial estimate of present cost of sub-contracts which will be procured by yard i to build ship j

$L_{ij}$  = initial estimate of present cost of labor to yard i for ship j. (This is further described below)

$S_i$  = average number of shifts operating per day at yard i during period of building ship j

$\{\alpha_{ni}\}$  = parameters, to be determined

The direct cost  $D_{ij}$  is found from  $R_{ij}$ ,  $V_{ij}$ , and  $L_{ij}$ , and is dependent on the time at which the ship is built and the experience with building type  $j$  ships:

$$D_{ij} = [L_{ij}(1+I_L)^t + R_{ij}(1+I_R)^t + V_{ij}(1+I_V)^t] (1+N_{ij})^{-\lambda_i} \quad (7.1-7)$$

where:

$I_L$  = labor inflation rate

$I_R$  = material inflation rate

$I_V$  = subcontract inflation rate

$t$  = time at which ship is built

$N_{ij}$  = number of ships of type  $j$  previously built at yard  $i$

$\lambda_i$  = learning curve coefficient for yard  $i$   
(with  $\lambda_i > 0$  to be determined from the data analysis)

Note that we have ignored the time elapsed between building the previous ships of type  $j$  at yard  $i$ . One might specify a cut-off point at which time previous experience is no longer considered valid. Also, it is clear that this formula would not hold for large values of  $N_{ij}$  (since  $N_{ij}^{-\lambda_i} \rightarrow 0$  as  $N_{ij}$  increases), but the fit is expected to be good for the smaller  $N_{ij}$ 's associated with ships. This will not give the usual learning curve values since several of the effects normally attributed to learning are specifically included in our direct cost equation. Rather it will be a yard specific value based on the cumulative data base from the specific yard.

The estimated split of cost among labor, material, and subcontracts would be based on historical data for the given yard with regard to the type of ship under consideration.

A distinction is made between raw material and subcontracts since practice varies among yards.

One way to estimate direct cost is to use the NAVSEA method, where the components of the ship and its design are classified according to subsystem as hull, propulsion, electric, command and surveillance, auxiliary, outfit/furnishings, armament integration/engineering, and ship assembly and support services. Manhours and material associated with each subsystem are estimated by using standard multiplicative factors in connection with the estimated weight of each of the physical systems. This is then allocated to main contract work and subcontracts for a given yard by means of allocation factors, as follows:

$$H_{ij}^0 = \sum_{k=1}^9 W_{jk} h_{jk} f_{ik}$$

$$H_{ijk}^1 = W_{jk} h_{jk} (1 - f_{ik})$$

$$R_{ij} = \sum_{k=1}^9 W_{ij} r_k f_{ik}$$

$$R_{ij}^1 = \sum_{k=1}^9 W_{jk} r_k (1 - f_{ik}) \quad (7.1-8)$$

where:

- $H_{ij}^0$  = initial estimate of manhours at yard i on ship j
- $H_{ijk}^1$  = initial estimate of subsystem k manhours by subcontractors if ship j is built at yard i
- $R_{ij}^1$  = dollar amount of material to be supplied by subcontractors if ship j is built at yard i at present time



$W_{jk}$  = weight of ship j which is classified in subsystem k

$h_{jk}$  = manhours/ton labor estimate for subsystem k of ship j

$r_k$  = dollars/ton material estimate for subsystem k at present prices

$f_{ik}$  = historical fraction of subsystem k work done in-house by yard i

Of the three quantities  $R_{ij}$ ,  $V_{ij}$ , and  $L_{ij}$ , these equations define  $R_{ij}$ . An expression for  $V_{ij}$  is given as

$$V_{ij} = R_{ij}^1 + \sum_{k=1}^9 c_{ik} H_{ijk}^1 + \sum_{k=1}^9 I_{ijk} \quad (7.1-9)$$

where:

$c_{ik}$  = average hourly labor cost for component work in subsystem k

$I_{ijk}$  = other indirect cost of including profit and overhead

The  $c_k$  will be taken as industry averages for the particular type of work required, and these may be estimated from historical data,  $I_{ijk}$  will be handled similarly. Alternatively one could estimate  $V_{ij}$  directly and derive the fraction of the labor and raw material it accounts for.

In order to compute labor costs for the yard itself, all labor is grouped together and an average rate per yard is used. The actual number of hours of labor at yard i will be different, in general, from the estimated baseline depending on the conditions existing in the yard at the given time. The variables selected are justified in the previous chapters. This is expressed as,

$$H_{ij} = \beta_{1i} H_{ij}^0 Y_i^{-1} (1 + \beta_{2i} T_i) A_i^{-1} (1 + \beta_{3i} S_i) \left(1 + \frac{\beta_{4i} V_{ij}}{L_{ij} + R_{ij} + V_{ij}}\right) E_{ij}^{-1} \left(1 + \beta_{5i} \left|\frac{\Delta M_i}{\Delta t}\right|\right) \quad (7.1-10)$$

where:

$H_{ij}$  = predicted actual manhours at yard i  
in building ship j

$H_{ij}^0$  = baseline manhour prediction

$Y_i$  = employment level factor for yard i,  
as discussed below

$T_i$  = turnover rate at yard i during time of  
construction expressed as fraction of  
workers who leave, plus fraction who  
join the yard, per year

$A_{ij}$  = average time, in yards, since hire of  
work force at yard i, at the midpoint  
in completion of the work on ship j

$E_{ij}$  = average experience time, in years, of  
first level supervision at yard i, at  
the midpoint in completion of the work  
on ship j

$\Delta M_i$  = change in total employment of yard (num-  
ber of workers) in time period of length  
 $\Delta t$  preceding midpoint in completion of  
work on ship j

$\beta_{ni}$  = parameters, to be determined

The yard employment factor,  $Y_i$ , recognizes that each yard has its own optimal employment "window" in which economies of scale can work to its advantage. At employment levels below this, lack of specialization and fixed costs start to make operation inefficient, while above this region the yard is not able to utilize its manpower efficiently due to overcrowding. The curve of  $Y_i$  is presumably concave downward, but we have chosen, for simplicity, to represent it as a piecewise

linear curve, which is greater than 0 at small employment levels. The level is less than one eventually as employment increases due to the physical inability of the facility to accommodate greater employment. Thus

$$\begin{aligned}
 Y_i &= 1 - \gamma_{1i}(M_{imin} - M_i), & M_{ij} &\leq M_{imin} \\
 Y_i &= 1, & M_{imin} &\leq M_{ij} \leq M_{imax} \\
 Y_i &= 1 - \gamma_{2i}(M_i - M_{imax}), & M_{io} &\geq M_{ij} \geq M_{imax} \\
 Y_i &= 0, & M_{ij} &\geq M_{io}
 \end{aligned}
 \tag{7.1-11}$$

where:

- $M_{ij}$  = average employment level at yard  $i$  during time of building ship  $j$
- $M_{imin}, M_{imax}$  = break points of yard efficiency, to be estimated or derived from data base
- $M_{io}$  = employment level at yard  $i$  which cannot be exceeded to be estimated or derived from the data base
- $\gamma_{ni}$  = parameters, to be estimated or derived from data base

If there are no data available for estimating  $M_{imin}$ ,  $M_{imax}$ , and  $M_{io}$ , then these quantities can be estimated by knowledgeable people (Delphi technique).

The direct labor costs are then given at yard  $i$  by

$$L_{ij} = H_{ij}W_i \tag{7.1-12}$$

where:

- $W_i$  = hourly wage rate in yard  $i$

To summarize the cost estimation step of the model: the NAVSEA estimate of the basic manhours needed to build a

given ship is adjusted for specific conditions at a given yard at a given time. The adjusted manhour estimate and average wage are used to find labor cost. Material and subcontract estimates, the effect of inflation, and the effect of the learning curve (which will be empirically tested, with all the other efficiency factors) will be combined with the labor cost to find the direct cost of the ship. Overhead costs, profit (as determined by the price estimation step), GFE costs, and administrative costs will be added to the direct cost to find the total price to the Navy of the given ship.

