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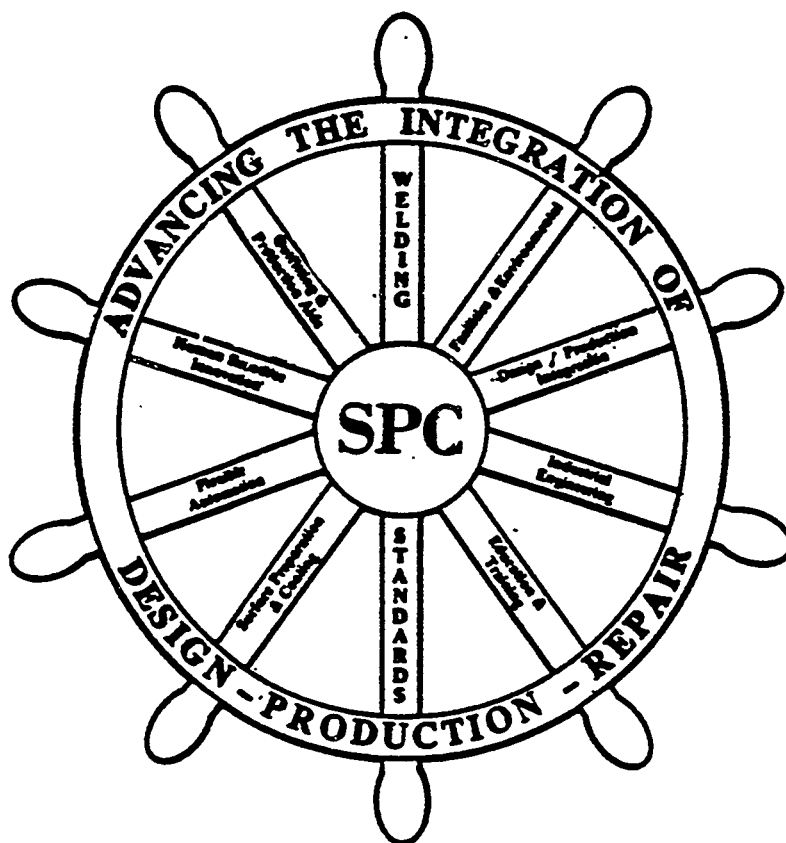
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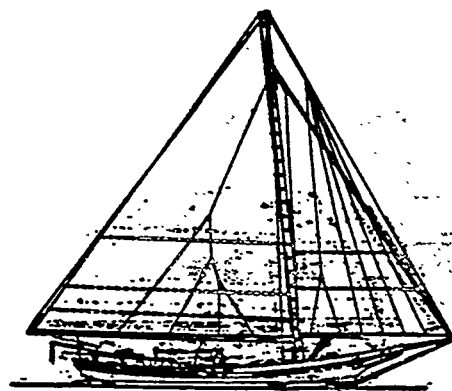
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No. 21

Information System Models — As a Tool for Shipyard Planning and Control

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ABSTRACT

This paper proposes the use of information system models of production as a tool to achieve rationalization and integration goals and to create a learning organization. It is shown that through use of these models it is possible to identify cost-benefit ratios for various rationalization and modernization tasks, and to create an action plan for their implementation. Proposed production information model aims at reducing every job into its smallest elements in the form of processes and activities as well as rationalizing the subjective concepts of complexity, size, quality etc. through the use of metrics. The paper also discusses the increasing reality variance of accounting systems and proposes the introduction of single-factor and total factor productivity for correct evaluation of operating performances and of investment decisions. While the model is generic enough to cover all eventualities, its application to specific yards require additional tailoring to reflect the effects of layout, facilities, organization and labor resources on the yard performance. The paper suggests that adoption of such models avoids sub-system optimization or importation of methods and techniques which might have been successful in some other operation and yet may not be appropriate in given circumstances.

1. PREAMBLE

During the 1970's, at the early stages of the decline of U.K commercial shipbuilding industry, BMT (then as BSRA) was asked to study the 'state of practice' in U.K. shipyards which, in 1977, led to a major effort with the title of 'Advanced Technology Shipbuilding'. One of the serious concerns of the project was the role of Management Information Systems (MIS) and its impact on shipyard performance. This report resulted in a comprehensive report [1], reflecting the state of affairs within that day's understanding. Since then periodical updates to the study have been issued to reflect the changes in technology, methodology and management practices. This paper is a summarized version of an update of the previous studies

to account for the changes in information technology and the emergence of a new manufacturing management philosophy, [2].

The problem faced by the shipbuilding industry is to produce a working design and to build the product from this information in a cost-efficient manner. The design of modern ships, especially warships and submarines, is a very complex process providing a configuration design to house the shipboard systems and equipment. During this process a large body of information is created and this information together with facility, yard layout, material and cost data has to be captured, analyzed and utilized in decision making for the shipyard to operate successfully. The volume, variety and complexity of this data especially in the face of compartmentalized thinking in various departments, may create confusion and turn into a liability instead of being an asset. The aim of this paper is to provide an overview of total system requirements, its components and their functions with due emphasis on integration. It is, however, to be understood that each yard, based on its facilities, production methods and management infrastructure, needs to tailor the system, as there can be no universal remedy valid for all shipyards.

2. THE NEED FOR RATIONALIZATION AND INTEGRATION

Since the Second World War manufacturing technologies, especially shipbuilding steadily declined in U.S.A. and U.K, gathering further pace since 1970. To some this was the manifestation of David Ricardo's famous law of comparative advantage '...that such an ancient and labor-intensive item should rightly be produced in countries whose workers had simple manual skills and low wage rates.' However, when high-technology companies found themselves losing position to foreign competitors (often from countries viewed as followers and copiers rather than technological innovators) the problem started to receive more serious attention.

Within the context of U.S.A. and U.K three alternative explanations have been proposed. According to the first school of

thought there was no real problem. The difficulties being experienced by the industry were simply the normal response of an economic system to a series of external shocks the maturation of certain "sunset" industries and the symptoms of an accelerating transition to a post-industrial service-dominated society [3]. This view became increasingly difficult to defend as industry after industry collapsed under the pressure of Far Eastern competitors.

An alternative explanation suggested that a serious problem existed and it was primarily due to macro-economic policies. The main causes being high interest rates and a tax system that warped investment decisions implicitly favoring consumption and borrowing over saving and investment, and residential construction over industrial modernization.

A third school also believed that the problem was serious and persistent, but simply correcting some of the obvious inconsistencies and imbalances in macroeconomic and industrial policies would not be sufficient to restore the industrial competitiveness. The main problem laid in the areas of manufacturing management and technological development [4]. Within this explanation, when one looks upon something as a liability, not as an asset, it tends to change management attitudes. One manages around it, not through it. It receives less of the corporate resource allocation with predictable consequences. Equipment runs down, buildings get old and dirty, and workforce relations get even more strained. In an effort to regain control, management installs more sophisticated central control systems which tend both to increase the overhead costs and to stifle innovation. Power and expertise increasingly migrate from the factory floor to the corporate accounting room. The prime motivator becomes the fear of failure and punishment. A downward spiral of performance, confidence and investment follows, leading to the closure of plant.

This trend can be reversed and recent resurgences in some manufacturing companies through rationalization and integration is the clear proof of potential of constructive action. Rationalization, in the first instance, require that management should focus on organization's resources, capabilities and energies on building a sustainable advantage over its competitors along one or more dimension of competitive differentiation; relative cost, relative quality, and relative innovativeness. Once it has been decided what kind of competitive advantage the organization is going to seek, it has to configure itself to achieve and continually enhance that competitive advantage. This requires making a series of coordinated decisions of both analytical and infrastructural nature. Analytical decisions refer to matters where estimates can be made, such as

the amount of total production capacity.

how this capacity should be broken up into specific production facilities,

what kind of production equipment and systems should be adopted by these facilities,

which materials, systems and services should be produced internally and which should be sourced from outside organizations, including the degree of relationship with suppliers.

By infrastructure, on the other hand, refer to management policies and systems which are used in the implementation of analytical decision. These are:

Human resource policies and practices, including training and management selection,

Product and process development policies,

Capital investment policies,

Performance measurement and reward systems,

Organizational structure design.

Integration on the other hand eliminate compartmentalized thinking, increases communication and awareness, encourages standardization and design for production and reduces redundancy and duplicity. Within a large organization one identify four levels of integration: design, data, decision and organizational integration.

