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0439

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Increasing U.S. Shipbuilding Profitability and Competitiveness

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ABSTRACT

The declining number of Government contracts for ship repair and new construction work. and the acknowledged competitiveness "Gap" has resulted in the need for U.S. shipyards to face the major challenge of reducing total ship cost, construction time and their general overall approach to meet the "necessary conditions" of commercial ship owners in order to obtain contracts. Increased profitability is also a necessary condition for short term survival but does not ensure that these shipyards will be competitive in the commercial ship world marketplace.

The significant impact on profitability and competitiveness resulting from reduction in construction time will be discussed. Construction time is defined as the time between contract award and delivery. The techniques that can be used to determine: What to change, What to change to, and How to cause the change will be described along with the paradigms that are present which greatly hamper the breaking of physical, policy and behavior constraints.

SITUATION

Well over 90% of all new construction and major conversion work of ocean going ships in the U.S is presently being performed by five major shipyards for one customer, the U.S. Navy. A1l of this work must be accomplished to meet Government type contract requirements. The challenge facing U.S. shipyards is to become more competitive in the market. U.S. shipyards can increase their profitability considerably and still not be competitive in the market.

Although all five shipyards have considerable backlogs and, when options and/or projections are included, this Navy work extends out into late 1997 and beyond. Anderson and Svedrup, 1993 in their discussion responded as follows to this author's question why the U.S. shipyards are not competitive: What lies implicit is that U.S. shipbuilding must be "determined!" to change in order to increase productivity which we consider to be THE problem for U.S. shipbuilders.

Anderson and Svedrup, also discussed two other very pertinent statements relative to U.S. shipyard's becoming competitive: (1) Specialize, do not have a "Dual-Use" shipyard, and (2) Shipbuilding must be viewed in the long term. U.S. shipyards with long term Navy work must deal with the dual-use problem and it is believed that all have committed to the long term view. There are many other areas that are not within the control of U.S. shipyards that have a significant impact on profitability, and more so on competitiveness, because they affect not only the shipyards, but have a greater effect on ship owners. Some of these areas are: foreign shipbuilding subsidies, International laws and regulations. depreciation laws, special financial agreements. and ship operational costs.

How Wide Is The Competitive Gap?

One of the major tasks U.S. shipyards face is trying to determine how big is this competitiveness "Gap." U.S. shipyards have not built commercial ships that can be used in any comparison in a long time.

Table I provides a 1993 evaluation of three other shipbuilding regions to the U.S. in eight major functional areas. The largest gaps are in the Marketing function followed by the Overall function and the Strategy Management which appears i two of the three range comparisons These comparisons seem to validat that management paradigms are the cor problems that must be addressed befor the issues of increasing profitabilit and reducing the competitiveness ga can be effectively resolved.

A comparison of schedul construction time for a U.S. shipyar and Japanese shipyards is shown i Table II.

SHIPBUILDING REGION	OVERALL	HUMAN RESOURCES	STRATEGY MANAGEMENT	TECHNICAL
EUROPEAN COMMIUNITY,	85-115	90-115	75-130	95-110
JAPAN, RANGE	95-120	100-125	95-125	90-ll0
KOREA, RANGE	90-110	100-120	85-110	85-105
USA, RANGE	65-90	80-l05	70-90	70-loo
RANGE of GAPS *	20/30/55	10/20/45	5/40/60	15/10/40

	MARKETING	PRODUCTION	PURCHASING	PLANNING
EUROPEAN COMMUNITY	85-120	90-110	85-115	85-115
JAPAN	100-115	90-110	90-125	100-125
KOREA	ll0-130	90-115	80-95	80-95
USA	40-60	75-95	.75-95	80-100
RANGE of GAPS *	45/70/90	15/20/40	5/30/50	0/25/45

*GAPS = Range of USA to other Regions: Low:Low/High:High/Low:High.
Underlines indicate lowest and highest in each functional category.

Table I Competitive Evaluations of Shipbuilding Regions
Index of Commercial Shipbuilding Competitiveness by Function
(100 = Average International Shipyard)

Source: Bunch, 1993.

Shipyard	USA	USA*	Japan	IHI	AJI	MHI	SHI	VLCC
CA to SC	61	39	22	34	34**	26	26	43
SC to D	79	79	38	43	39	39	39	47
CA to D	140	118	60	77	73	65	65	90

* Based on Japanese Material lead times. ** 50% before Contract Award.
IHI = Ishikawajima Harima Heavy Industries.
AJI = Advanced Jointless Information Systems by Assimilation and Inheritance
MHI = Mitsubishi Heavy Industries, 80,000 TWDT Double Bottom Product Carrier
SHI = Summitomo Heavy Industries, 85,000 TwDT Bulk Carrier.
VLCC + Very Large Crude Carrier.
CA = Contract Award, SC = Start of Construction, D = Delivery.

Table 11 Construction Time (in weeks) Comparisons

Source: Bunch, 1987, Bennett and Lamb, 1994.

Although the above figures represent several different types of ships, the one U.S. shipyard requires an average of 29, 37, and 66 more weeks for the CA to SC period, SC to D period and the CA to D period respectively: around double the time.. Table 11 indicates that almost 50% of the total gap results from actions taken during the period from CA to the SC and that more than 50% of the total gap takes place from SC to D.

Actions taken during this first period will have a significant impact on construction time because these actions provide the prerequisite information needed to accomplish the multitude of construction tasks.

The reported difference (1980) between a U.S. shipyard building a similar ship in the SC to Launch period, i.e., fabrication, assembly and erection activities is 2.4, 2.6 and 2.5 times that of a Japanese yard respectively (Bunch, 1987).

Some one berth or single dock Japanese shipyards can complete five or six ships in a year; and with four month erection times, this means there must be berth or dock times overlapping (Bennett and Lamb, 1994).

All tasks performed in the construction of a ship are in accordance with the shipyard's management systems (set of formal and informal rules). These rules are in effect ❑any paradigms. Apparently following these paradigms has resulted in no significant reductions in U.S. shipyard construction times.

"...no U.S. shipyard, has to the best of our knowledge, offered the Navy alternative approach, benchmarked against its foreign competition, that would satisfy the Navy that their particular build strategy was indicative of world class standards." (Spicknall and Wade, 1993).

The Navy also has paradigms which may not be congruent with the U.S. commercial shipbuilding needs relative to ship construction times.

Another significant gap area between U.S and foreign competition is in construction manhours. A comparison of the manhours required to build similar ships in a U.S shipyard and a Japanese shipyard indicated the Japanese shipyard required 39% of the effort of the U.S. yard (Bunch, 1987). Presently, the gap although significant is not as great as estimated in 1987 (Bunch, 1987, Storch and Clark, 1994).

The present administration, concerned about the ability of U.S shipyards to make the transition into the global commercial shipbuilding market have initiated a program to help narrow the gap. The five main elements of their program (Beargie, 1993) are:

1. Title XI Loan Guarantees.
2. Research and Development administered under the Department of Defense organization called MARITECH,
3. Elimination of unnecessary government regulations which impose burdens on the shipbuilding industry,
4. New market promotion program to help U.S. shipyards identify and win potential foreign orders (one objective will be the facilitation of cooperative agreements between U.S. and foreign shipyards), and
5. Continuing efforts to end foreign ship building subsidies.