## 7.2 EVALUATING YARD WORKLOAD CONDITIONS FOR A GIVEN SCHEDULE

The equations of the previous section are based on yard conditions at the time that a ship is built. These conditions, however, depend on many other factors associated with the business of the yard, and not just on the ship under construction. For instance backlog and due dates are important, as well as local labor market conditions. In this section we present an approach which will establish equations which relate these yard conditions to its previous history and to other work contracted for or expected to be contracted for. The validity of these equations will be tested by use of historical data of previous yard operations.

Assume that a set of ships  $\{j\}$  is to be built at a set of yards  $\{i\}$  within a time frame specified for the model. Commercial business, as well as repairs and conversions, will be included in the set  $\{j\}$ , along with Navy ships. An assignment will be made beforehand, as input to the model, of each ship  $\{j\}$  to yard  $\{i\}$ .

It is convenient to list and number ships at any given yard  $\{i\}$ . Let us call this list the sequencing  $\{r\}$ , and let

$P(r,i)$  = time period at which  $r$ -th ship at yard  $i$  is due to be delivered, where time periods of a fixed length (such as 3 months) are defined, starting at the beginning of the program as first period, second period, etc. We assume that if  $r_1 < r_2$  then  $P(r_1,i) \leq P(r_2,i)$  so that the sequence  $\{r\}$  is in the order of due dates

From this it is clear that the  $j$ -th ship in the original ordering becomes the  $r$ -th ship at yard  $i$  if and only if  $j$  is assigned to  $i$  and there are exactly  $r-1$  ships in  $\{j\}$  assigned to  $i$  with due dates prior to that of ship  $j$ . Further let

$N(r,i)$  = number of ships previously built at  $i$  of the same type as the  $r$ -th ship, at the time of building the  $r$ -th ship

$N_0(r,i)$  = number of ships previously built at  $i$  of the same type as the  $r$ -th ship, as of the beginning of the program

$q(r,i)$  = type of the  $r$ -th ship at yard  $i$

$P$  = total number of time periods

Then

$$N(r,i) = N_0(r,i) + \sum\{1:k < r, q(k,i) = q(r,i)\} \quad (7.2-1)$$

for each  $r$  and  $i$ .

Let  $B(i,p,p^1)$  represent the backlog at yard  $i$ , in manhours, at the beginning of the  $p$ -th period and which is due in the  $P^1$ -th period. That is  $B(i,p,p^1)$  represents the amount of work which must be done, starting at the  $p$ -th period, to

finish all ships due in the  $p^1$ -th period or before. We shall give a method later of computing the required manhours on a given ship. The labor-force level desired at yard  $i$ , during period  $p$ , will be assumed to be a linear function of backlog, although later investigation may suggest a different representation. Let

$M^1(i,p)$  = desired labor force level at yard  $i$   
 at the end of time period  $p$  (in  
 numbers of production workers)

Then

$$M^1(i,p) = \sum_{p^1=1}^p \theta_{p^1} B(i,p,p^1) \quad (7.2-2)$$

where the  $\theta$ s are the parameters to be determined.

The sum ranges over all values of  $p^1$ , including  $p^1 < p$ , since it is possible that previous deadlines have not been satisfied.

We shall assume, for the simplicity of this representation, that all work done in a given period at a given yard is applied first to the  $r$ -th ship, where  $r$  is the lowest number ship not yet completed by that period, then to the  $(r+1)$ st ship, etc. Let

$$MP_o(p,i) = \sum \{MS(r,i) : P(r,i) \leq p\} \quad (7.2-3)$$

and

$$TW(p,i) = \sum_{v=1}^p W(v,i) \quad (7.2-4)$$

From there we get the expression for  $B$ :

$$B(i,p,p^1) = \begin{cases} 0 & \text{if } MP_o(p^1,i) \leq TW(p-1,i) \\ MP_o(p^1,i) - TW(p-1,i) & \text{otherwise} \end{cases} \quad (7.2-5)$$

Thus backlog is determined at each period based on work in the previous periods. The desired work force level  $M^1(i,p)$  may not be reached at the end of period  $p$  if it requires a too rapid buildup in the labor force at  $i$ . Let

$$M(i,p) = \begin{array}{l} \text{actual labor-force level at } i \text{ at the} \\ \text{end of period } p \text{ (men)} \end{array}$$

We shall impose the constraint, based on historical experience, that yard  $i$  cannot grow faster than a given rate  $g_i$ , so that

$$M(i,p) \leq (1+g_i) M(i,p-1) \quad (7.2-6)$$

There is also a growth limitation based on the available labor pool in the area of yard  $i$ , expressed as a constant. Thus,

$$M(i,p) \leq M(i,p-1) + K_i \quad (7.2-7)$$

where  $K_i$  is the maximum possible labor growth at yard  $i$  during one time period. The final equation describing  $M(i,p)$  is given by

$$M(i,p) = \min\{M^1(i,p), (1+g_i) M(i,p-1), M(i,p-1) + K_i\} \quad (7.2-8)$$

Strictly speaking,  $K_i$  depends on time as well as the yard, but for this model we shall assume dependence on  $i$  only. Note that no restriction is placed on how fast a yard's labor force may decrease in size.

We assume that the transition from level  $M(i,p-1)$  to level  $M(i,p)$  is done in a linear fashion over the  $p$ -th interval. The total work done in that period is computed as follows.

The curve of labor-force level during period  $p$  is expressed by the equation

$$y = M(i,p-1) + [M(i,p) - M(i,p-1)]x \quad (7.2-9)$$

where  $x$  varies from 0 to 1. We assume, as in the previous section, that there is an efficiency factor  $Y_i = Y_i(y)$  associated with each level of labor force, and also a penalty for change associated with effective labor output. We will calculate  $W(p,i)$  as the effective work output, which means that a factor must also be included to account for subcontract work. For this last, we define

$$SU(p,i) = \begin{array}{l} \text{subcontracting factor at yard } i \\ \text{during period } p \end{array}$$

$SU(p,i)$  will be a linear combination of  $M(i,p-1)$  and  $M(i,p)$  whose value is 1 for an "average" work level at  $i$ . The coefficients of the linear expression are to be determined statistically.

Using the above, the expression for  $W(p,i)$  is

$$W(p,i) = \frac{SU(p,i)}{1 + \beta_{5_i} [M(i,p) - M(i,p-1)]} \int_{M(i,p-1)}^{M(i,p)} y \cdot Y_i(y) dy \quad (7.2-10)$$

where  $\beta_{5_i}$  is as in the previous section.



Since  $Y_i(y)$  is piecewise linear in  $y$ , the integral will, in general, be a sum of three integrals of quadratic forms in  $y$ , giving a sum of three cubic forms in  $y$ . The specific equations are dependent on whether  $y$  is increasing or decreasing, and the breakpoints in the  $Y_i$  curve.

Finally, we must determine the date at which a ship will be finished. For purposes of computing finish dates it is convenient to assume that ships are built sequentially. Thus the  $r$ -th ship at yard  $i$  will have a completion date in period  $p(r,i)$ , where  $p(r,i)$  is such that

$$TW\{\bar{p}(r,i) - 1,i\} < \sum_{v=1}^r MS(v,i) \leq TW\{\bar{p}(r,i)i\} \quad (7.2-11)$$

The actual time at which the  $r$ -th ship is completed may be taken as the midpoint of period  $p(r,i)$ , for purposes of computing costs. The time span during which the  $r$ -th ship was constructed is not taken as starting at  $\bar{p}(r-1,i)$  but rather at  $p(r,i) - CT(r,i)$ , where

$CT(r,i)$  = expected construction time required  
to build the  $r$ -th ship at yard  $i$

Inflation for materials is figured throughout the time span  $\{\bar{p}(r,i) - CT(r,i), p(r,i)\}$ , but may all be computed at time

$$t = \bar{p}(r,i) - 0.5CT(r,i)$$

where  $t$  is as in the previous section.