Most organizations believe that they have successfully implemented a new operating technology when the system is working without serious bugs, reliably and new technology has a high utilization rate. However, this definition ignores the most important reason behind the implementation of a new technology; value for investment. One can therefore propose two levels of success in the implementation of technology:

Technical success

Realization of benefits
(economic success)

Technical success generally refers to reduction in errors and effort requirement to the elimination of paper-driven steps, and growth in enabling capability and functionality. Economic success, on the other hand, implies:

Realization of productivity increases
(e.g. reduced labor, increased throughput, reduced cycle-time, etc.)

Realization of non-productivity benefits such as reduced lead-time, quality improvements, increased flexibility, cost-effective design, etc.

Translation of these benefits into competitive gain (value).

Various surveys conducted in different segments of the manufacturing industry indicate that successful design and data integration generally leads to technical success with only limited economic benefits. The real competitive advantage comes with the decision and organizational integration. However, unless design and data integration is complete, decision and organizational integration cannot be achieved successfully.

Achievement of these goals require time and investment. Figure -1 illustrates time and cost implications of integration where design integration is included within the data integration. Successful implementation of rationalization and integration relies heavily upon the design and operation of a distributed data collection, analysis, planning and control systems and the establishment of a data base and an information system satisfying these requirements, which contains at least three levels of information covering strategic, functional and operational aspects and appealing to the needs of different tiers of the hierarchy (see Figure 2). In a larger organization strategic information of one tier may well become an operational level information of a higher tier.

3. SHIPYARD INFORMATION SYSTEMS

During the evolution of the shipbuilding industry each shipyard has

developed its own systems by which to plan and control its operations. These systems varied from yard to yard, each being developed according to its own needs. Small yards building simple vessels with only a few hundred employees sometimes relied largely verbal communication whereas large yards, perhaps spread over a number of separate sites, and employing many thousand of workers needed to resort to a more formalized approach by instituting standard forms, standard reports, uniform collection of manhour data etc. Invariably, the larger companies use computers as an aid to handling information.

However, despite the wide spectrum of systems found in the industry, it is felt that the objectives underlying those systems correspond to a common framework of requirements and it is the development of this into a set of minimum requirements, with due emphasis on planning and evaluation, that has been the object of this work. The existing systems have been examined in detail and the essence of each of the various functions extracted. From this it has been possible to identify a number of system modules, i.e. routines or procedures each with a well defined purpose, and with inputs and outputs which are recognized requirements for planning and controlling the functioning of a shipyard.

As an aid to clarity of presentation these system modules have been grouped together into seven main functions. These

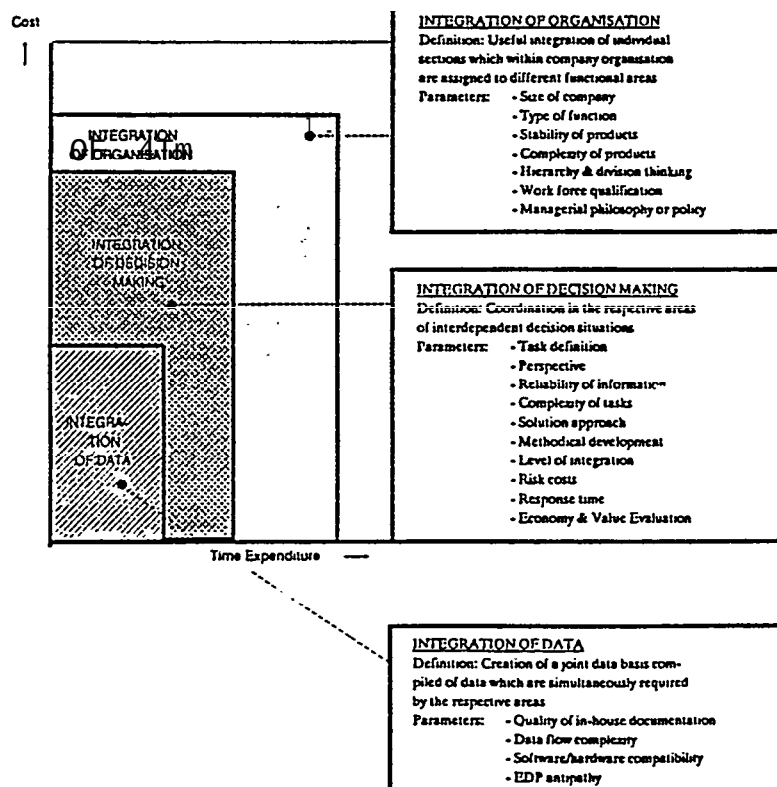


FIGURE - 1. LEVELS OF INTEGRATION - TIME & COST IMPLICATIONS

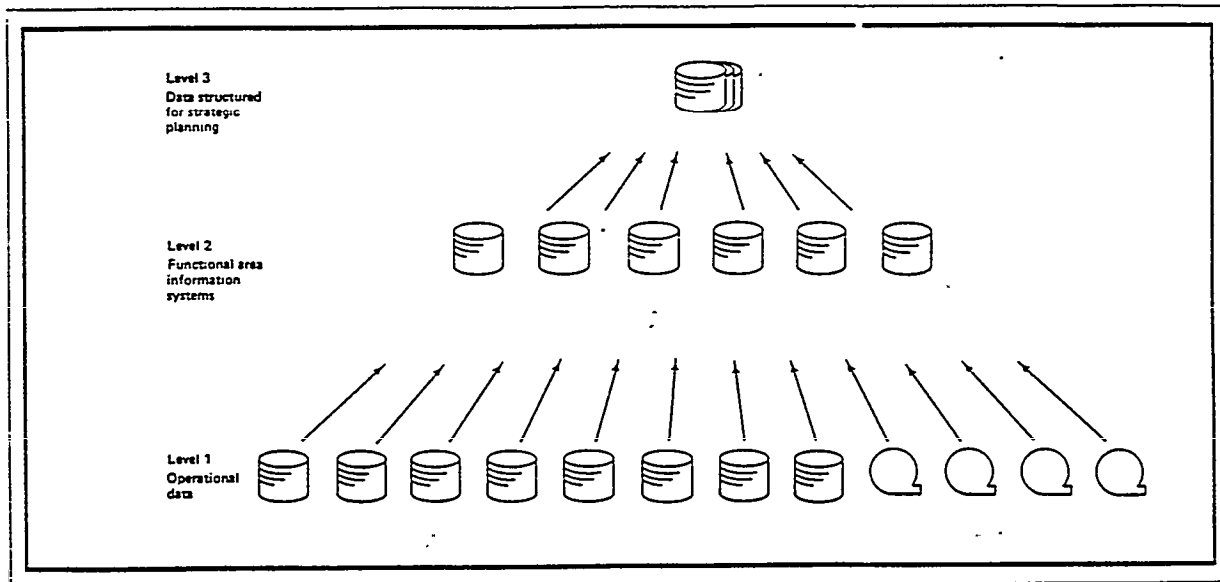


FIGURE - 2. HIERARCHIAL INFORMATION & DATABASE STRUCTURING

functions correspond to established shipyard practices but a clear distinction must be drawn between activities which are carried out within each function, and any departmental structure which may be found in a particular shipyard. Only by recognizing this distinction will it be possible to correctly assess current systems and procedures in order to discover areas in need of improvement. These main functions are

CONFIGURATION DESIGN: To create a ship configuration with all of its elements and to analyze its functionality to ensure the proposed design satisfies the attribute requirements and accommodates producibility demands of the shipyard.

PLANNING: To set dates, targets, and cost and quality implication which will ensure compatibility between the requirements of production, the availability of resources and technical information, and the limitations imposed by financial and contractual obligations.

PRODUCT DESIGN: To convert configuration design into a detailed product, to identify and specify the total material and equipment required for the construction of a ship, and to prepare technical information to meet the requirements of production.

MATERIAL CONTROL To procure all materials and services for the construction of a ship and operation of a shipbuilding business at economic cost to meet contract requirements.

Production ENGINEERING: To define, in conjunction with planning the, building methods and units of work for the construction of a ship, to define the sequence of operations and the material requirements for each unit of work and to collate production information for each unit of work.

Production CONTROL To initiate the production process by means of a short term schedule, having regard for the availability of material and status of work in progress.

MANAGEMENT ACCOUNTING: To accumulate and collate all data relating to labor, material and overhead costs for a contract and present reports for control action by management.

Three important supporting functions are also identified as "cost/value engineering," "financial accounting" and "personnel." The purpose of the definitions is more as a descriptive aid to the reader as opposed to a definitive statement or constraint. From the viewpoint of shipyard efficiency cost and value engineering provides a critical role both in terms of the selection of the appropriate building strategy as well as the utilization of resources, by linking design, planning and production engineering functions.