The Advanced Research Project Agency (ARPA) is managing the Maritech program and has already awarded numerous cost-sharing contracts totaling many millions.

Under the new Title XI program, ship owners (foreign (except for U.S. flag ships) and domestic) can obtain 25-year financing for up to 87.5% of the actual cost of constructing a ship for export-at a fixed interest rate. Some Title XI monies also are for U.S. shipyard modernization.

Increasing foreign labor costs and positive exchange rates may also help to narrow the gap. However, the challenge to reduce the competitive gap and leapfrog the competition must be the major goal of U.S. shipbuilders.

WHAT (PARADIGMS) TO CHANGE? AND WHAT (PARADIGMS) TO CHANGE TO?

U.S. shipbuilders are in need of a transformation from the way that they have been doing business in the past. To paraphrase Barker (1992), shipbuilding is a business that has many paradigms: management, material, marketing, engineering, planning and scheduling, accounting and many others. In addition there are even more paradigms in the cultural behavior of the shipyard's management, workers, vendors, etc., not to mention the primary customer's (U.S. Navy) numerous paradigms.

The interrelationship of all these paradigms is crucial to the success and longevity of any U.S. shipyard. "A paradigm, in a sense, tells you that there is a game, what the game is, and how to play it successfully...A paradigm tells you how to play the game according to the rules...A paradigm shift, then, is a change to a new set of rules to be used in the game." (Barker, 1992)

The idea of a game is a very appropriate metaphor for paradigms because it reflects the need for borders and directions on how to perform correctly.

The highly interdependent structure of the "forest" of paradigms that are integral with shipbuilding, coupled with the condition that there has essentially been only one "customer" for a long period of time, has resulted in only one set of rules for "playing the game."

To meet the present necessary conditions in the market, numerous paradigm shifts (transformations) will be required because the rules of this "new game" are quite different.

The two basic levels of the Transformation Process by which a company reconceptualizes and redesigns itself (system) to remain competitive are (Swartz, 1994):

1. A systematic approach to Continuous Linear Improvement and

2. a systematic approach to Continuous Non-Linear Improvement redesign of the system.

Continuous Improvement is usually linear and consists of reduction of valueless time, activity, and variance. System redesign is usually non-linear and involves: new process intent, new process models, new learning and improvement system, and new value-adding technology. Reward systems are a necessary condition of any learning and improvement system. Learning is defined as - new concepts and new ideas entering your brain. Improvement is the process by which one learns to change:

1. What one does,
2. What others do, or
3. The system that affects peoples lives.

The major transformation for U.S. shipbuilders is how to make the necessary changes to "leapfrog" the competition. Benchmarking can provide insight as to what the competition is doing, but world class competitors are not waiting for the U.S. shipyards to catch up and as time moves on, the "Gap" actually increases as shown in Figure 1.

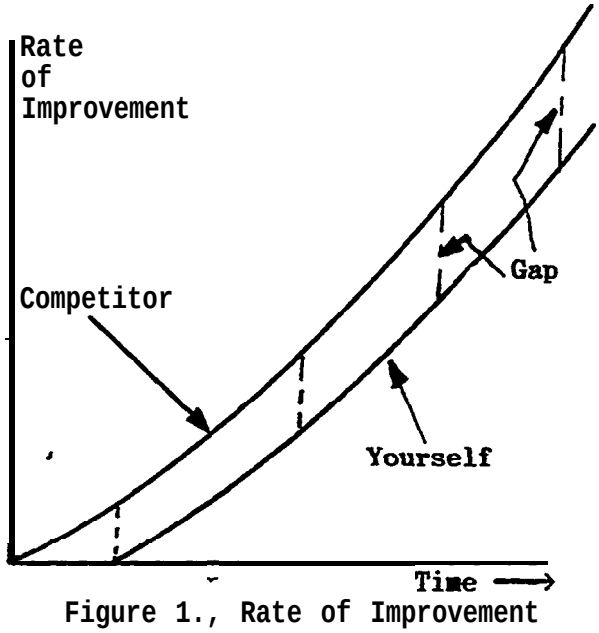

Figure 1., Rate of Improvement

Source: (Goldratt and Fox, 1986)

A good starting point to look for paradigms-that are hampering U.S. shipyards from being competitive was paraphrased by Walton in 1986: Deming explained that workers' performance is determined solely by the system in which they are working. Management, he said, must not only recognize that most of the failure for a system to produce the desired results is due to the system itself, but that management must change itself, and the system, to improve outcomes.

Deming identifies two major paradigms in the above statement, the "system" and that management must change itself (its thinking) before it can change the system. The system that U.S. shipyards are using is based on years of trial and error and experience to meet customer requirements. With the demise of commercial shipbuilding in the U.S. the system that has been developed to meet one customer's requirements is in itself a major paradigm, but not the core problem.

The Key Paradigm - Thinking

After the second World War, analysis became the dominant mode of thought, so much so that even today analysis and thinking are used as synonymous terms. The following definitions provide a clear distinction between two thinking approaches. The analytical approach utilizes the following three steps (SBM, 1993):

1. Reducing the problem to a set of solvable problems,
2. Solving the component problems, and then
3. Assembling them into a solution as a whole.

The systems approach is an alternative to the analytical approach. A system is a collection of parts which must satisfy the following three conditions. First, the performance of the system as a whole is affected by every one of its parts. Second, the way that any part affects the whole depends upon what at least one other part is doing. The third condition is that if one takes any number of parts and groups them in any way, they form sub-groups which will be subject to the same first and second conditions as the original parts are.

Two principles of systems thinking follow (SBM, 1993).

1. If one takes a system apart to identify its components, and then operates those components in such a way that every component behaves as well as it can, the system as a whole will not behave as well as it can.
2. If a system is behaving as well as it can, none of its parts will be.

The Key Paradigm Shift

Traditionally, successful managers have strong problem-solving skills. When a real problem occurs, they solve it. This is how most managers are evaluated as to their effectiveness on the job. Most shipyard managers are paid to solve problems whether they are trivial or complex, so naturally managers spend most of their time doing just that.

Barker, 1992 describes this condition as a "great big buzzing confusion." This condition is also commonly called a "Mess." What reaiity consists of are messes, not problems. A mess is a system of "perceived problems" or "symptoms" of the underlying cause that drives the system. The traditional way of managing is to treat the mess analytically, but if a true belief that the systems approach does exist, then an analytical approach can not provide a solution to the mess; only a situation referred to as "fire-fighting" can solve the mess.

One of the most important management skills during times of high turbulence is anticipation (Drucker, 1980). There it is suggested that managers improve their skills so that their actions are mostly in the upper

right quadrant shown in Figure 2. The area bounded by the oval ("A") is the area between anticipation, problem avoidance and opportunity identification where managers should strive to operate. The lower left quadrant where most of oval ("R") is located is the area between problem solving and reaction where most managers now operate. It is in the opposite area ("A") that the greatest leverage over the future can be realized - personally, organizationally, and nationally.