The initial estimate of man periods required for a given ship,  $MS(r,i)$ , is founded on considerations stated in the previous section. If  $H_{ij}$  is the initial estimate of the number of hours of work at yard  $i$  to build the first ship of a

given type, then this figure is multiplied by  $(N_{ij}+1)^{-\lambda_i}$  to get MS for this ship. Thus if the r-th ship at i is listed as ship j in the original list, we have

$$MS(r,i) = KH_{ij}(N_{ij}+1)^{-\lambda_i} \quad (7.2-12)$$

where K is a constant to correct for different measures (e.g., manhours to manmonths or to manyears).

We may also want to compute the average backlog for ship r in yard i, throughout its construction life. If NP(r,i) is the number of periods in CT(r,i) (next higher integer), then the average backlog for ship r at i is

$$AB(r,i) = \frac{\sum_{p=\bar{p}(r,i)}^{\bar{p}(r,i)} \bar{p}(r,i) - NP(r,i) + 1}{NP(r,i)} B(i,p,P) \quad (7.2-13)$$

Similarly, the average labor-force level during that time is

$$AL(r,i) = \frac{\left[ 2 \cdot \sum_{p=\bar{p}(r,i)}^{\bar{p}(r,i)} \bar{p}(r,i) - NP(r,i) \right] M(i,p) - M[i, \bar{p}(r,i) - NP(r,i)] - M[i, \bar{p}(r,i)]}{2 \cdot NP(r,i)} \quad (7.2-14)$$

where the numerator represents the sum of average labor-force level during each period (multiplied by 2 for convenience of notation).

In summary, the inputs to this phase of the model are

- P(r,i) = due date of r-th ship at i
- $N_0(r,i)$  = number of ships already built at i  
of same type as r-th (at time 0)
- q(r,i) = type of r-th ship i

$MS(r,i)$  = manpower requirements for r-th ship  
at i

$g_i$  = maximum growth rate of yard i

$K_i$  = maximum growth amount at i

$SU(r,i)$  = function describing the amount sub-  
contracted at i

$CT(r,i)$  = construction time of r-th ship at i

as well as all parameters in equations and all input required  
for the previous section. The outputs from the model are:

$N(r,i)$  = number of ships of same type as r-th  
built at i (to be computed for the  
"last" r of each type)

$B(i,p,p^1)$  = backlog at each period at i, by due  
date of ships

$AB(r,i)$  = average backlog during the building of  
r-th ship

$AL(r,i)$  = average labor-force level during the  
building of each ship

$M(i,p)$  = labor-force level at the end of each  
period

$W(p,i)$  = total work done at i during each  
period

$t$  = median time at which construction  
takes place

$\bar{p}(r,i)$  = period during which construction finishes  
on a ship

### 7.3 MODELING COMPETITIVE ALLOCATION: PRICE ESTIMATION

In this section of the report an approach to modeling  
competitive allocation is presented. The application of com-  
petitive allocation to Navy shipbuilding programs is then  
examined. Two cases are presented as examples.

"Competitive allocation" is the allocation among shipyards of a production plan which uses the price benefits of competition and the stability benefits of allocation to result in a shipbuilding program which will cost the Navy the least, given other objectives and constraints such as suitable quality of products, attainment of schedules, and maintenance of industry capacity.

### 7.3.1 Approach to Modeling Price Estimation

Minimum cost allocation can be determined with a model of the costs of each yard. The process involves the minimization of total cost of procurement for ships in the Plan for M yards for N periods. Implicit in the minimization is the constraint that ships will only be allocated to yards which can meet the required completion date. The output of this minimization is a time sequence of contracts which should be allocated to each yard. The output can be used to guide the Navy's decisions about the allocation and competition for ships.

The process by which the actual allocation is made equal to the desired allocation involves the objective functions of each of the yards, i.e., the actual financial objectives established by the management of each yard. It is assumed that the yard is aware of the fact that it is facing a demand curve which gives quantity of contracts as a function of its price. The problem then reduces to asking how the Navy should respond to the prices of the yards such that the demand function for each yard is of the form which results in the desired allocation.

### 7.3.2 Demand and Objective Functions

A demand function relates the number of contracts awarded to a given yard and to its price. While the Navy on the whole has a single demand function, each yard will face a different demand function due to differing Navy perceptions on efficiency, quality of work, desire to use multiple yards, etc. We shall assume the demand functions for the yards have the form

$$q_{ij} = [d_{ij}P_{ij} + e_{ij} \sum_{k \neq i}^M P_{kj} (M-1)]D_j \quad (7.3-1)$$

where:

- $D_j$  = total quantity of ships of type j desired
- $q_{ij}$  = quantity of ships of type j contracted for in yard i
- $P_{ij}$  = price of ships of type j in yard i
- $d_{ij}$  = price parameter of demand based upon yard's own price
- $e_{ij}$  = price parameter of demand based upon other yard's prices
- $M$  = number of yards in the market for ships of type j

A technique for determining the coefficients  $d_{ij}$  and  $e_{ij}$  will be given later. In general, one expects  $d_{ij}$  to be less than zero and  $e_{ij}$  to be greater than zero. This says that as the price of a ship in yard i goes up the quantity contracted for will go down and as the average price charged by other yards goes up the number contracted for in yard i at a given price will go up. The size of these two coefficients expresses how sensitive the Navy is to prices in a given yard.

The problem can be formulated under the assumption that  $e_{ij}$  is identically zero. This, however, would greatly reduce the stability of the system with regard to errors in estimating the costs. It does, however, raise the question of whether such information is available to the individual yard. From our discussions with the yards we believe this information is available to the yard and is being used at the present time.

A yard's objective function will be defined as the relationship between price and quantity which it want to achieve in order to obtain its ultimate financial objective. Different yards will have differing financial objectives, e.g., maximizing profit or sales, or obtaining a specific return on investment. For example, if a yard is a profit maximizer, its objective function is

$$P(q) + q \frac{dP(q)}{dq} = \frac{dC(q)}{dq} \quad (7.3-2)$$

Notice that in order for this equation to be expressed in terms of only  $P$  and  $q$ ,  $P(q)$  and  $C(q)$  must be known.  $P(q)$  is simply the inverse of the demand function and  $C(q)$  is determined by the cost model. In effect, the technique determines the coefficients of the demand function which will yield the desired allocation and price. The assumption here is that the cost function is a known function of the physical factors in the yard and is not effected by the choice of demand function. For further model development we will investigate relaxation of this assumption.

An objective function need not be the result of maximizing behavior; it may simply be the result of an arbitrary goal set by the management. For example, suppose the management decided to produce at a point where they obtained "a"

percent return on their cost, the objective function then becomes

$$P(q) \cdot q = (1+a) C(q) \quad (7.3-3)$$

This function is then solved simultaneously with the demand function to determine the value of P and q.

### 7.3.3 Derivation of $d_{ij}$ and $e_{ij}$

In order to determine  $d_{ij}$  and  $e_{ij}$ , the firm's objective function is expressed in terms of quantity. This expression is equated with a generalized demand function, which contains  $d_1$  and  $e_1$ , and which also is expressed in terms of quantity. Manipulations of the resulting equation yield  $c_{ij}$  and  $e_{ij}$ .