It must also be stressed that the grouping of the system modules into functions has been done on the basis of the work done in each module. Thus the planning function contains all the elements of planning even though done at widely varying levels of detail. In structuring the system modules it is essential to reduce the description to a level which corresponds to a function within the yard with a defined action and information flow logic as shown in Figure -3.

A useful format to adopt is to show the function within which the module lies, the title of the particular module and its objective and then to consider three elements of each module. The first essential element is the input data required if that module is to operate. This itself is divided into internal and external information. Internal information exists

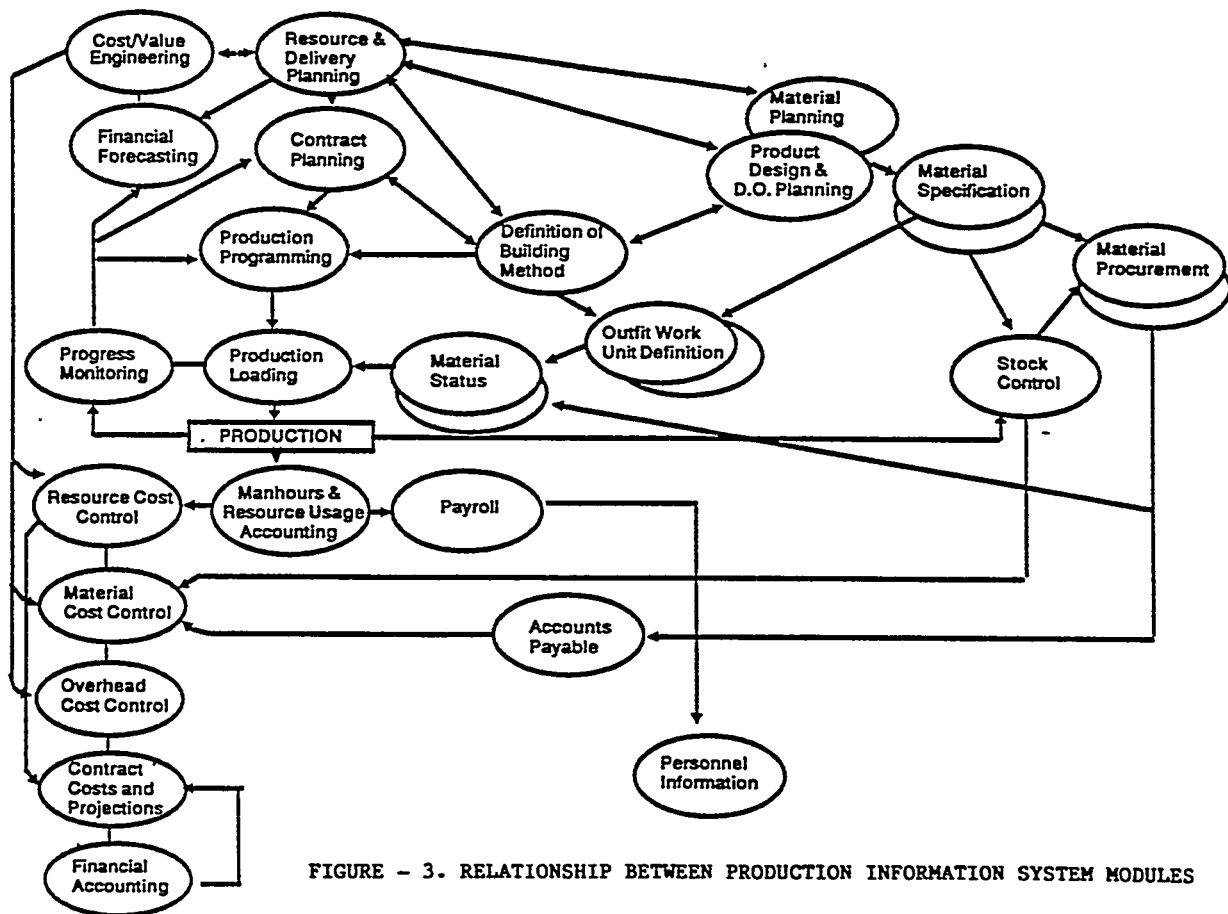


FIGURE - 3. RELATIONSHIP BETWEEN PRODUCTION INFORMATION SYSTEM MODULES

within, or is generated by the function, i.e. files of data reference information etc., or the expertise or experience of personnel. External information is generated as output from other system modules and transferred physically or verbally between the modules. In many cases (where advanced computer systems are in use) this transference of data may be achieved by many modules having access to the same database.

The second element is the output from the module. As with the input the medium of transfer is not usually specified, but in many cases will be an organized database system. This does not, however, exclude other forms of communication.

The third and last element described for each system module is the method. Only an outline of the method is given because the nature of the shipyard will, in any implementation process, determine the precise details. Some methods will probably always remain manual, while a great majority will be achieved by the use of computers, especially where accuracy and rapid operation on or transfer of data is required. This concept of presentation, together with the connectivity diagram, is illustrated in Figures 4 and 5.

The concept of defining groups of operations or tasks as 'work units' and referring to the same units for planning, material status checking, progress monitoring and cost monitoring is a common theme in several of the system modules. The work unit concept is already widely applied for steelwork fabrication and outfitting where typically one or more steel blocks and their outfit elements are treated as work units. The definition of work units will vary from one shipyard to another and from one ship type to another depending on the way the work is organized. The general definition of work unit may be stated as:

A set of production operations or tasks grouped together for cost-efficient production and assigned to be so, for the purposes of planning and control.

There must be a recognizable and definitive start and finish for every work unit to facilitate progress monitoring and there must be clear responsibility for each work unit at 'shop floor' or trade management level.