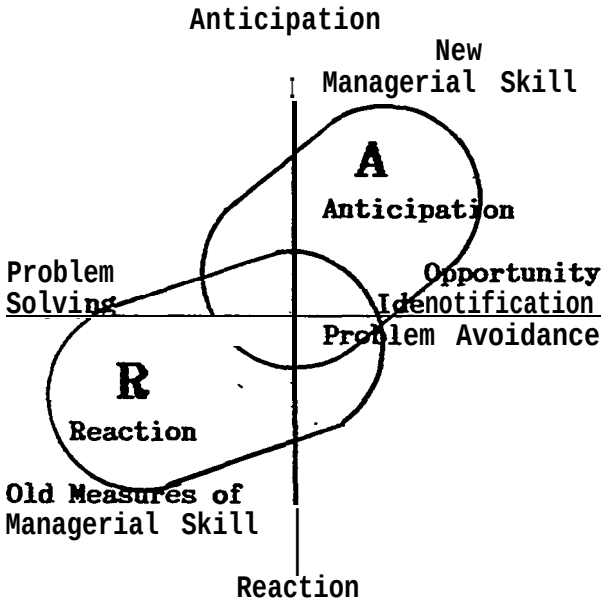

Figure 2. New Measures of Management Skill

Source: Barker, 1992

The time between changes is decreasing and the magnitude of change is increasing. Organizations and people must move from the old style of solving problems (firefighting) to a new style of anticipating potential problems before they happen and try to keep them from occurring in the first place. Peoples' and organizations' attentions must shift from looking for the fire-fighting type of solutions to developing processes which will assure the maintenance or improvement of solutions over time.

The competitiveness gap facing U.S. shipyards indicates that initial efforts should be in the area of system redesign. A prerequisite to system redesign will be the implementation of systems thinking by management. Management must change itself, and the system, before the key paradigm shift can result.

Primary Focus - Another Key Paradigm

Unfortunately, organizations and people live in an impatient world that confuses fire-fighting reaction type actions as progress. Most organizations have invested and continue to invest millions in improvement programs under many banners such as Manufacturing Resources Planning (MRP II), Total Quality Management (TQM), Just-In-Time (JIT), Theory of Constraints (TOC), and other such programs. Each one of these programs in isolation appears sensible, and many have resulted in initial impressive improvements as Curve A in Figure 3 indicates. However, experience has shown that the slope of Curve A (the rate of sustained improvement) does not continue. This rate of improvement flattens out over time, then is stagnant and in some cases declines to the point of bankruptcy!

Until a proposed action plan is rigorously checked out to make sure that it has a high degree of assurance that it will lead to the long term desired effects (goals), then the application of time, resources, and capital will usually result in a process of on going linear improvement and Curve A type results.

It is this lackof primary focus on what drives a system that leads managers to do the wrong thing. If organizations and people do not take the time to clarify what they want - by trying to understand all the possible ramifications of their proposed programs - their actions can not be strategically congruent.

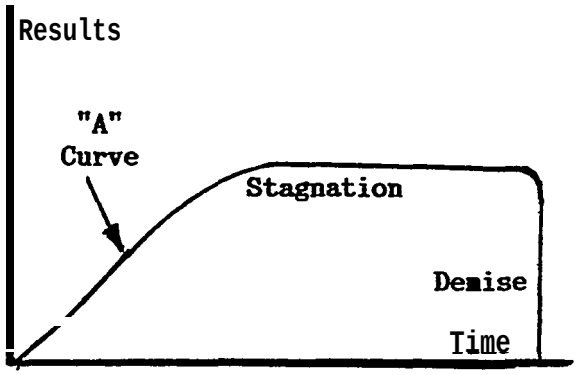

Figure 3. Rate of Improvement

Source: Goldratt, 1990

U.S. shipyards, like other for profit businesses, have been traditionally organized along functional lines which include sales, production, engineering, materials, finance, human resources, and so on. Each of these functions are usually broken down into smaller functional groups (departments), which in turn are further subdivided into levels such as managers, superintendents, supervisors and in some cases leadmen. If, as traditionally done, each of these levels and each of these functions perform as efficiently as they can, then according to the systems approach described above, the shipyard will not be efficient!

One has only to look at the history of U.S. shipbuilding to confirm that paradigms have been developed that conform to the analytical approach. Government contract requirements which require performance measuring of individual work order budgets and schedules reinforces the analytical approach.

The current goal of U.S. shipyards' is fairy clear: To become more profitable and competitive in the world market. In order to achieve this purpose, the synchronized effort of many resources is needed. The fundamental principle of the Theory of Constraints (TOC) is: The organization should be viewed as a chain composed out of many links.

The contribution of any link is strongly dependent upon the performance of other links - A chain is only as strong as its weakest link.

Very few organizations operate as a chain (all dependent operations in series), most operate as a grid of chains. Thus the number of weakest links (constraints) that determine the performance of an organization, depends on the number of independent chains comprising the grid. The more complex the organization (like a shipyard), the fewer the number of independent chains it contains; more complex means more dependencies. Thus, if an organization wants to improve its performance, the first step must be to IDENTIFY the systems constraint (Goldratt, 1990).

The traditional shipyard practice of trying to improve the budget and or schedule performance of any one of the thousands of work orders (links) required to build a ship is contrary to the above TOC principle. The bottom line impact resulting from solving independent (links) problems is usually very small.

To get out of the "mess", logic must be used. Not the correlation techniques used in the soft sciences and predominantly by managers today, but the logic of Effect-Cause-Effect (ECE) used in the hard sciences to answer why things are related. When this paradigm shift from using correlation techniques to using ECE techniques is made, then the problem solving process can be better relied upon in the search for good iterative solutions and in preparing practical strategic plans.

These same ECE techniques along with a procedure called: Categories of Legitimate Reservations (CLRs), are used to specifically build and check the accuracy, logic, and existence of all causes, effects and relationships. This challenging of all logic is integral to the TOC, Thinking Processes (TPs), and the applications derived from their use.

These TPs are applicable to all types of organizations. The TOC TPs empower managers with tools to systematically, logically, and effectively answer three fundamental questions:

1. What to change,
2. What to change to, and
3. How to cause the change.

The TOC TPs also provide the logical techniques to not only answer: Why is the system sick, but also *two* other major questions: What changes are required to the system, and most importantly: What actions does management have to take to effectively implement the cure?

Elmes,(1992) concludes that: "most of the procedures used in TP, have a solid scientific basis... Furthermore, it is now possible to document the techniques. ..because it contains some unique feature (the effect-cause-effect and evaporating cloud techniques), and because the entire package of techniques is aimed at improving organizational problem solving."

Other Major Paradigms

One only has to look at how most organizations, people, and as the best example, the Government act relative to problem solving to confirm the following statement: The tendency is to look for the easy way out by circumventing the requirements instead of exposing the hidden assumptions.