### 7.3.4 Example

From discussions with Bath Iron Works and Todd, it was determined that Bath's objective is to maximize its return on investment, and Todd's objective is to maximize cash flow. In terms of prices, quantities, and functions existant in the cost model the two objectives are:

$$\text{Bath: Maximize} \quad \frac{q_1 P_1(q_1) - C(q_1)}{I_F + I(q_1)} \quad (7.3-4)$$

$$\text{Todd: Maximize} \quad q_2 P(q_2) - C(q_2) + K\delta(q_2) \quad (7.3-5)$$

where  $I(q)$  is the incremental investment required as a function of the number of ships to be built, and  $\delta(q)$  is the rate of depreciation as a function of q. This simply says that Bath is very sensitive to the level of investment required and

that Todd will not replace capital loss due to depreciation. This results in the following objective function for Bath

$$\frac{dP_1}{dq_1} = \frac{P(q_1) - C(q_1) \frac{dI}{dq_1}}{[I_F + I(q_1)]q_1} + \frac{\frac{dc}{dq_1} - P(q_1)}{q_1} \quad (7.3-6)$$

The objective function for Todd is:

$$\frac{\partial P_2}{\partial q_2} = \frac{\frac{\partial C}{\partial q_2} - P(q_2) - K \frac{d\delta}{dq}}{q_2} \quad (7.3-7)$$

The form of the demand functions to be faced by the competitors is

$$\text{Bath:} \quad q_{1j} = (P_1 d_1 + P_2 e_1) D_j \quad (7.3-8)$$

$$\text{Todd:} \quad q_{2j} = (P_2 d_2 + P_1 e_2) D_j \quad (7.3-9)$$

Differentiating Eq. 7.3-7 and substituting Eq. 7.3-8 into Eq. 7.3-6 yields

$$d_1 = \frac{1}{D} \frac{[I_F + I(q_1)]q_1}{P(q_1) - C(q_1) \frac{dI(q_1)}{dq_1} + [I_F + I(q_1)] \left[ \frac{dC(q_1)}{dq_1} - P(q_1) \right]} \quad (7.3-10)$$

Substituting this back into the demand Eq. 7.3-8 and solving for  $e_1$  we have

$$e_1 = \frac{q_1}{DP_2} - \frac{P_1}{DP_2} \frac{[I_F + I(q_1)]q_1}{P(q_1) - C(q_1) \frac{dI(q_1)}{dq_1} + [I_F + I(q_1)] \left[ \frac{dC(q_1)}{dq_1} - P(q_1) \right]} \quad (7.3-11)$$



All the terms on the right hand side of Eqs. 7.3-8 and 7.3-9 can be determined from the cost model once the desired prices have been determined. At this state of development, the model can determine desired prices by adding what is considered "a fair rate of return" to the costs estimated in the first step of the model. If, for example, a fair price is determined to mean a ten percent return on costs, then

$$P_1 = 1.1 \frac{C(q_1)}{q_1} \quad (7.3-12)$$

Using Eq. 7.3-12 all the terms on the right hand side of both equations are known, so it is possible to solve for  $d_1$  and  $e_1$ .

The same procedure applied to the objective function of Todd yields

$$d_2 = \frac{q_2}{\left(\frac{dC}{dq_2} - P_2 - K \frac{d\delta}{dq_2}\right)D} \quad (7.3-13)$$

and

$$e_2 = \frac{q_2}{DP_1} \left[ 1 - \frac{P_2}{\frac{dC}{dq_2} - P_2 - K \frac{d\delta}{dq_2}} \right] \quad (7.3-14)$$

Again all the terms on the right hand side of the equations are known. It is therefore possible to specify exactly the demand function.

In the examples presented above, reasonable assumptions yield, as expected, negative values for  $d_1$  and  $d_2$  and positive values of  $e_1$  and  $e_2$ . Also the form of the expressions for these variables are important because they tell us exactly what the important factors are in determining the

price sensitivity of the Navy with respect to either of the yards. For example, an estimate of how quickly investment is increasing ( $\frac{I}{q}$ ) is a potentially significant factor in determining  $d_1$ , however, this factor has no significance with regard to  $d_2$ .

#### 7.3.5 Further Development of Price Model

The price model at this preliminary stage shows how the industry can be modeled when taking into account different yard objectives. Further development of the model will include the interaction between yards' prices and the positive effects of competition on price due to reduction in both amount of profit and production costs.

#### 7.4 USE AND MANIPULATION OF MODEL

The basic use for the cost model is to estimate the cost to the shipyards of constructing individual ships in a Plan, if each ship has been assigned to a given shipyard. To find the minimum total cost of ship construction in a Plan, a minimum cost assignment must be found. This will be done by the executive module. Since the model is designed for computer evaluation, the computer would change the choice of yards or ships, taking into account the constraints imposed upon such choices. In this way many plans would be evaluated and the least cost plan identified. The computer can make these comparisons very quickly. However, even a modern computer is limited in speed so that there is an upper limit to the number of plans that can be tested in a reasonable computation time. For example, for the current Five Year Plan, even if the fact that most ship types can be built only in certain yards is taken into account, the number of possible ways of distributing shipbuilding contracts is on the order of  $10^{61}$ .

Other constraints, however, will further limit the set of choices. For example, if a minimum number of ships must be built on a particular coast, the size of the computation will be reduced. It is not known at this time how much such constraints will cut the problem down to a reasonable size. If there are still too many possible allocations, an algorithm will be devised to limit the number of actual allocations tested.

Little effort has been devoted to algorithm derivation at this time. The algorithm will depend on the final form of the model equations and on the specific constraints which have been selected to simplify the problem. However, there are some general approaches which may be adapted later to this particular situation. They are based on minimizing, or "optimizing," the total cost, and are briefly explained here. This problem is one of efficiency rather than feasibility. It will be handled by the executive block of the analytic model.

#### 7.4.1 Sequential Optimization By Dollar Size

A suboptimization procedure which offers a good chance of achieving near optimal costs is the optimal allocation of all ships of a given type at one time, disregarding all other ships in the program except those that have already been allocated. This is done first for the ship that is estimated to have the greatest construction cost, then for the ship with the next highest cost, and so forth. (See Table 7.4-1 as an example of ship cost and relative rankings). This allows the most expensive ship to be assigned first, to be sure that its assignment is correct, for its minimum cost. Then the next most expensive ship is assigned, and so on. This method is based on the reasonable assumption that the percentage to be saved is roughly the same for all ships, so the bigger ships should be assigned first. The optimization

TABLE 7.4-1  
COMPARISON OF SHIPBUILDING COSTS

SHIP TYPE	NUMBER OF SHIPS PLANNED, FLY 79-83	ESTIMATED COST PER SHIP (\$Billion)	RANK BY COST PER SHIP	ESTIMATED COST FOR ALL SHIPS (\$Billion)	RANK BY TOTAL COST
SSBN Trident	6	1.2	2	7.2	1
SSN 688	5	0.43	6	2.15	5
CV SLEP	2	0.44	5	0.88	7
CVV	1	1.5	1	1.5	6
CGN-42	1	0.70	4	0.70	9
DDG-47	7	0.76	3	5.32	2
LX (LSD-41)	2	0.37	7	0.74	8
DDG-2	10	0.24	8	2.4	4
FFG-7	26	0.19	9	4.94	3
MCM	5	0.11	11	0.55	10
T-AGOS	12	0.03	13	0.36	11
T-AO	1	0.18	10	0.18	12
T-AK	1	0.04	12	0.04	13

SOURCE: Department of Defense Authorization for Appropriations for Fiscal Year 1979, Hearing Before the Senate Armed Services Committee, March 23, 1978, p. 4309.

procedure may also be based on total ship cost for a given class (i.e., the cost per ship multiplied by the number of ships). Finally, one might estimate (possibly with the use of a computer) the difference between possible maximum and minimum costs for each ship or ship class, to indicate possible savings for each. With this method, the ship with the greatest possible savings is allocated first.

#### 7.4.2 Simplification of the Cost Function

If the procedure in Section 7.4.1 does not give satisfactory results, e.g., because there are too many ship types which can realize similar savings, then an analytic procedure will be sought. In general, the first step in

determining such a procedure will be to make certain simplifying assumptions about the form of the cost function, for the purpose of using an analytic optimization method. Studying the problem may suggest algorithms that also lead to an optimum. This approach will not be considered until more information is available to estimate the actual size of the computation problem.

It may also be desirable to change the five-year plan by computer, in order to optimize a Navy objective. This can be done either before, or simultaneously with, the variation in allocations for a given schedule. That is, schedule may be optimized in detail for each change of the five-year plan or both may be changed and tested simultaneously, arriving at a joint optimization scheme. Again, the choice of scheme will depend on the final form of the model equations and on the form of the constraints to be imposed.

No matter what method is adopted to test different possible plans and allocations, it is planned that the overall program will be set up to run in a period of time less than one hour on a modern computer. If it is necessary to resort to an heuristic approach then this will be done. On the other hand, if simplification of the objective function will result in a simple but realistic optimization then this will be the approach used.