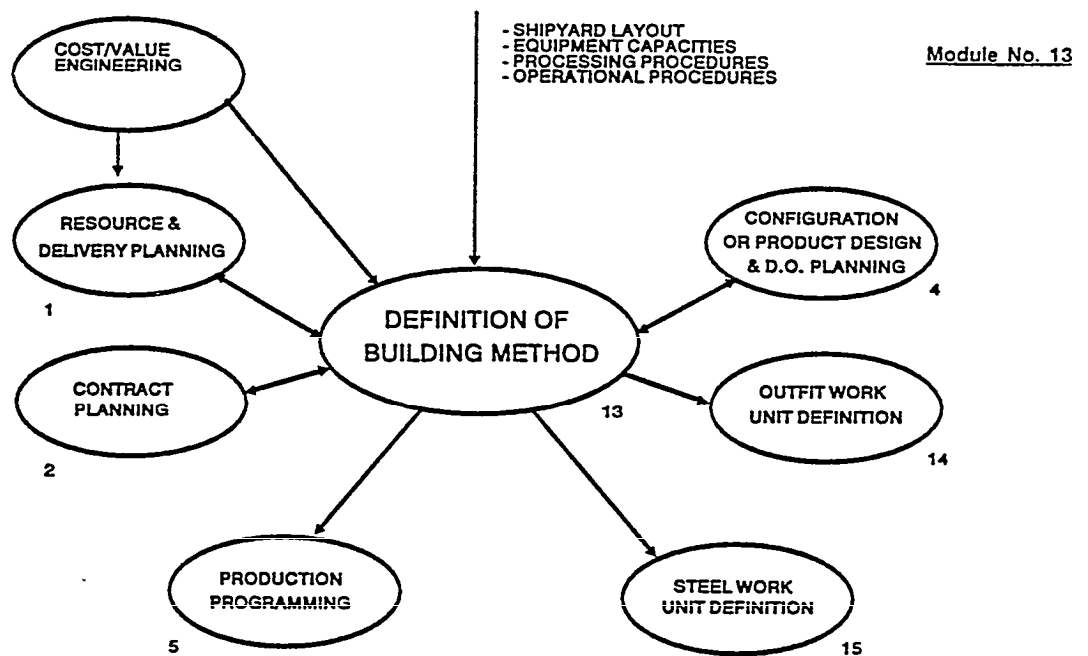


FIGURE - 4. AN EXAMPLE MODULE CONNECTIVITY DIAGRAM

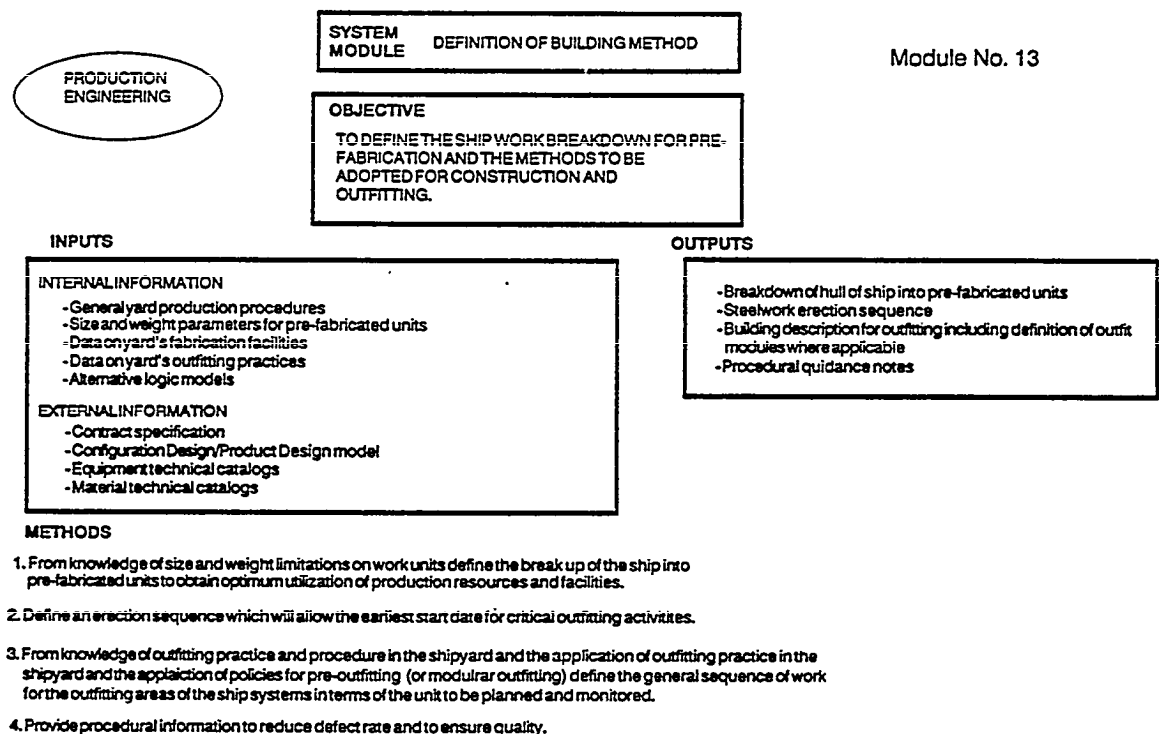


FIGURE - 5. AN EXAMPLE OF MODULE DESCRIPTION

4. RELATIONSHIP BETWEEN DESIGN AND PRODUCTION

Historically, many shipyards employed a compartmentalized approach to design and production, segregating these functions from each other. In fact, in some shipyards drawing production and design are considered to be the same thing. In the present era of rationalization and integration one of the very first issues to be settled is to define the function and interrelationship of each activity to ensure cost effective operation. Within the context of shipbuilding design refers to the generation of a configuration and product, satisfying all the functionality requirements in a cost efficient manner. Here, configuration design refers to the top-down stage of the design where each component or system is defined and analyzed to satisfy the functionality requirements, just like defining the main bone structure and organs of human body. Product design then operates on configuration design to add the necessary details and information, and reduces it to an assembly of elements, each in a producible or procurable state.

During the configuration and product design, a large number of production decisions are implicitly or explicitly made. Historical data on cost saving potential vs. cost to change indicate that earlier consideration of the cost and producibility provides the maximum gain, as depicted in Figure 6. However, achieving this end requires development and establishment of a cost effectiveness analysis.

Cost effectiveness within the context of this paper includes value analysis and value engineering. Value, for definition purposes, is the fair equivalent in services or commodities that an owner/buyer receives in

exchange for money. "Value Engineering" (VE) is a creative, organized approach whose objective is to optimize cost and/or performance of a facility or system. The VE approach is directed toward analysis of functions. It is concerned with elimination or modification of anything that adds cost to an item without contributing to its required functions. During the process all the expenditures relating to design, construction, maintenance, operation, replacement etc. are considered (see Figure 7). Such an

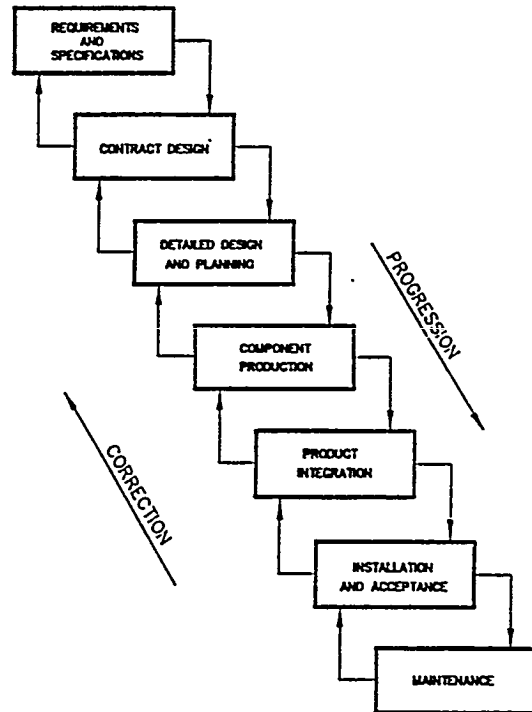


FIGURE - 7. THE WATERFALL MODEL OF THE PRODUCT LIFE CYCLE.

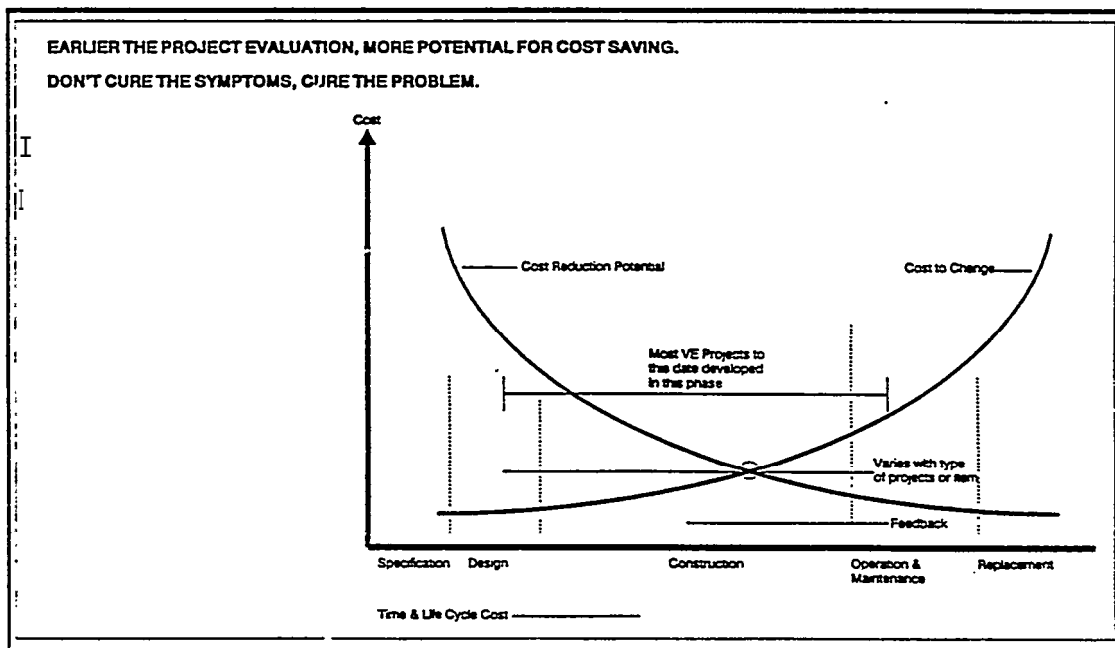


FIGURE - 6. COST REDUCTION POTENTIAL DURING THE PRODUCT EVOLUTION

evaluation relates to the life cycle considerations which represent continual activities involving design, evacuation, production, comparison and modification.

Through the use of creative techniques and the latest technical information regarding new methods, strategies, materials and processes, alternate solutions are developed for the specific functions.

Cost effectiveness aims at the efficient identification and removal of unnecessary costs, i.e. costs which provide neither quality, use, life, appearance, nor customer required features. It improves the effectiveness of work that has been conventionally performed over the years, by filling in blind spots. Once a high cost area has been isolated, quite commonly 15 to 25 per cent, and very often more, costs can be removed. As such, it is not:

just eliminating the "gold plating"

cutting costs by substituting items, processes, materials, and systems which do not meet the requirements

cutting costs by degrading performance, maintainability, or reliability below the requirements

reflecting adversely on the professional competence of the designer.