Complexity in problem solving results when compromises are developed to satisfy more and more requirements. In reality, what has been developed are actually tolerable compromises. Tolerable compromises are generally a result of some policy that management has established and implemented at some time in the past to solve a problem existing at that time. The assumptions made at that time, upon which these managerial decisions or policies were based were sound, but have rarely been challenged. The results are that many of these policies have become constraints.

Many managerial decisions and long established policies also adversely affect the throughput of a manufacturing company. These types of constraints are difficult to identify and much harder to change due to the tremendous amount of Inertia that has been built up over many years because the organization becomes comfortable with the status quo. These types of management decisions and policies can magnify problems created by other systems or they can encourage decisions that lead to global suboptimization of the "present operational "System" of the organization.

For example, the use of Economical Order Quantity (EOQ) or Economical Batch Size (EBS) techniques have been used in production and purchasing as a standard policy in many U.S. companies. Setting batch sizes based on EOQ or EBS is still a common practice (policy) in many manufacturing plants around the world, except for those implementing JIT technology. JIT challenged the traditional assumptions upon which Figure 4 is based relative to setup costs and proved that the reduction of inventory was a major driver to increased throughput and profitability.

By implementing new innovative techniques the Japanese reduced setup costs significantly and they reduced the size of transfer batches which enabled them to start the next operations much earlier. The role of reduced inventory was one of the major reasons Japan was able to leapfrog competing nations in manufacturing areas as this paradigm shift (policy) improved products in the quality and engineering areas, resulted in higher margins and lower investment per unit in the price area, and improved responsiveness by creating shorter quoted lead time and better due date performance. (Goldratt, 1986)

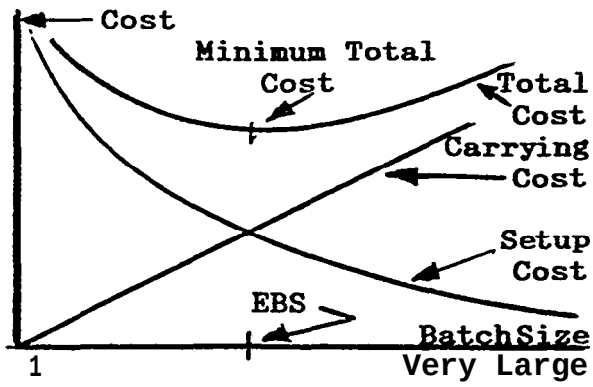

Figure 4 Total Cost Curve for EOQ Batch-Sizing Approach

Source: Umble and Srikanth, 1990

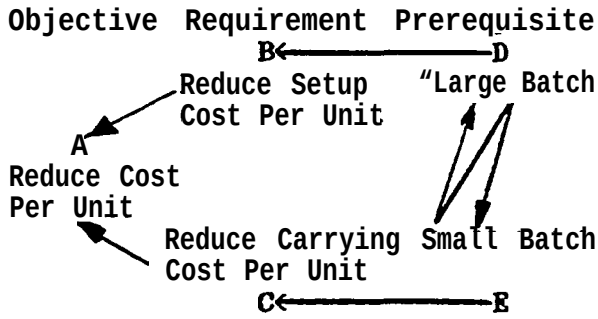

Figure 5 EBS Batch-Sizing Evaporating Cloud Diagram

Source: Goldratt, 1990

The Japanese consider inventory a liability. However, on their financial balance sheets, inventory is listed as an asset. Generally Accepted Accounting Practices (GAAP) also list inventory as an asset. This apparent conflict can be resolved by using the TOG Evaporating Cloud (EC) technique. A win-win solution results: Inventory is only an Asset when it protects Throughput (Rack, 1992).

The EC technique is one of the processes used in the TOC TPs and is based on the following three steps:

Step 1. Present the problem in a diagram format.

Step 2. Expose and verbalize the assumptions behind the various arrows.

Step 3. Challenge the assumptions to the point that one or more is exposed as invalid or irrelevant.

The conflict shown in Figure 5; large batches v. small batches) is essentially resolved (evaporates) because the correct course of action (valid assumptions) is evident.

The EOQ or EBS EC diagram would look like Figure 5. The Objective, Requirements, and the Prerequisites are known and the Conflict is - large batch or small batch.

The traditional solution was to relax the requirements by making a compromise by establishing an EOQ or EBS. The EOQ or EBB concept is not a win-win solution. The JIT solution was based on correlations and appeared to be a satisfactory solution-reduce setup costs and transfer batch sizes. The TOCTP techniques are based on ECE which rely more on a process rather than just good intuition to guide users in search of a good iterative solution and strategic plans. Using the TOG TP techniques, the assumptions and the challenges of these assumptions reveals a more powerful solution. Table III, lists the assumptions behind the arrows and the reasons why these assumptions are invalid or irrelevant, (erroneous).

The apparent win-win solution relative to the Figure 5 objective is that large production (setup) batches are required for cost effective constrained resource operations and that small transfer (inventory) batches should also lead to cost effective operations. A traditional EOQ or EBS tolerable compromise and the improved solution offered by JIT methods can be replaced by use of the TOG EC techniques and result in improved (second order) solutions.

The JIT approach does not recognize the inherent differences in resource types (constrained and non-constrained). In reality, inventory is required to maintain present throughput and to protect future throughput.

The conflict as to inventory being a liability. or an asset is therefore not resolved. The TOC EC technique resolves this conflict.

Table III EC Assumptions and Reason Assumption is Erroneous

EC Assumptions

B←D There is no distinction between the value of setup time at a bottleneck versus a non-bottleneck.

C←E The carrying cost are the only the dollar cost to actually carry the inventory.

D←→E There is only one aspect of hatch size to consider. "A Batch is a Batch."

Reason Assumption is Erroneous

B←D Distinction is that savings in setup time usually results in more idle time on non-bottlenecks.

C←E There are numerous additional costs associated with carrying inventory such as handling, records etc.

D←→E Setup is a production prooess and constraints require large batches to minimize loss of throughput. Moving inventory is a transfer operation and small transfer hatches should improve throughput. There are two types of batches (process and transfer) to be considered

Logistic Paradigms

Most logistic paradigms result inherent constraints in the production Planning and Control (PPC) system in use by most if not all U.S. shipyards. Logistic constraints are often difficult to identify and/or change. Statistical fluctuations and the numerous dependent resources are integral in the construction of a ship and usually result in a significant negative impact on the throughput of the system and more importantly, the shipyard's bottom line.

Logistical constraints are internal constraints (within the control of the shipyard). To break these types of internal constraints usually requires a drastic change to existing PPC systems that have been in place for many years.

Scheduling of a shipbuilding manufacturing environment is basically a combination of Project Management systems and PPC systems. A shipyard's PPC system is a combination of Continuous Production systems (fabrication and assembly line manufacturing), like a general job shop, and Intermittent Production systems, characterized by batch production. These two systems in turn use different systems for more detail scheduling. Continuous Production systems use Flow Control systems while Intermittent Production system use Order Control systems which are generally more complex.

Program Management systems currently use two techniques for establishing overall planning and scheduling parameters, the Project Evaluation and Review Technique (PERT) and the Critical Path Method (CPM). PERT and CPM assume that unlimited resources are available for project activities.