In any event, a relatively short "executive" program will be developed which will be able to inform the Navy quickly of the effects of different decisions, constraints, and allocations. It is expected the model would be used every time new data on yard operations are available or allocations are made so that a current planned allocation and estimate of future costs would always be on hand. (The PARAIDE type package would be used to update the parameters of the model

when the operations of a yard change fundamentally, approximately yearly). A more detailed analyst's model would also be developed to provide more detail and accuracy and permit more experimentation with options and planning approaches.

8.

DATA NEEDS AND SOURCES

Since published data are not specific enough for the purposes of the model, data will be sought primarily from the Navy and the shipbuilders, via the Shipbuilders Council of America. A request for the preliminary identification of the availability of the desired data has been sent to NAVSEA. Tables 8-1 and 8-2 indicate the historic data which will be needed to accurately estimate the parameters of the cost-estimation part of the model. Table 8-1 indicates the data needed for each Navy ship built in each yard for the past twenty years if possible. Table 8-2 indicates the data needed per period in each yard for the past twenty years if available; monthly or quarterly data are desirable.

If specific categories of data are not available, the equations will be modified to use data in available format. The PARAIDE statistical package will be used to indicate the appropriate degree of confidence in the results determined by the data.

TABLE 8-1  
SHIP-SPECIFIC DATA NEEDS

Shipyard: Ship Number:						
Ship Class	Number of Ships of Same Class Built In Total Yard History	Contract Start Date	Contract Due Date	Actual Delivery Date	Class C Budget Estimate	Actual total Direct Costs Charged
Ship Subsystem			Total Actual Manhours Used To Build Each Ship Subsystems		Actual Cost of Material for Each Subsystem	Weight of Ship Subsystem
a) hull structure		a)		a)		a)
b) propulsion plant		b)		b)		b)
c) electric plant		c)		c)		c)
d) command and surveillance		d)		d)		d)
e) auxiliary systems		e)		e)		e)
f) outfit and furnishings		f)		f)		f)
g) armament		g)		g)		g)
h) integration/engineering		h)		h)		h)
i) ship assembly and support services		i)		i)		i)

8-2



TABLE 8-2  
PERIOD-SPECIFIC DATA NEEDS

Shipyard:						
Period	Average Number of Shifts Operating Per Day	Employment of Full-Time Production Workers	Average Hourly Wage Rate for All Full-Time Production Workers	Average Months of Shipbuilding Industry Experience of First-Level Supervision	Average Months of Shipbuilding Industry Experience of Production Workers	
1.						
2.						
.						
.						
.						
Period	Backlog Measured In Man-Months	Per Cent Overhead Charged	Total Separations	Total Rehires	Total New Hires	
1.						
2.						
.						
.						
.						

8-3

9.

CONCLUSION

During Phase I of the contract for an Analysis of the Shipbuilding Industry, TASC has demonstrated the feasibility of developing a program to utilize more effectively the Navy shipbuilding resources through more efficiently distributing the work load within the shipbuilding industry. A modeling approach has been discussed in the analysis for performing long-range planning of the Navy shipbuilding program with an industry level perspective, yet with visibility at the individual yards. Significant specific achievements of this feasibility demonstration include:

- Identification of a mathematical model describing the essential comparative features of individual yards for purposes of computing shipbuilding costs for a given allocation
- Derivation of an analytic approach to capture the competitive nature of the industry and the noncongruent hierarchy of objectives of the Navy and the individual yards
- Provision of an analytic basis for the competitive allocation concept
- Identification of the required data elements and an identification of their sources
- Identification of a statistical approach which will relate the data base in a maximum likelihood manner to the parameters of the analytic model
- Interviews with key individuals in the Navy and industry to capture the insight and experience of practitioners

- A review of the potentially applicable literature for concepts and results -- particularly those which are useful to the industry viewpoint of the study objectives.

In particular, for the purposes of this analysis, TASC has integrated all of these elements into a single modeling approach. As it is currently being developed, this model will provide a unique tool capturing: the best understanding of the comparative cost to produce in different yards, the elements of competitive allocation, and the minimum cost of an overall shipbuilding program plan.

The long range planning model under development in this contract has been generally recognized as having the potential for a huge payoff to the Navy in terms of cost and orderliness of ship acquisition. Based on this fact, the demonstrated feasibility of the approach justifies continuing development of this valuable tool. Our evaluation verifies the conceptual feasibility of improving Navy ship procurement through better planning mechanisms. It is extremely desirable to pursue further development through, 1) quantitative demonstration of the approach through exercise of the model, 2) more detailed study of the impact of related areas, e.g., contract types, 3) demonstration of the suitability of the existing data, or the collection of new data, and 4) more sophisticated modeling of market interactions.

The approach to developing this model has been to create a useful tool, which accurately expresses the specific nature of the shipbuilding industry. That the model incorporated the main features of the industry was insured by interviews of shipbuilders, Navy and Maritime Administration personnel, and academic and other researchers of the industry. The uses of the model, and its potential policy implications, are significant.

First, the model estimates program costs, which makes it useful as a budget preparation tool. The model allows the Navy to quickly provide information to Congress and the Administration not only on the original budget request, but also on the cost effect of deviations from the initial request. These effects are expressed as differences due to the different yard efficiencies of various shipbuilding programs, as well as the more obvious cost differences due to changes in the actual ship requirements. Another aspect of the model which would be of interest to Congress and the Administration is that it will aid in determining the relative shipbuilding costs for different strategic approaches, including the effects on yard efficiencies. Additionally, it will provide information on the different average yard employment levels needed for different shipbuilding programs, which is of particular interest to Congress.

The model will further aid the Navy by identifying yard costs for particular programs for the purposes of allocating ships or staging competitions. The model can be used to find the solution of the best distribution of shipwork among yards, given Navy objectives and constraints such as "all three coasts must maintain shipbuilding capability." Wherever appropriate, allocations of shipwork can be made to efficient yards. In other cases, competitions can be staged in such a way that only efficient, qualified yards are allowed to compete. This would protect the Navy from unqualified yards buying in; would reduce the "auction" atmosphere of the market for Navy ships; and would encourage the cost and performance benefits of competition.

Another characteristic of the model which would benefit the Navy is that it can be used as a tool for stabilization, because it aids in making decisions for the Five-Year Plan and the Extended Planning Annex. The model would remind both

Congress and the Department of Defense to think in terms of the Five-Year Plan. More important, the model can be used to quickly estimate the cost of deviations from the Five-Year Plan, or the costs of instability; the knowledge and recognition of such costs should encourage decision-makers to seek industry stability.

APPENDIX A

REVIEWS OF INDIVIDUAL STUDIES  
AND LIST OF OTHER STUDIES

NAVAL SHIP PROCUREMENT PROCESS STUDY  
Final Report

Assistant Secretary of the Navy,  
Manpower Reserve Affairs and Logistics,  
Department of the Navy  
Washington, D.C., July 1978

The Naval Ship Procurement Process Study analyzes problems in the ship acquisition procedure to find ways to reduce claims. This study included an analysis of the "workload window" concept, adding to the current opinion that demand stability is desirable. Experience indicates to those who deal with the shipbuilding industry that there is a range of shipyard employment which is efficient; going above or below this range can significantly lower productivity due to overcrowding of the yard or of difficulty in covering fixed costs, respectively. Workload stability is a key factor in being able to keep shipyard employment within efficient ranges.

The study identifies three types of risks involved in naval shipbuilding: technical risk due to complex design; schedule risk due to the four-to-seven-year period needed to construct a ship; and cost risk due to difficulties in predicting costs. Because of the need to fairly allocate risk, the study concurs with the growing support for the use of a cost-type contract for the lead ship of a class. It suggests that, since follow-on ships are often contracted before the completion of the lead ship, cost-type contracts be used for follow ships until risk is sufficiently low to make a fixed-price incentive contract suitable. The success of the FFG program was here again noted as support for contract distinction between lead and follow ships and for additional yards for follow ships.

The "workload window" concept is one which seems for some time to have been in the minds of those who deal directly with the industry, although it has not received much attention in the literature. Judging from several recent shipbuilding programs, it deserves further attention. Thus it has been incorporated into the TASC model permitting both cost and schedule effects from overloading and underloading a yard to be accounted for. Discouraging employment in a shipyard beyond either of its efficiency bounds should also result in greater employment stability. This is expected to have benefits of its own, such as reducing labor turnover, and improving worker morale.