The techniques employed in value analysis are not new when taken on an individual basis (in fact we have been overwhelmed by fragments of knowledge but have had no way to structure this knowledge). What is new is the systematic and structured approach which converts observations and data into information and knowledge to be used in the analyses to be performed. Cost effectiveness is concerned with both the economic and the use values. Use value, or the properties and qualities which satisfactorily and reliably accomplish a use, is closely related to function. Performing a function based value analysis is to determine the usefulness of any item or element, whereas traditional cost reduction efforts give little thought to functional considerations of the user's need and attempts to perform an item-oriented cost reduction.

To facilitate a functional analysis, the function of any item, component or design is defined literally by two words: a verb and a noun. For example, the basic function of a hatch cover is to 'control access' - control is the verb, access the noun. Similarly the function of a wire is to "conduct current;" that of an elevator to 'convey weights.' Here, the verb answers the question, What does it do? This question focuses attention on the function rather than on the particular design and the subsequent function analysis involves thinking about why an item is necessary, rather than thinking about the item itself (see Figure 8).

Since a specific monetary value may have to be assigned later during the process of relating cost to function the type of noun to be used is important. A measurable noun together with a verb provides a description of a 'work' function (e.g. transmit load, support deck, store waste). Function definitions containing a verb and a nonmeasurable noun are classified as 'sell' functions. They establish qualitative statements, e.g. satisfy code, provide symmetry, assure convenience.

The technique of stating function using a verb-noun helps to reduce a problem to its fundamentals. The advantage of the approach are

Forces conciseness. If one cannot define a function in two words, either there is not enough information or one is trying to define too large a segment of the problem.

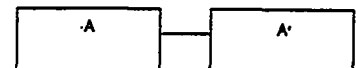
Avoids combining different functions and ensures that only one function will be defined at one time.

Facilitates the task of distinguishing between primary and secondary functions.

Aids in achieving the broadest level of disassociation from specific design or previous solutions.

Once the function-item relationship is established, functional analysis can be performed. The first step in any functional analysis is to classify the verb-noun function as either prime or secondary. The objective is to use an organization methodology to determine if there are functions that are unnecessary, overly expensive, or can be combined. The purpose is to simplify the logic in design, leading to making items less expensive.

Item-oriented cost reduction involves looking at item A and asking the question - "How can item A be made at a lower cost?" The result is item A', a modified version of item A, as shown below:



Value Engineering involves looking at item A and asking the questions - "How can the basic functions of item A be provided at a lower cost?" The result is item B, which is sometimes a completely different item, as shown below:



FIGURE - 8. FUNCTION-ORIENTED VS. ITEM-ORIENTED COST REDUCTION

'Prime function' is the performance feature(s) which must be attained if an item or design is to work or to meet the owner's requirements. The item may be a facility, a system, piece of hardware or software, service, method or procedure. An item may possess more than one basic function. For example, a superstructure bulkhead can be functionalized as "enclose space" and "support load". If the bulkhead is for an internal subdivision its "support load" function can be fulfilled by other means, hence its prime function is to "enclose space", the other being a secondary function. "Secondary function" is any characteristic of an item which is not essential to the user for the desired application of the item and does not contribute directly to the accomplishment of a prime function. In some cases secondary function performing items may result from honest wrong beliefs and assumptions, or the perpetuation of obsolete requirements.

Unless an item in question has also a prime function, for function analysis purposes, most secondary functions have zero use value. Secondary functions are support functions and usually result from the particular design configuration. Generally, secondary functions contribute greatly to cost. Where secondary functions are essential to the performance of the prime function, or required by codes, they have value.

Functional Analysis System Technique (FAST). As a rule functional analysis in design is performed from the top down. The relative position of an item in the total design is called its 'level of indentation'. If the function of the total design is dependant upon the indented item, the function is prime, - otherwise secondary. Functional analysis may be applied to all indented items, regardless of their function.

For study purposes, functions of secondary indented items are potential candidates for saving. However, when looking at the overall design and life-cycle costs, many secondary indented items may have essential functions in terms of maintenance, operations, safety or environment.

Level of indentation is derived by the ladder of abstraction method which has been developed as a thought-forcing process. Asking the question, Why? drives one's thinking up the ladder into higher order functions. Asking the question How? forces the thought process down the ladder of abstraction into lower order functions. A formal process of generating level in indentation through the use of level of abstraction is known as Functional Analysis System Technique (FAST). Use of FAST involves a function block diagram based on the answers to What? Why? How? The result is a hierarchy of functions showing their logical relationship. Within a FAST diagram the answer to the "How" question should lie to the immediate right of the function, and the answer to the "Why" question should lie to the

immediate left, about which the question was asked. In this way a chain of verb-noun function description is obtained which links the prime function to sequential supporting prime functions. However, for these functions to exist, a number of support functions need to be performed. If those support functions are required at the same time (i.e. concurrent) they are listed below that function, connected with a vertical line, forming a vertical chain of functions. Some support functions happen all the time and they are placed above the main horizontal function chain. Design Criteria and Codes are treated as all the time support functions. Scope lines determine the limits of the study, and the prime function under study always lies to the immediate right of the higher order scope line (see Figure 9).

Through the use of FAST diagrams one can identify all the prime functions, required and other secondary functions, and the analytical cost effectiveness procedures may then be applied.

Analytical Evacuation Procedure. The basic procedure of a cost effectiveness study is the function-worth-cost approach. For each major prime function all the related items and their functions are listed and identified as prime, required secondary and secondary. Cost of each item is calculated and added together to determine the cost. Then the worth of each item is determined and added together to calculate the worth. Worth is defined as the lowest cost to perform the prime function and required secondary functions in the most elementary level feasible, within the state of the present technology. Other secondary items are assigned to zero worth. In general, worth can be established from an analysis of historical costs, using collected costs for items performing similar functions. Worth may or may not be equal to cost for the same function can be performed more cheaply by other means.

Functional analysis item list is then completed, and estimated cost and worth for the function are determined. The cost/worth ratio provides an indication of the efficiency of a design or item. Experience gained in the fields of process and civil engineering suggest that when the cost/worth ratio is greater than two, there may be a fair potential for improvement.

Once a function is a candidate for potential savings, alternative ideas are generated and evaluated in the same manner. In the generation of new ideas the aim is to reduce the deficit between the cost and the worth. Some of these ideas may be impractical and eliminated on various grounds. The final decisions, however, are made by considering the life cycle costs.

Life Cycle Cost Methodology. Life cycle costing (LCC) is an economic assessment of an item, area, system or facility considering all the significant costs of ownership over an economic life, expressed in terms of

equivalent money. Life cycle cost analysis is defined as LCC plus use of a non-economic adjustment of results using utility evaluation techniques. Non-economic considerations include performance, safety, environment, etc. Because the expenditures are spread across different points in time, a 'baseline' time reference must be established and all the costs should be brought back to the baseline using proper economic procedures to develop equivalent costs.

To perform a LCC analysis information regarding the facility economic life, the anticipated return on investment, cost of money, and operation modes, as well as non-economic requirements such as performance, safety, etc, must be determined. With this information one can carry an analysis of several criteria, including economic and non-economic factors, each carrying a given degree of importance (weight) depending upon the circumstances of the project. Within this context decision making becomes a utility assessment process. At present a large body of knowledge and techniques are available for use. Because of its simplicity and other advantages, especially least dependence on data availability, makes simple ranking methods (weight assignment) the most preferable approach to be adopted.

Weight evaluation provides the tools for complex decision making through a formally organized process for the selection of optimum solutions in areas involving several criteria. In the process, criteria are assigned differing weight values according to their potential impact on a project. The alternative designs are then evaluated against the criteria. During the evaluation process, it is important to consider and weigh the following issues:

needs vs. desires
important vs. unimportant
trade-off vs. non-trade-off

The procedure for weighted evaluation consists of two stages: the criteria weighting process and the analysis process. The criteria weighting process (Figure 10) is designed to isolate important criteria and establish their weights or relative importance. In the analysis phase, performed through a matrix analysis (Figure 11), each alternative is listed and ranked against each criteria. The rank and weight of each constraint are multiplied and totalled. The alternatives are then scored for recommended implementation.

In criteria weighting, only those criteria which have significant impact in comparing alternatives should be listed. In addition, criteria should be unique and not overlapped by other criteria of similar properties. For example, reliability, maintainability, and proven quality have too many overlapping properties: only one should be listed.

Having determined the criteria to be used, the next action is to compare them and establish their relative significance. The degrees of significance are ranked as slight, minor, medium, and major preference. When a decision of importance cannot be made between two criteria, the two criteria can be indicated as equal by using both fetters in scoring the matrix and by scoring each at one point.

To standardize the weighted evaluation process, the raw scores are converted to a scale of 0 to 10 as the normalized weights, ten being the criteria receiving the highest raw score.