Simulation, as well as other research, investigating traditional PERT and CPM assumptions, has demonstrated that current PERT/CPM based scheduling techniques generate critical path estimates that consistently underestimate project duration. While PERT techniques do recognize activity variability, they do not recognize the fact that critical chain path interactions can delay project completion. Many of the assumptions required to deal with Resource Constraint Project Scheduling problems can be relaxed through the use of simulation which, unfortunately can lead to tolerable compromises.

Figure 6 depicts the shipbuilding scheduling problem in EC format.

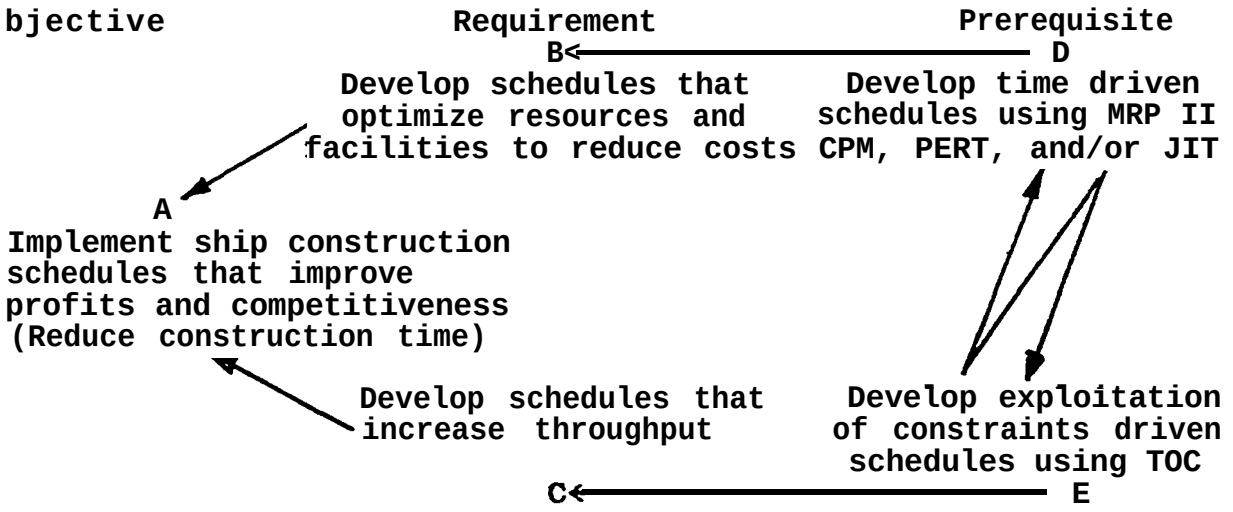

Figure 6 Shipbuilding Scheduling Evaporating Cloud Diagram

Table IV below, lists the assumptions behind the arrows and the reasons why these assumptions are invalid or irrelevant (erroneous).

EC Assumptions

A←B Schedules that optimize resources and facilities will reduce costs and result in improved profits.

B←D Time driven schedules produced by traditional systems will result in optimized resources and facilities.

D←→E Time driven traditional scheduling will meet objective.

Reason Assumption is Erroneous

A←B The optimization of any resource except the constraint-usually does not reduce cost.

B←D The optimization of non-constraint resources will increase inventory and increase costs.

D←→E Time driven schedules increase ship construction ti~ and costs.

Table IV EC Assumptions and Reason Assumption is Erroneous

Traditional methods of scheduling shipbuilding work use time as the driver. Over the years more and more time has been inserted in these schedules to act as buffers. The real effect of these buffers result in an extension of the scheduled construction time. Goldratt, 1990, provides a detailed discussion of traditional scheduling methods. Using the "exploitation of the constraints" as the "Driver" produces physical constraint free schedules that are realistic and immune to a reasonable level of disruption. Candidate realistic schedules should be judged against the fundamental TOC measures: Throughput (T), Inventory (1), and Operating Expense (OE) which are defined later.

Realistic schedules are resource feasible schedules. There is no conflict between the system's constraints and there is no resource contention which occurs anytime that an activity or operation must be delayed due to lack of resources. Immune schedules are not affected by statistical fluctuations and dependent events.

It is important to distinguish Operations Scheduling (OS) from Master Production Scheduling (MPS).

MPS determines the kinds of products and the quantities to be produced in some future period. OS is at the lowest level of the planning hierarchy and requires a greater amount of detail. The TOC scheduling technique combines MPS and OS in away that causes them to be less disernable as separate entities than tradional methods. In this light, MPS is not ignored and the traditional OS problems are incorporated into the focus of the management environment comparisons that must be made by management.

Umble and Srikanth, 1990, discuss the following principle: Make sure the critical resources are working on the right activities at the right time. This requires the identification of Critical Capacity Resources (CCRs), defined as: Any resource which, if not scheduled and managed, is likely to cause the actual flow (critical chain) of product through a plant to deviate from planned flow. When identified, they become the focus point for management's attention as they have a significant impact on the throughput of a shipyard.

If CCRS exist, every spare minute that couldbe "squeezed out" of the available time on theses CCRS should be utilized. Table V provides a Schedule/Time Analysis based on the time available per week.

1 Shift	Scheduled	Non-Scheduled
5 of 7 days	23.3%	76.2%
7of7 days	33.3%	66.7%
2nd Shift		
5 of 7 days	47. 6%	52. 4%
7of7 days	66.7%	33.3%
3rd shift		
5 of 7 days	67.0%	33*0%
7 of 7 days	93.3%	6.7%
* 5 of 7 days	71.4%	28. 6%

* Production operations continue through lunch periods either by working overtime, assigning extra teams, or by other means.

Table V Schedule/Time- Analysis

The percentages listed represent the productive scheduled time and the protective non-scheduled time on 1, 2, or 3 shifts and for 5 of 7 days and 7 of 7 days. Also shown is the added capacity gained by working through lunch hours. U.S. shipyards usually work a full 1st shift and a partial 2nd shift. Table V indicates that the 3 shifts 5 days a week schedule results in 33% additional available time and the 2 shifts, 5 days a week schedule has more time available than scheduled time {52.4% v. 47.6%).
"An hour lost at a bottleneck is an hour lost for the total system" (Goldratt, 1984). Therefore an additional non-scheduled hour worked on a bottleneck is equivalent to an hour worked by the total system. The resulting positive impact on a shipyard's profit would be significant.

Cost Accounting Parmdigms

The fundamental problem with Generally Accepted Accounting Practices (GAAP) is that they can not correctly measure the impact of local decisions and actions on the bottom line. Another basic problem, confirmed by GAAP experts, is that many of the original assumptions upon which these practices are based, are no longer valid.

McFarland, 1966, discussed the following key points in his study of management accounting concepts:

1. The presence of capacity constraints is a distinguishing characteristic of short run planning.
2. Identification of the constraints of a system is a prerequisite for distinguishing relevant costs.
3. Maximize contribution margin in terms of constraint resources.
4. Interdependence of the entities need to be considered in product and market segmentation decisions.