Lastly, TASC concurs that contracts which adequately recognize and reasonably allocate risk can significantly benefit the Navy's shipbuilding programs by contributing to industry viability.



THE PROFITABILITY OF THE  
U.S. SHIPBUILDING INDUSTRY, 1947-1976

June 20, 1978  
Edward M. Kaitz  
(Laidlaw Management Services,  
for Office of Naval Research)

This study, prompted by the conclusion of Profit 76 that shipbuilding was the least profitable industry in the Defense Industrial Base, examined shipbuilding profits in detail. The study concluded that industry-wide profits were unsatisfactory, but that profitability varied between two types of firms. Kaitz found that the yards with conservative sales growth and small, consistent investment in fixed assets experienced consistent profits. The newer, aerospace oriented shipyards, which sought rapid growth and experienced volatile sales, fared much worse financially; this supports the hypothesis of this present study that demand stability will alleviate shipbuilding industry problems. No direct evidence could be found to support any difference in profitability between Navy and commercial construction. The study's findings supported the conclusion that shipbuilding profits are more a function of management than a function of problems inherent to the shipbuilding environment.

The Kaitz study holds that the characterization of the market as an oligopolist facing a monopsonist is misleading for several reasons. First, the industry has experienced relatively low demand since the early 1950's, which implies that shipyards have little of the market control conferred by being in an oligopoly. Second, if Congress allowed, the Navy could build ships in public yards and further diminish the economic power of the shipyards. Lastly, this power of the

Navy is balanced by the Navy's interest in maintenance of industry capacity. These factors, according to Kaitz, make the characterization of the market as monopsonistic or oligopolistic too simplistic.

The Kaitz analysis contains a shortcoming which is beginning to become more recognized in economic thought: the error of confusing industry structure with economic power and behavior. The Navy is the sole buyer, whether or not it has an interest in keeping yards open. There are few suppliers in the industry, regardless of their degree of market control. This concept of the distinction between industrial structure and market forces is important for the purposes of the present study, which is examining the feasibility of using acquisition procedures to encourage the forces of competition to operate in an industry which does not currently have a highly competitive structure.

DEFENSE SCIENCE BOARD SUMMER STUDY  
1977 REPORT OF THE SHIP ACQUISITION TEAM  
OF THE ACQUISITION CYCLE TASK FORCE

N. Sonenshein, August 26, 1977

This study discusses the ship acquisition process with emphasis on factors which affect the length of acquisition times. Five procurement programs were examined and the conclusion was reached that program stability and acquisition flexibility are the most promising methods to shorten acquisition times. Program stability should be improved by a Congressionally authorized five-year Ship Construction-Navy (SCN) program; by increased "management commitment" to present programs; by increased Navy/MARAD program coordination, which has long been recommended but not successfully implemented; and provision for continuity in RDT&E funding in the design phases. Acquisition strategy should be flexible and based on ship type and maturity, degree of subsystem development, and the posture of the industry. This flexibility should be carried out in several ways, including the procurement approach and type of contract used.

These findings are reflected in our current contract to provide the tools necessary for implementation. We agree that increased program stability would shorten acquisition time. This opinion is reflected in the use of the five-year planning period in the TASC model and in the inclusion of commercial demand in the model. We also agree that the choice of contract type should be influenced by the type of ship being built and the stage of program maturity, e.g., cost-type contracts for lead ships.

A PRELIMINARY REVIEW OF THE UNITED STATES  
SHIPBUILDING INDUSTRY AND ITS ABILITY  
TO SUPPORT THE UNITED STATES NAVY

John D. Morgan, et al.  
July 1977; IDA Paper P-1272

This Institute for Defense Analysis (IDA) study contains an overview of the shipbuilding industry, a description of its structure, an analysis of its capacity and ability to meet mobilization requirements, and an identification of its problem areas.

Certain conclusions of the study were relevant for our purposes. The study classified the industry as an oligopoly, with certain yards having a monopoly on certain ships. We agree with the recognition that there are monopolistic industry segments, but would like to add that there are other segments with differing degrees of concentration, and that it is important to recognize the monopsony power of the Navy.

We concur with the study's view of industry competitions. The yards know who their competition will be for given procurements. In addition, we think it is likely that yards often know their competitors' cost well enough to predict their bid price.

The IDA study recommends negotiated procurements over advertised procurements. Negotiated procurements have the advantages of allowing work to be spread more evenly over a larger number of yards and of allowing workloads to be stabilized. In addition, they may be more appropriate for shipbuilding because of limited Navy demand and of the limited number of potential suppliers for many ship types. The IDA

study also expressed the view that it may be desirable to increase the profitability of Navy contracts even if this results in higher costs for some contracts.

We agree that stability is desirable and that increased profitability may be needed to maintain industry viability; but it is our view that higher contract costs should not be necessary. We believe that a method of allocating ships which both stabilizes shipyard workloads and encourages the forces of competition would increase profitability by decreasing the industry inefficiencies due to both fluctuations in yard workloads and lack of meaningful competition for specific contracts.

THE UNITED STATES SHIPBUILDING INDUSTRY  
AND INFLUENCES OF CONGLOMERATES

Gary Lee Kavanagh  
Technical Report No. 1  
Sloan School of Management  
Massachusetts Institute of Technology, June 1977

This study gives an historical overview of the U.S. shipbuilding industry, a description of the major governmental programs and policies which influence the industry, and a description of contemporary U.S. shipbuilding as a background to its discussion of conglomerates in the industry. It describes the history of the acquisition of shipyards by conglomerates and motives behind the acquisitions. It describes six influences of conglomerates on U.S. shipbuilding. First, they may have helped the industry by facilitating capital investment. Second, they have altered the organizational structure of the shipyards because conglomerate-owned yards are not independent, but are segments of divisions within conglomerates. Third, conglomerates have modernized the management approaches in shipyards. Fourth, while conglomerate acquisition of shipyards was not a primary factor in the recent claims problem, it may have been a contributing factor. Fifth, conglomerates have the capacity to contribute more leverage on the government than independent shipyards. Last, conglomeration of shipbuilding has provided the opportunity for yard financial data to be incorporated into and obscured by the financial reports of the parent corporation. The study concludes with several recommendations for further research.

UNDERSTANDING CONTRACTOR MOTIVATION  
AND CONTRACT INCENTIVES

Phillip E. Oppendahl, Commander  
USN, Defense Systems Management College,  
May 1977

This study concerns the concurrence of contractor motivation and contract incentives. Recent contracts for weapons systems are examined, and the conclusion is reached that profit incentives are the major ones used. A review of the literature of contractor motivation indicates, however, that the profit motive is not necessarily predominant. The study instead concurs with the description of contractor motivation as a hierarchy of needs which changes as the corporation matures. The need which is predominant in the earlier stage is survival; then profit becomes the main motive; profit is in turn succeeded by the desire for growth; then market share; then prestige. Thus the majority of contract incentives, which are profit-oriented, may not concur with motivation. The study finds little evidence that contract incentives encourage cost control or the desirable trade-offs among cost, schedule, and performance; contractors tend to be more performance-oriented, and less cost-oriented. The suggestion is made that contracts be made to vary with corporations in response to their motivations. Another conclusion of the study is that formal regulations and Congressional and public opinion strain the Government's relationship with industry. Finally, the study states that "perhaps it is time to develop a new acquisition process. This can only be done by erasing all of the current restrictions and structuring the new concept from an ideal basis, one in which industry, Congress and the DoD share the concept development burden."

The TASC model addresses the problem of different contractor motivations in the allocation equations by providing the flexibility to allow the specific expression of each yard's goals. For the shipbuilding industry, however, if contracts are not appropriate, it is probably not because their incentives do not conform to the shipyards' motives, but that they are inappropriate for the ship being built. Shipbuilders are an exception to the statement that defense contractors are more performance- than cost-oriented. The shipbuilding industry is not characterized on the whole by profits high enough to allow much concern over prestige or growth; and in a number of cases, individual yards already have a significant portion of the market for particular ship types, and are not likely to gain a larger portion. Indeed, some yards still are concerned with survival. For this reason we think that it is important to reduce the risk to the shipbuilder by the use of appropriate contracts and increased workload stability.