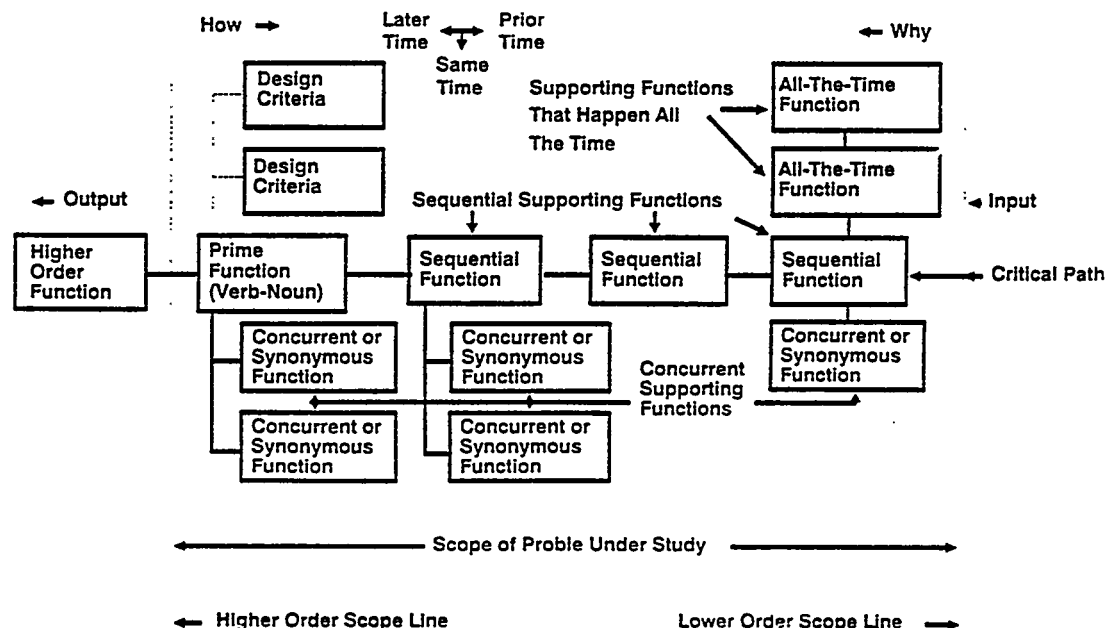


FIGURE 9. - FUNCTION ANALYSIS SYSTEM TECHNIQUES (FAST) DIAGRAM PROCEDURE

The matrix analysis is designed to take the criteria and weights developed and to establish a format for evaluation of the response of various alternatives against the criteria. Total weighted evaluation scores aid the decision-maker in the selection of best alternative. The input data consist of the criteria weighting process results and the alternatives under consideration.

LCC - Criteria Weighting Process

Project _____ Item _____

Team _____ Date _____

Criteria	Weight	Raw Score
A		
B		
C		
D		
E		
F		
G		
H		
I		

Criteria Scoring Matrix

How Important

4 - Major Preference
3 - Medium Preference
2 - Minor Preference
1 - Slight No Preference
One point each (Latter/Lesser)

	B	C	D	E	F	G	H	I
A								
B								
C								
D								
E								
F								
G								
H								

FIGURE 10. - FORMAT FOR CRITERIA WEIGHTING PROCESS

LCC - Matrix Analysis

Analytical Phase _____

Prime Function _____

	Desired Criteria	Weight of Importance (0-10)							Total
		a	b	c	d	e	f	g	
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									

Excellent - 5 Very Good - 4 Good - 3 Fair - 2 Poor - 1

Seek The Best - Not Perfection

FIGURE 11. - FORMAT FOR ANALYSIS MATRIX

5. COST ENGINEERING

Cost Structure. Since costs are the whole foundation of a cost effectiveness study, cost modeling and cost estimating form one of the most important part of the study. Estimation depends on the available design information and it has to follow the same stages with the engineering design; i.e. concept, preliminary, contract and detailed stages. Cost estimating is the rational application of quantitative methods to problems of estimating designs. The modifier rational suggest the establishment of correct cause-effect relationship as well as the satisfaction of accuracy requirement with due account for the difficulty in obtaining accurate and useable data.

Two essential elements of cost estimating are a rational cost breakdown structure and rational cost models for cost elements. Rational cost breakdown is an integral part of the overall technical database management system. The most critical element in cost breakdown is the presence of a logical structure in the form of hierarchies such that as the design progresses lower levels of the hierarchical structure are introduced into the estimation process. Such an approach necessarily leads to a direct reference to basic items in their lowest level and require the establishment of a knowledge base.

Cost Models. Cost estimates may be used for two purposes; to serve as a tool of the cost effectiveness analysis (as a guide for choosing amongst alternative designs), and to determine an actual budgeting requirement. The aim is to use the same cost models to serve both purposes, however in practice, different cost models are used for each of these purposes. The need to include value and cost considerations for the entire life cycle also demands consistency of cost models employed in different stages of design and construction, such that trends predicted in concept design level will not be contradicted in the later stages of the design and construction.

Although various classifications are always possible, based on their logical structure three major types of cost medals can be distinguished: (1) intuitive models, (2) correlative models, and (3) causal models.

Intuitive cost models employ simple design characteristics to apply quantitative reasoning. A typical cost model of this type is costing by weight groups, using past data. Correlative cost models interrelate several variables on the basis of past information, generally by means of a multi-variable regression. As such, these models are mathematically more complex than the intuitive models. They may produce more accurate cost estimates, but they are not necessarily any more insightful. Causal models are designed to represent the effects of some variables caused by changes in the others through a cause-effect analysis. Therefore causal models cannot be obtained

solely by a mathematical manipulation of data like a regression analysis. Their development requires a deliberate causal structuring, based upon either a formal theory (i.e. system identification), or at least some plausibility arguments and a strict validation process.

The major difference between the causal and other models is its ability to forecast as well as predict, i.e. incorporation of changes in technology, materials, methods and environment to anticipate how these changes may affect the future.

One feasible way of achieving a causal model is to define product, process, size and complexity metrics to reduce subjectivity and arbitrariness. Metrics are objective and algorithmic elements for the measurement and quantitative estimation of product features in relation to a product model. As such they can be used in estimation of cost, size, quality, complexity etc. For example, complexity of a hull system can be expressed using "Cyclomatic Complexity Number (CCN)" employing a decision flow graph (see Figure 12).

1 1 This definition has been borrowed by cybernetics.

CCN = $e - n + p$
 e = number of operations in a unit
 n = number of element
 p = number of connections with other units