Many cost and management accounting textbooks and courses have

reinforced the erroneous impression of analytical independence. Managerial accounting is highlighted as focusing on parts or segments of an organization.

TOC has enhanced our understanding of constraints in at least three important ways:

1. Recognition that every system is constrained,
2. The important role of non-constraints relative to exploitation of the constraint decisions, and
3. The recognition that the constraint(s) of a system need not be physical in character.

Policy and cultural behavior type constraints are very important considerations.

These three observations have immense implications in the practice of management accounting. The primary reason that cost accounting practices are so hard to break is that these practices (paradigms) have been the way that people have been educated, businesses have been operated, and financial and performance measurements have been calculated and evaluated for many years. Management and business schools are still teaching many of these obsolete subjects. This has resulted in many organizations and people having hugh amounts of INERTIA.

The TOC EC technique can be used to resolve the conflict as to what cost accounting method (GAAP v. TOC) should be used to measure the results of shipyard improvement programs. By challenging the assumptions (Table VI) behind the logic (arrows) in Figure 7 a clear coarse of action is revealed.

GAAP results in an accurate determination of overall (global) company financial conditions except for the previous identified conflict on Inventory measurements.

The GAAP and TOC formulas will provide similar global measurements except in the conflict area. These global financial measurement are good for developing strong paradigms for judging the "System" but are very limited in judging the impact of local actions on the goal relative to:

1. Buying new equipment,
2. Investing in quality,
3. Product pricing, and
4. Workcenter performance, etc.

These cost Accounting and conventional reporting systems paradigms result in using the cost figures produced by the "system" that emphasize cost control first, then throughput and then inventory. Both operating expense and inventory have absolute limits, they can not be reduced below zero.

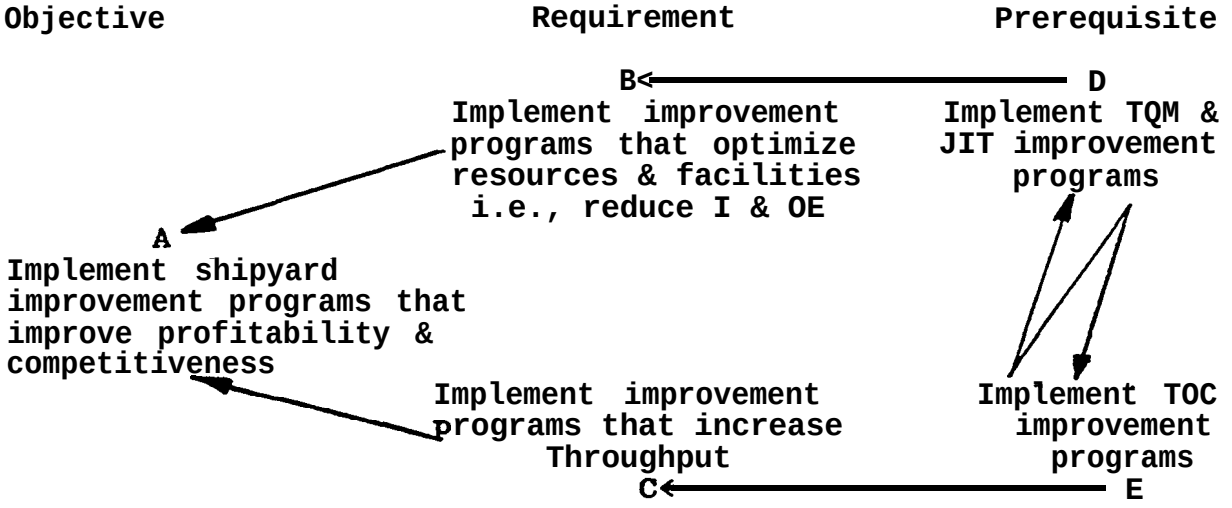

Figure 7 Improvement Programs Evaporating Cloud Diagram

EC Assumptions

A←B Optimization of resources & facilities improve profits & competitiveness.

B<-D TQM & JIT programs will reduce Inventory and Operating Expense costs.

D<->E TQM & JIT programs that optimize resources and facilities improve profits and competitiveness.

Reason Assumption is Erroneous

A<-B Optimized resources & facilities have little impact on profits & competitiveness.

B<-D TQM & JIT programs do not address constraints only inventory and Operating Expense reductions.

D<->E Increasing Throughput, not reducing Inventory and Operating Expense costs, will have biggest impact on profits and competitiveness.

Table VI EC Assumptions and Reason Assumption is Erroneous

The TOC formulas listed below offer an alternative to GAAP. All four formulas include at least two of the three following TOC definitions.

Throughput (T): All the money the system generates through sales.

Inventory (I): All the money the system invests in purchasing things the system intends to sell.

Operating Expense (OE): All the money the system spends in turning Inventory into Throughput.

The conversion of T, I, OE, and Net Profit (NP), Return On Investment (ROI) is intuitively straightforward. T generates money, I invests money and OE spends money.

$$NP = T - OE \quad (1)$$

$$ROI = T - OE + I \quad (2)$$

T, I, OE, can also be used for another set of measurements - Productivity (P) and Inventory Turns (IT):

$$P = T \div OE \quad (3)$$

$$IT = T \div I \quad (4)$$

From a practical standpoint as operating expense and/or inventory is reduced, at some point the reductions will limit throughput. Also from a practical point of view any significant reduction in operating expense actually means layoffs. In the shipbuilding (government contracting) environment, reducing inventory is offset by the desire for "Progress Payments."

Shipyards should always emphasize increasing throughput to realize the greatest gains in profits, then reducing inventory, and finally reducing operating expense. By challenging and breaking the assumptions behind the A←B←D←→E arrows in Figures 6, 7 and 8 the correct courses of action can be established.

Performance Measurement paradigms

Performance measurements are needed to monitor subsystems as well as complete systems. Traditionally in Us. shipbuilding this has been performed under two types of systems. Gessis, 1993 describes the U.S Navy's "Cost/Schedule Control System (CS^2), and Karlson, 1992 describes the Maritime Administration's (MarAd), Ship Project Monitoring System, also called the 10,000 points system Variations of both of these systems have been in operation for quite a few years which has resulted in the developing of very strong paradigms. However, a cursory review of each of these system's reveals that their foundations are based on the analytical approach and independent variables. Figure 8 and Table VII relate to this measurement conflict.