PRODUCTION AND CONSTRUCTION:  
A COMPARISON OF CONCEPTS IN SHIPBUILDING  
AND OTHER INDUSTRIES

Dr. Franz A.P. Frisch  
NAVSEA 075  
Department of the Navy  
Washington, D.C., July 1976

This paper discusses the two basic methods of manufacturing, production and construction, and compares and contrasts ship construction with more production-oriented manufacturing industries. It discusses the management implications of the differences between production and construction. The major philosophical theme of the paper is the necessity of an inter-disciplinary approach to shipbuilding industry problems. Production industries, such as automobile manufacturing, involve the repetition of processes. Construction industries, such as shipbuilding, involve non-repetitive processes. No industry is at either extreme of being totally construction or totally production; all industries lie somewhere in between.

According to Frisch, the application of production management to the construction of ships is the cause of the present problems in the industry. This mismanagement was a result of the "team philosophy of the 60's", so called because it was not developed by any one person. This philosophy held that: "(1) everything which cannot be rationally understood should be ignored; (2) that all material aspects can be calculated and therefore can be optimized; and (3) that a unique rationality in solutions and in behavior exists and, therefore, a rational prediction of the future is possible." This team philosophy justified corporate conglomeration of unrelated divisions, and the imposition of a uniform management system

on all these divisions. Thus, when the conglomerates acquired shipyards, they imposed production-oriented management on a construction industry. The discrepancy between the nature of the management and the nature of the product is the cause for problems in the industry. Interestingly, the Kaitz study found that the "new aerospace oriented" conglomerate owned shipyards were less profitable than the "old line" shipyards. This finding supports Frisch's viewpoint that production managers should not be in charge of construction-oriented manufacturers such as shipbuilding if profit is seen to be a measure of management success.

Frisch illustrates how shipbuilding differs from production industries by contrasting numerous aspects of shipbuilding with the production industries of watchmaking and the automotive industry. These aspects include: the shipbuilding industry's lower capital intensity; more concentrated market; greater number of components of the product; and its much greater building time per unit.

Other features which distinguish shipbuilding from many other industries are the limited planning which can take place before manufacture of the product; the great number of decisions, changes and experimentations which must be made during the manufacturing process; the limited predictability of problems; and the impossibility of predicting risk. Problems such as these encouraged us to develop a model which has both stochastic and deterministic elements.

REPORT OF THE NAVY MARINE CORPS ACQUISITION  
REVIEW COMMITTEE

Shipbuilding Annex,  
Office of the Secretary of the Navy  
January 1975

This annex to the Navy Material Acquisition Review Council (NMARC) study examines a number of issues related to the ship acquisition process. Certain recommendations in this annex are relevant to our model and approach. The recommendation that acquisition approaches should be evaluated for their suitability for given shipbuilding programs concurs with our understanding of how some major problems have developed with previous programs. We also agree that cost-type contracts for the lead ships provide more of the needed protection from risk to the shipyards for this type of procurement. Again, we concur that the success of the lead and follow yards method used in the FFG procurements implies that this method should be used more when new ships are being designed.

Another recommendation, which supports the concept of competitive allocation, is that of using two-step negotiated procurements in competitive situation. The first step is the identification of fully qualified offerors (5) for a given program; the second is the one-time solicitation of cost proposals from these offerors. This approach has the advantage of discouraging unrealistically low bids due to an "auction atmosphere" and several iterations of contract negotiations.

The study also recommends that several steps should be taken which increase program stability, such as intensification of efforts for Congressional authorization of a five-year plan, and expansion of detailed advance planning for ship

overhauls. Such recommendations are widely held; we concur that stable long-range planning would facilitate the Navy's shipbuilding programs.

SHIP/OPS I  
NATIONAL SHIPYARD OPERATIONS MODEL  
PROJECT TRANSIM, UCLA

SHIP/OPS is a computer simulation model which was developed for MARAD. It "addressed the probabilistic nature of shipwork demand and shipbuilding performance" and "is designed to analyze the risks attendant in maintaining shipbuilding capacity at any particular level or in selecting a particular program to cover a range of contingencies."

It is designed to determine real resource requirements of different shipbuilding programs; ship project schedules for national shipbuilding programs based upon specified levels of available shipyard resources; national shipwork capacity at different levels of available shipyard resources; location and magnitude of critical resource scarcities which limit this capacity; and the impact of special ship programs such as mobilization.

The SHIP/OPS I model is a model which simulates the yards, and focuses on capacity and physical resource needs. At TASC we decided to avoid the simulation approach as being less appropriate than a parametric approach for a model which estimates shipbuilding program costs, because differences between yards are of importance and computation time with the parametric approach is faster. The parametric approach will allow us to more quickly take into account the effects on cost and scheduling of different distributions of shipbuilding programs within the industry, and the feedback effects of different programs. The SHIP/OPS simulation approach is more suitable to problems which focus on detailed shipbuilding schedules.

INFLUENCES ON NAVAL SHIP COST ESTIMATING  
FOR BUDGET PRUPOSES

G.H. Main, J.A. Fetchko  
Naval Systems Command  
Department of the Navy  
March, 1970

This paper reviews the major factors which influence cost estimation of naval ships. These include inherent problems, controllable problems, and noncontrollable problems. The inherent problems are the high complexity, high technical risk, and long project duration involved in building naval ships. The controllable problems include insufficient definition or description of the ship to be estimated; lack of adequate bid data received from shipbuilders; insufficient time to develop estimates; shortage of trained government personnel for cost estimation; problems due to delays in the programs and need for estimates for budget authorizations before completion of ship design; and the risk due to commitment to major systems prior to their completed development. Noncontrollable problems include the prediction of economic conditions and market conditions.

The study concludes that the future development of computer models of cost estimation should be designed to include market conditions and trade-off analyses; that improvements in dealing with the cost estimation problems listed above would prove more fruitful in the long run than improvements in accounting; and that decisions about shipbuilding programs should be made more quickly in order to reduce the errors in cost-estimation introduced by market condition uncertainty.

The difficulties of estimating the costs of ships underscored for us the advantages of using a cost-type contract for lead ship in order to fairly divide the risk between the contractor and the shipbuilder. In addition, these difficulties were the cause for the belief that the TASC model would estimate shipbuilding costs more quickly and economically if its ship-cost estimating sub-unit adjusted the Navy base-line man-hour estimate for yard efficiencies, rather than if it summed the costs of numerous yard processes as a PERT simulation would do. This paper also provides useful information about procedures of acquisition and estimation which are used within the Navy.

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Chapters: National Shipyard Posture, Review of Major Events; Shipbuilding Labor; International Shipbuilding and Ship Repair

Shipbuilders Council of America 1977 Annual Report, Washington, D.C.

MARAD '77. The Annual Report of the Maritime Administration for Fiscal Year 1977. U.S. Department of Commerce, Maritime Administration.

Annual review of MARAD's activities and a number of aspects of commercial shipbuilding

1977 Report on Survey of U.S. Shipbuilding and Repair Facilities. U.S. Department of Commerce, Maritime Administration.

Describes current capabilities, current workload, and new investments of the major U.S. commercial shipyards

Relative Cost of Shipbuilding. A Report to the Congress on the Relative Cost of Shipbuilding in the Various Coastal Districts of the United States. U.S. Department of Commerce, Maritime Administration, June 1977.

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APPENDIX B

PUBLISHED SOURCES OF DATA ON THE  
SHIPBUILDING INDUSTRY

There are a number of sources of consistently published data on the shipbuilding industry. These data are for the most part descriptive of the shipbuilding and ship repair industry (Standard Industrial Classification 3731), which consists of some 400 establishments. They generally are not disaggregated either by shipyard or by commercial or Navy shipwork. They do, however, probably indicate general trends for the major yards in the industry, since these yards are responsible for about three-quarters of the industry's factor usage and output. Very few data on specific yards are available from open sources, so any attempt to model yard-specific aspects of the industry must depend on non-published data obtained from the shipyards and the Navy.