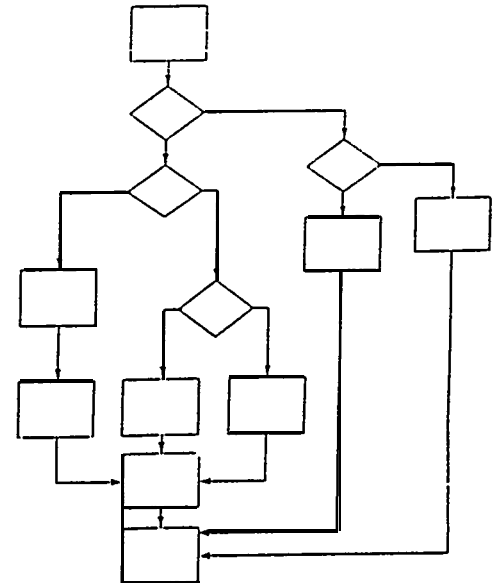


FIGURE 12. - COMPLEXITY ANALYSIS FROM A WORK SCHEDULE FLOW GRAPH

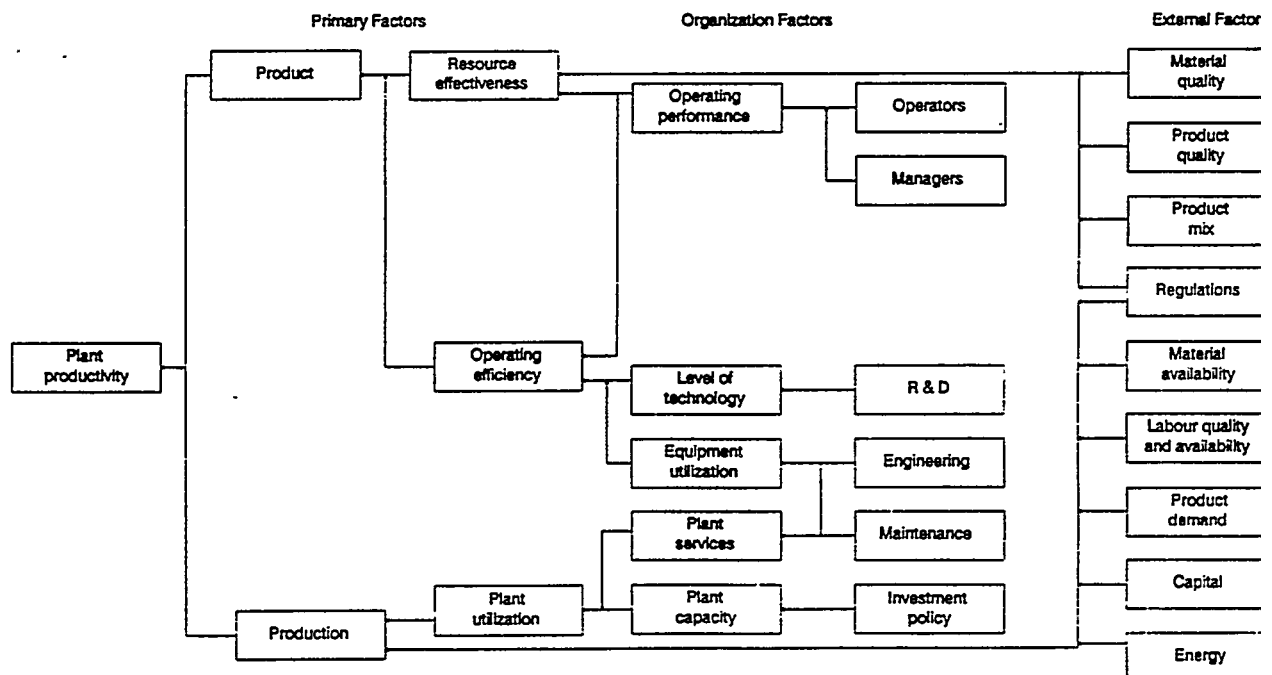


Figure 13 - FACTORS THAT INFLUENCE PRODUCTIVITY

6. RELATIONSHIP BETWEEN SHIPYARD MANAGEMENT STRATEGY AND INFORMATION SYSTEMS STRUCTURE

Since the early days of industrial revolution the method of shipbuilding and its management have undergone considerable changes. Until the end of the Second World War artisan mode of operation and hands on personal leadership, based on the know-how of the master, were the basic principles of operation and management. This structure was replaced by graduate managers and strong central control, which largely led to the downfall of Western manufacturing industries by stifling innovation and by creating top heavy organizations. Since early 1980's a number of manufacturing industries have moved to a new style known as the 'learning organization', by studying and adopting (not copying) the approach adopted by the successful Japanese manufacturing companies. Table -1 displays a comparison of the two approaches, the major differences being the adoption of a graduated control system and worker participation.

Adoption of a graduated control system require the implementation of a distributive information system where the operational data is collected and analyzed locally on the shop floor to provide immediate information and to determine the necessary action. In such a system information needs to travel both upwards and downwards, necessitating flexibility and extendibility as the worker participation will tend to improve evolving tasks and alter the information requirements.

Within this context definition of productivity and its measurement require special attention. In the first place it is to be understood that total productivity evolves from the amalgamation of a number of factors (see Figure - 13); some of these factors are outside the direct control of the shipyard, some others are dependent on the organization end operation of the shipyard, and yet the most important factors relate to the ship design and shipyard facilities and production technology. It is incorrect to assume that workers are only elements to measure productivity.

A meaningful approach for the measurement of productivity is the introduction of single factor and total factor productivity indices, [5]. Here, single factor productivity (SFP) refers to the ratio of output of a product and the input of resource, e.g.

SFP = $\frac{\text{Output of A}}{\text{Input of Resource 2}}$

It is important to note that here both A and Resource 2 are in raw variables. In the definition of total factor productivity (TFP) inflation adjusted percentage contribution to cost appears as a weighting factor, i.e.

TFP = (Inflation Adjusted Percentage Contribution to Cost).SFP]: Change in SFP and TFP provides a realistic vehicle for the evaluation of performance and for the diagnosis of problems. Figure 14 illustrates four of many potential trends which can be detected from such an analysis.

A shipyard information system designed to capture and analyze this level of productivity data will not only assist in the achievement of performance improvement

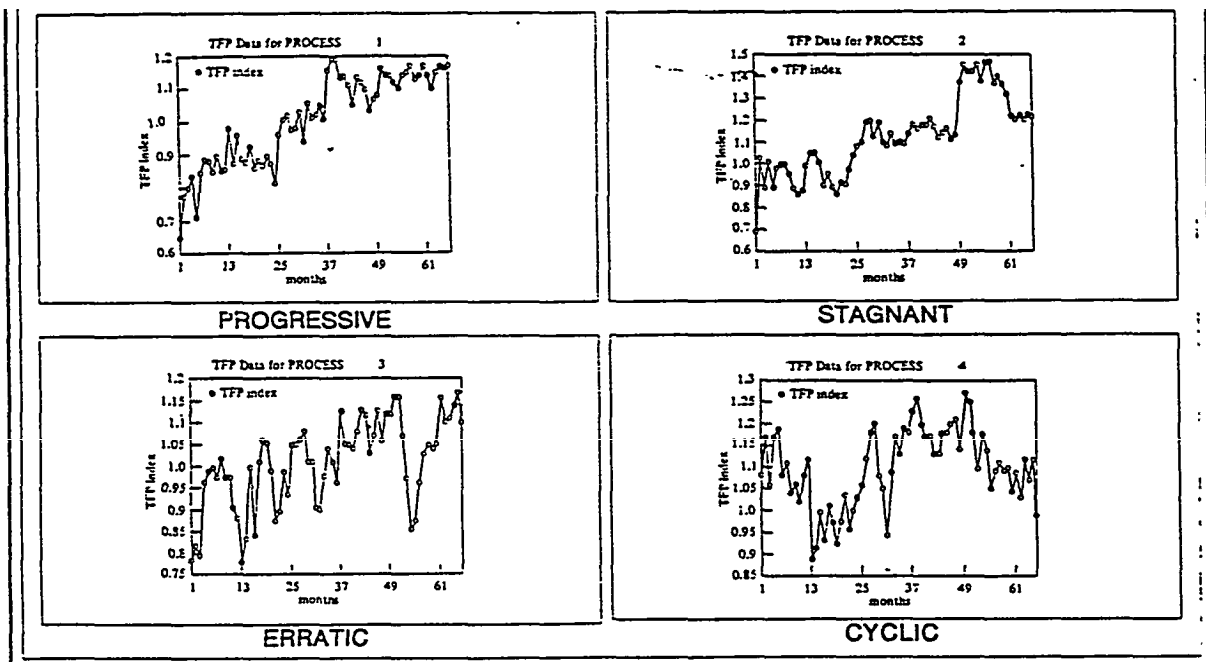


Figure 14 - DIAGNOSTIC ANALYSIS USING TOTAL FACTOR PRODUCTIVITY

but also be able to capture and predict the effect of learning (both capital and non-capital related) on productivity improvement. Such a knowledge base will help the corporate management in the planning and justification of further capital investment. In a large number of investment planning studies this effect is totally ignored as a consequence of the generally acceptable accounting practices (GAAP). Figure -15. displays the total factor productivity improvement in a fabrication plant over a period of ten years, where nearly half of the improvement is due to the capital related learning effect.

Information management starts with the premise that the key information in an organization can be identified and cataloged. Converting the data into information is the main aim of capturing and retaining data. Increased use of computer applications increases the amount of data in such a way, if it is not managed in a meaningful manner, it can quickly turn into a liability. Therefore it becomes necessary to create information about the data in the organization, known as "metadata". An efficient method of organizing the metadata is the use of data dictionaries.

The data dictionary system can be viewed as a postcode system, knowing where all the data are, their cross-relationships anti hierarchy, and the methods of access and updating. It constitutes the constitution of shipyards' data processing environment. The main functions of a data dictionary are:

- 1 Identification of entities that enter into the system, and the association of these entities.
- 1 Establishment of naming standards and guidelines
- 1 Provision of information on the availability of data for shared use.

Overall planning for applications so that data duplication is avoided wherever possible.

Provision and enforcement of security procedures.

Provision and implementation of procedures to maintain the integrity of databases.