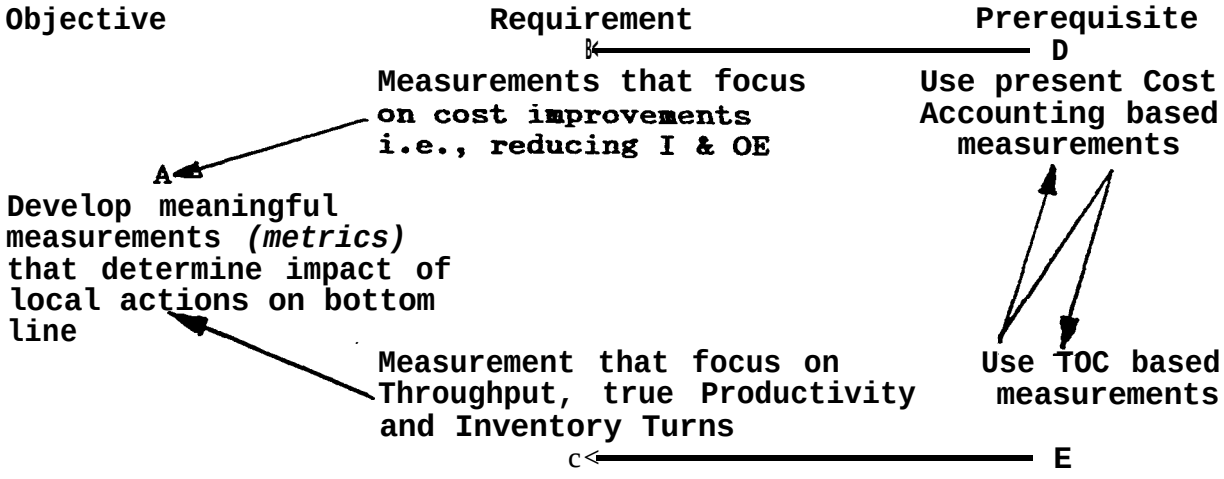

Figure 8 Measurements, Evaporating Cloud Diagram

EC Assumptions

A+B Significant bottom line impact can be gained by reducing costs.

IW+D Present Cost Accounting measurements are satisfactory for measuring *reduced costs* at local levels.

D - E Same as B:D above.

Reason Assumption is Erroneous

A+B Reducing costs do not have significant impact on bottom line and reducing OE costs really equate to laying off people-an organization's most important resource.

B-D Local improvements that reduce costs have little impact in bottom line as improvements are usually made in non-constraint areas. Present cost accounting and/or Activity Based Costing (ABC) methods provide erroneous measurements.

D-E Same as B:D above. TOC measurements provide accurate measures and also by using TOC "Control Measurements" variance to schedules and true accountability is measured.

Table VII EC Assumptions and Reason Assumption is Erroneous

Traditional methods for measuring variance to schedule dates, budget performance, number of delivery dates missed, number of plans late to schedule issue dates, etc., all essentially are a measure of performance against the individual standard (schedule and/or budget) assigned to each item and all deviations basically carry the same significance (weighted value). Since all these measurements apply to each independent item, the negative impact of this dependency on other items is not measured. TOC methods provide measurements in terms of both relative importance to the bottom line (Throughput) and relative to variances from a valid schedule using Throughput and/or Inventory Dollar Day methods (Goldratt and Fox, 1988).

The effectiveness of TOC methods depends on two prerequisites:

1. an accurate material cost, &
2. a valid schedule.

Us. shipyards can meet the first prerequisite, but not the second because the scheduling methods used are based on time as being the driver instead of using exploitation of the constraints as the driver (Goldratt, 1990).

Existing local measurements, like: worker's efficiency and process or schedule variances; encourage rather than suppress doing things that

should not have been done (Goldratt and Fox, 1988). In addition, the progress payment clauses in most ship construction contracts results in a tremendous buildup of inventory in U.S. shipyards because the schedules do not differentiate the critical work required to support the flow of work through the constraint resources and the critical chain. The magnitude of the negative impact on true costs and schedules therefore can not be measured. The TOC control measurement concepts can be fully explained only after the concept and procedures of buffer-management are understood (Goldratt, 1990).

TOC measurements also identify another important paradigm shift that needs to be made in the area of capital expenditures. The role of non-constrained activities within an organization is to support the constraint in the best way possible, All capital expenditure requests for new equipment that will be used in unconstrained areas should be analyzed to ensure that the proposed expenditure will not result in diminishing the capability of the non-constraint area to support the constraint. This analysis is particularly relevant if the proposed new purchase involves consolidating similar activities, as flexibility and responsiveness may be lost. In addition, changing the traditional erroneous practice of justifying capital expenditures based on improving non-constraint performance should be discontinued.

Production Paradigms

Many millions of dollars are spent each year in U.S. shipyards on facilities, computerization of systems and other non-constraint equipment.. These major investments in most cases have not resulted in making U.S.. yards competitive in the commercial world market. One major area recognized as contributing to improved productivity and reducing construction time is where the ship construction work is performed. The two lists of "Difficulty Factors" shown in Table VIII are representative of the magnitude of the savings that can be realized by moving construction work earlier in the schedule.

Location	(A)	(B)
In Shops	1.0	1.0
On Platen	1.5 to 3.0	5.0
Erection Area	4.5 to 7.0	10.0
In Water	10.0 to 15.0	20.0

Table VIII Ship Construction "Difficulty Factors"

Reference (A) Wilkins, Kraine, and Thompson, 1993.
Reference (B) Snodgrass, 1982.

For example, if an item can be installed in a shop as opposed to doing the work in the water, the labor hours would be reduced by a factor of between 10 to 15 or 20 (Table VIII). The magnitude of bottom line benefits resulting from moving work earlier (WE) can result only if two necessary conditions are present: (1) the work that is moved earlier is in the critical chain and (2) the ship construction schedule (delivery) is reduced to reflect the productivity improvements. If this work is not in the critical chain then the benefits that could be realized will likely be lost due to other delays encountered before ship delivery. Likewise, if the overall schedule time is not reduced the shipyard workers will work to the issued schedules with very little bottom line impact.

A 1982 barge construction project (Rack, 1982) provides a good example of not only the WE concept, but also illustrates two other concepts that can significantly reduce ship construction time: Work In Parallel (WIP) and In Multiples (IM). WIP is defined as performing similar operations at the same time in another work station.

improvement programs would look like the "B" curve in Figure 9. In reality, very few non-linear programs have been implemented because they require a redesign of the existing system and management's recognition that they must change before the system can be changed (Walton, 1986).

The practical rate of improvements of continuous non-linear processes will take the appearance of the Figure 9 "C" curve. The plateaus in the "C" curve represent the time required before an organization identifies the next "weakest link" (constraint) and implements a satisfactory solution.

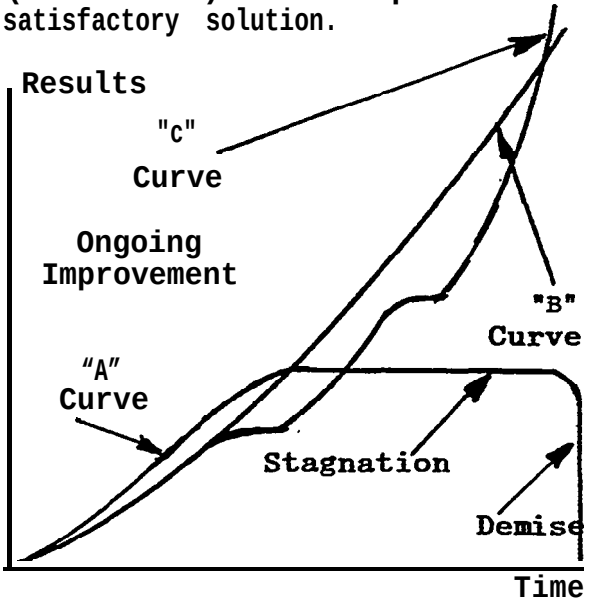

Figure 9. Rates of 1improvenemt

Source: Goldratt. 1990)

All of these referenced approaches have documented improvements of varying degrees. However, these improvements become the new paradigms and sooner or later, every paradigm begins to develop a very special set of problems with no evident solutions. New paradigms put everyone practicing the old paradigm at great risk. The higher one's position, the greater the risk. The better one is at that paradigm, the more one has to lose by changing paradigms, a condition called "paradigm paralysis" (Barker, 1992).