Sources of shipbuilding industry data which are aggregated above the yard level include:

1. Employment Data

A. Bureau of Labor Statistics: data from Employment and Earnings (industry level aggregation).

- (1) All employees
- (2) Women employees
- (3) Production workers
- (4) Production workers avg. weekly earnings
- (5) Production workers avg. hourly earnings
- (6) Production workers avg. weekly hours
- (7) Accessions/100 employees
- (8) New hire/100 employees

- (9) Separations/100 employees
- (10) Quits/100 employees
- (11) Layoffs/100 employees

B. MARAD: Average monthly shipyard employment for selected commercial shipyards with facilities to construct ships 475 by 68 feet. Data are disaggregated by nature of shipwork and by customer. Employment data are for:

- (1) Total plant
- (2) Total direct labor
- (3) Ship construction and conversion, total direct labor
  - (a) MARAD
  - (b) Navy
  - (c) Other Federal
  - (d) Private
- (4) Ship repair, total direct labor
  - (a) MARAD
  - (b) Navy
  - (c) Other Federal
  - (d) Private
- (5) Non-shipwork, total direct labor

## 2. Labor Turnover Data

In addition to the labor turnover for the industry published by the Bureau of Labor Statistics (BLS), the Navy's SUPSHIPS publishes total separation rates for selected major shipyards. These two sets of data exemplify the problems involved with industry-aggregated data. An average of the total separation rate from SUPSHIPS for 1976 for nine of the eleven shipyards interested in doing Navy work, weighted by employment as of the first of the year, was 39%. The annual weighted average total separation rate of the BLS sample for 1976 was 75.6%. This discrepancy is probably largely due to the different samples used in the two averages; apparently smaller, ship repair-oriented yards have higher turnover rates. This discrepancy shows how the use of industry-level data may be misleading, due to the wide variation among shipyards and the sorts of work they perform.

3. Financial Data

A. Financial data on the shipbuilding industry have been analyzed by Edward Kaitz (see "Review of the Literature"). His sources were:

- (1) Dow-Jones archives
- (2) Annual reports of shipbuilding firms
- (3) S.E.C. documents

B. The IDA study also analyzed shipbuilding industry financial data, using mainly:

- (1) Standard and Poors publications
- (2) Annual Statement Studies by Robert Morris Associates

C. The Internal Revenue Service publishes data based on a sample of corporate return, aggregated over the ship and boat building and repair industry (SIC 3730). The use of corporate data may imply that unrelated divisions are included, or that some important yards are excluded. These data, disaggregated into thirteen groups by asset size, include balance sheet, income statement, tax, and investment credit items. Their inclusion of boat building and the corporation reporting problem, limit the usefulness of these data for analysis of the shipbuilding industry.

4. Census of Manufacturers and Annual Survey of Manufacturers

These Bureau of the Census data are aggregated mostly at the industry level. They include data on output, wages and employment, cost of materials, capital expenditures, and fixed assets. The quintennial Census of Manufacturers differs from the Annual Survey of Manufacturers (ASM) largely in the fact that the ASM is a survey, while the Census is a census. The statistics are identical in most aspects. However, statistics for Census years are not always as detailed for other years (for example, they exclude energy expenditures). The Census

years include one important breakdown the ASM does not include -- the breakdown of most of the "general statistics) (see following) by employee size of establishment. This enables us to see, for example, what the wages were for companies with more than 2,500 employees.

The ASM has statistics for SIC 3731, shipbuilding and repair, for the following

A. General Statistics

- (1) All new employees
  - (a) Number
  - (b) Payroll (dollars)
- (2) Production workers
  - (a) Number
  - (b) Manhours
  - (c) Wages
- (3) Value added by manufacture (dollars)
- (4) Cost of materials, fuels, etc.
- (5) Value of industry shipments. (This is actually "value of work done" to allow for the fact that it may take more than one year to build a ship)
- (6) Capital expenditures, new. (Expenditures for fixed assets)
- (7) Gross value of fixed assets
- (8) End-of-year inventories
- (9) Specialization ratio. ("The proportion of product shipments (both primary and secondary) of the industry represented by primary products")
- (10) Coverage ratio. ("The proportion of primary products shipped by the establishments classified in the industry to total shipments of such products by all manufacturing establishments)

These "general statistics" are broken down this way in the ASM:

B. Value of Shipments of Product Classes

- (1) Nonpropelled ships, new construction
- (2) Self-propelled ships. U.S. military, new construction
- (3) Self-propelled ships, nonmilitary, new construction
- (4) Ship repair, U.S. military
- (5) Repair of nonmilitary ships
- (6) Shipbuilding and repairing, not specified by kind

C. Value of Manufacturer's Inventories

- (1) Total
  - (a) Finished products
  - (b) Work in process
  - (c) Materials, supplies, fuels, etc.

D. Fuels and Electrical Energy Used

- (1) Total cost
  - (a) Purchased fuels plus electric energy (dollars)
  - (b) Purchased fuels (dollars)
- (2) Electric Energy
  - (a) Purchased
    - i. Quantity m. kw. hr.
    - ii. Cost
- (3) Generated less sold

E. Expenditures for New Plant and Equipment

- (1) Total new expenditures
  - (a) New structures and additions to plant
  - (b) New machinery and equipment

- F. Gross Book Value of Depreciable Assets,  
End of Year
  - (1) Total
    - (a) Structures and Buildings
    - (b) Machinery and Equipment
  
- G. Employment and Labor Costs
  - (1) Employees
  
  - (2) Total Labor Cost
    - (a) Payroll
    - (b) Social Security and other legally  
required payments
    - (c) Employer payments for other  
programs

The ASM disaggregates data by region. Great care has been taken to avoid disclosing information about individual companies.

5. Contract and Delivery Data

- A. The Shipbuilders Council of America also published industry data. Their Statistical Quarterly contains accessible compilations of Census data and lists of descriptions of Navy contract awards and MARAD-subsidized contract awards. Their Annual Report includes data on merchant and naval orders and deliveries, backlog information, and repair and conversion information.
  
- B. The MARAD Annual Report includes listings of commercial contract awards and commercial ship deliveries.



APPENDIX C

LIST OF PERSONS INTERVIEWED

PERSONS INTERVIEWED		
NAME	TITLE	ORGANIZATION
Schaefer, H.K.	Vice President and Asst' General Manager	Todd Pacific Shipyards Corp.-- Los Angeles Division
Harvie, James	Manager of Marketing	Bath Iron Works
Clark, Commander Rolf		NAVMAT Code 01
Adamson, Stuart	Vice President	Shipbuilders Council of America
Spar, Capt. E.F.	Ship Systems Staff Coordinator	Acquisition Policy
Frisch, Dr. F.A.P.	Acquisition Research Coordinator in the Office of Advanced Planning Acquisition Policy and Appraisal	Division of Deputy, Commission for Acquisition
Varley, Thomas C.	Program Director, Operations Research	Office of Naval Research
Stryker, Russell	Assistant Administrator for Policy and Administration	Maritime Administration
Grossman, Thomas	Deputy Director	Ship Construction Conversion and Overhaul Program and Resource Planning Division
Friedberg, Arthur	Director	Maritime Manpower
Shettler, Kathy	Manpower Management Officer	Maritime Manpower
Piersall, Capt. Charles	Project Manager	Amphibious Ship Acquisition Project
Hammon, Captain Colin		Center for Naval Analysis
Graham, David	Head Facilities in Services Branch	Naval Air Systems Command
Fetchko, J.	Branch Head, Cost Analysis	NAVSEA
Kaitz, Edward	President	Edward M. Kaitz and Assoc., Inc.
Orem, Captain John		O.U.S.D.R.&E. (A.P.)
Pyatt, Everett	Principal Deputy, Asst. Secretary of the Navy for Logistics	Office of the Asst. Secretary of the Navy Manpower Reserve Affairs and Logistics
Otth, Adm. Edward		Naval Sea Systems, Command SEA 90
Hartigan, John	NAV 0723 Head Manpower Practices Branch	Industrial Activity Performance Evaluation Division