Success of data dictionary system in a shipyard largely depends on its relevance to the activities of the shipyard, consisting of two main tasks. The first task consist of establishing a comprehensive list of agreed

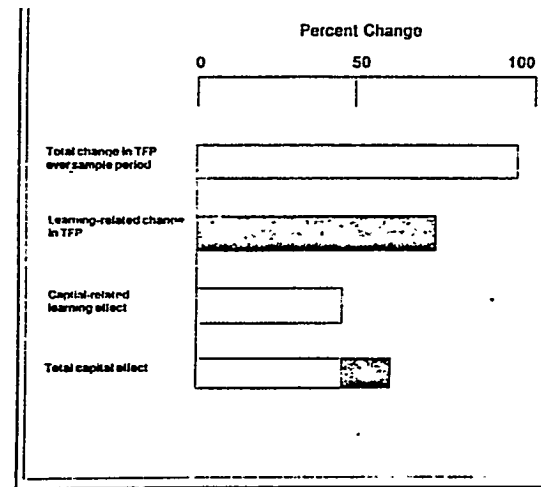


Figure 15 - • TOTAL FACTOR PRODUCTIVITY (T

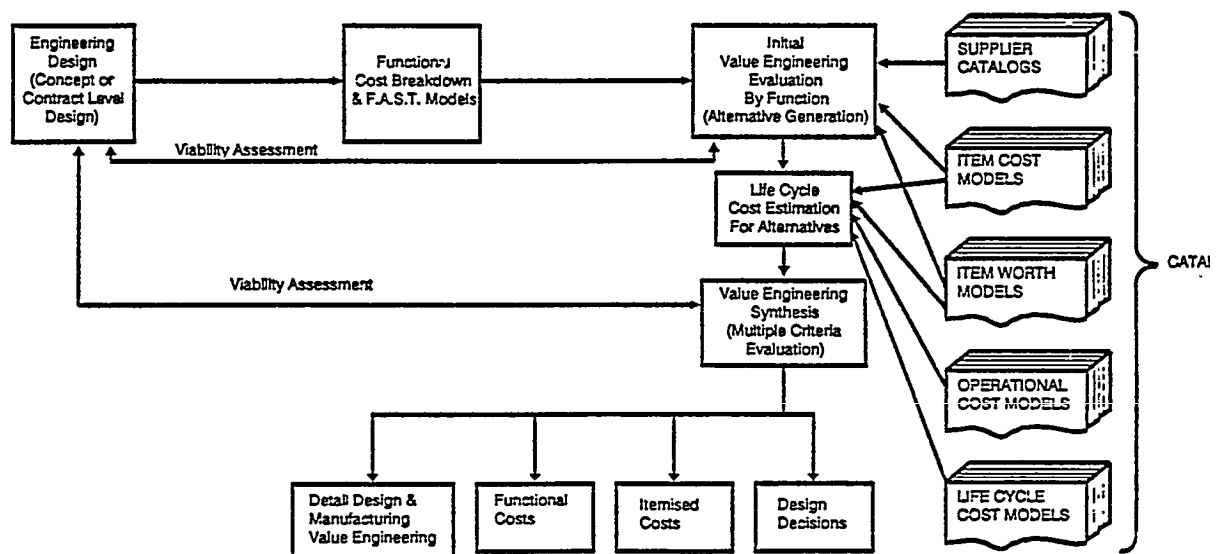


Figure 16 - DECISION INTEGRATION - COST & VALUE ANALYSIS DURING THE DESIGN CYCLE

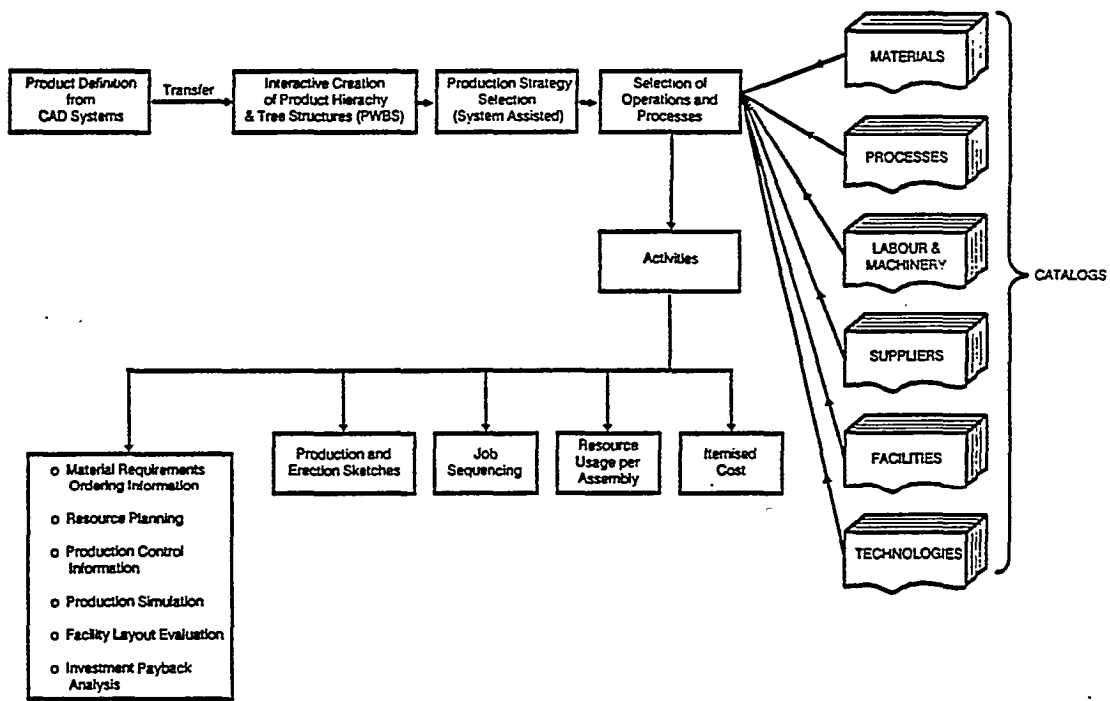


Figure 17- DECISION INTEGRATION - COST & VALUE ANALYSIS FOR MANUFACTURE PLANNING

	<i>Conventional Organization</i>	<i>Learning Organization</i>
Assumptions underlying the operating principles	Optimize defined tasks	Improve evolving tasks
	Productivity; adherence to best practice	Productivity; develop better practices
	Decisions deferred to higher levels	Decisions where needed
	Narrow job definitions	Broad job definitions
Role of the work	Physical effort	Mental & Physical Effort
	Minimize skills (deskilling)	Maximize worker's skills (both technical and problem solving)
	Process should be worker independent	Worker can add value to the process by improving it
Information needs	Coordination (what & when) and control	Process improvement is everybody's job
	Fixed responses to problems through standard operating procedures	Flexible responses to problems as they arise
Management control	Direct control (variance analysis, direct supervision, and inflexible procedures)	Performance evaluation based on success of the business
	Boss knows the answer	Second-order (systems & procedures) and third-order (norms & values) control
	Strict hierarchy and status	Boss supports and helps
		Peers working as a team

TABLE 1. - CONTRASTING VIEWS OF WORKERS' ROLE IN TECHNOLOGY ORGANIZATIONS

definitions of data. The result is analogous to an ordinary dictionary. The second task, coding and classification, is complementary to the first and consists of establishing an overall organization of the data items (classification) and then providing effective means of identifying the place of each item within an overall indentation structure (coding). A close analogy here can be made with that of setting up bibliographic system, such as Dewey Decimal System used in many libraries. U.S. Navy's extended PWBS provide a reasonably comprehensive list of ship items. It however does neither contain the purpose of use, e.g. costing, standards, specification, design, etc., nor does it relate to production related activities and processes. An alternative is the BMT coding and classification system, which satisfy these additional requirements but require further updating.

The major advantages of employing such a coding and classification system are the ability to link up with the design and production processes, work content and building logic, group technology and sorted bill of materials. This system also allows for embedding standards and procedures into the database system and make the design, production, installation, quality and acceptance as standard/procedure driven actions.

7. POTENTIAL APPLICATION IN U.S. SHIPYARDS

Each shipyard has certain characteristics in their use of information systems that are unique to that shipyard. Their future development of systems will be governed to some extent by the nature of the shipbuilding market they are operating in. Each shipbuilder can make an assessment of their systems relative to the requirements and desirable presented in this paper, and identify those aspects that are significantly at variance with the logic and the approach. It is hoped that the issues raised in this paper will be assistful in the adoption of information technology models within the U.S. shipbuilding industry. A typical logic of such an application is illustrated in Figures 16 and 17.

Achievement of a satisfactory and economically beneficial information system demands investment and takes time to be functional. As such, it requires the commitment of the highest level. Taking shortcuts and development of disjointed elements are the biggest dangers on the road to success. Involvement of workforce in the design, development, consolidation, and operation of the information system is a critical factor to make the system workable and acceptable.

It is the belief of the present authors that successful resolution of this issue is one of the key elements in the revival and growth of the U.S. Naval and Commercial Shipbuilding industries.

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