The actual bringing about of a paradigm shift in an organization, requires:

1. Creating and sustaining the motivations for appropriate changes.
2. Creating, in the organization, the capacity for appropriate thinking.

Both of these items require, in turn:

3. Creating the atmosphere and developing the capacity for open communications, which allows for an in depth reevaluation of hidden assumptions, individually and collectively" (Malin, 1992).

One has only to look at how U.S. shipyards are organized (pyramids with many functions and many levels within each function) and how they have been operating (analytical thinking) for many years to appreciate the magnitude of the paradigm paralysis that has resulted and why it is so difficult to stimulate internal innovation. so, until U.S. shipyards can change that attitude and stimulate their people to be more flexible and break out of their paradigms to search for alternatives, the great new ideas will probably be discovered outside the shipyard's organization (Barker, 1992).

The various necessary conditions. that have to be present to cause change include: (Malin, 1992)

1. Aspiring goals,.
2. Motivation,
3. Togetherness,
4. Ownership,
5. Appropriate thinking (having the necessary knowledge and having the right methods and capacity to use them),
6. Communications,
7. Organizational cooperation instead of competition, and
8. Greatly expanded use of dialogue.

The dialogue expansion includes:

1. open listening,
2. looking at one's thoughts. which arise in response or reaction to

others' pronouncements, and in particular,

3. discovering the hidden assumptions, the paradigms behind one's thoughts, and

4. being willing to suspend these assumptions.

Deming, (Stevens, 1994) expressed thoughts on how to cause change: [With only inside understanding] "What you do is only to dig deeper the pit you are in...To get out of the pit we require an outside view. No chance from the inside. A system cannot understand itself. Understanding comes from the outside. An outside view provides a lens for examination of our present actions, policies... (Bold added) Knowledge from outside is necessary. Knowledge from outside gives us a view of what we're doing, what we might do, a road to improvement, continual improvement ."

An essential part of change in any organization, any group . . . . is the creation of conditions in which people can explore the fixity of their own thoughts, the confusion between "presentations" and "representations," the real nature of what they call "facts," etc. Such conditions are the prerequisites for communications among members of the group, communication which is, in turn, a precondition for change (Malin, 1992).

U.s shipyards have been operating for many years in accordance with systems that are based on analytical thinking, independent variables and knowledge gained from an educational system that: "what they teach is continuance of our present methods of management, which are failures. They teach how to fail, how to continue to fail", (Walton, 1992).

This situation is made worse because of the strong paradigms practiced by U.S. shipyard managers and workers and by working to a system designed to meet contract requirements. Many of these contract requirements are based on a different set of objectives to meet a different '"set of rules" (goals) than those of the shipyards.

The key and major paradigm shifts that are considered necessary to meet the present situation facing U.S shipyards were discussed earlier in this paper.

However, "When our frames of reference are fixed and rigid, they become a substitute for thinking. Learning takes place when we have flexibility to change our frames of reference. The most creative efforts of human beings involve departing from existing frames of reference and constructing new ones", (Rubinstein, 1985).

The flexibility for learning in U.S. shipyards has been restricted by this paradigm paralysis. This condition has prevailed for many years because much of the technology being used by managers has been proven to be not only very fixed and rigid but is also flawed in that it has led to "Cost World" results (Rack, 1991).

Significant immediate profits can be realized through productivity improvements by making certain paradigm shifts such as implementation of the WE WIP IM concept-s, increased manning and/or number of shifts worked and also other physical (facility) changes.

To implement and sustain true continuous non-linear and linear improvement processes a paradigm shift from paradigm paralysis (hear nothing but threats) to paradigm pliancy (hear nothing but opportunity) is necessary, (Barker, 1992).

To paraphrase Swartz, 1994, U.S. shipbuilders have to develop The Non-Linear Solution:

To become a WORLD LEADING COMPETITIVE SHIPBUILDER one must TRANSPORM THEMSELVES (managers and workers) and then the BUSINESS in order to MAXIMIZE the RATE and QUALITY of LEARNING and IMPROVEMENT.

IM is defined as doing multiples of the same operation in the same work station with essentially no increase in time or manhours.

The combination of these three concepts results in the possibility of having the combination of three multipliers instead of just the WE multiplier (WE X WIP X IM v. WE).

Once again the controlling factors (necessary conditions) are that the multipliers are only effective if the work is in the critical chain and the overall schedule time is reduced.

The author (Rack, 1982) was not aware of the TOC at the time this barge facility was designed. However, the concepts used can be compared to the TOC Drum-Buffer-Rope (DBR) technology (Goldratt, 1990). This concept also meets both necessary conditions.

The Drum is the perceived market requirement of a barge every other day (2 day deliveries). The barge faciiity has 52% excess capacity as it was scheduled to work only 10 shifts (5 days a week, 2 shifts) when 21 shifts (7 days, 3 shifts) are available. This excess capacity means there are no physical constraints in meeting the Drum beat of the market (a barge every other day).

The panel stiffener machine was established as the constraint and became the Drum on which the production schedule was based.

The "Rope" between the Drum and the material release "Gate" determined when material had to be released so that buffers could be established to provide a continuous flow to and from the panel stiffener machine and ensure meeting the Drum beat of perceived market. It was discovered that the only original work station that did not support the continuous flow of one barge every other day was the single rake assembly work station. The solution was to add another station.

Another constraint was the weather. All platen type work had downhand welding of rake stiffeners was done at the erection position. However, all other outside operations could be delayed by bad weather. Therefore five additional stations were added to accomplish any weather delayed work.

The positive bottom line impact resulting from these three concepts (multipliers), henceforth called: "WE WIP IM" was significant.

Table IX indicates the construction work that was moved earlier from the erection area to the shop and elimination of all platen work.

Potential weekly throughput equated to:

5 days + 2 days X 570 tons = 1,425 tons per week (5)

Potential yearly throughput equated to:

1,425 X 52weeks = 74,100 tons (6)

The WIP operations consisted of doing panel welding at both the inlet and exit panel welding stations, simultaneous rake assembly in two stations, and the flexibility of doing any uncompleted outside erection and blast and paint work in the five additional buffer work stations.

IM operations consisted of multiple panel stiffening (up to 9 at a time), tank top plug welding (6 at a time) and the most important operations leading to a significant reduction in construction time and costs-the joining of all erection units in the shop (3 "super" units (1 bottom & 2 sides), Rake &Transom).

Although the above discussion and Table IX data pertain to inland waterways barge construction many of the WE WIP IM concepts can readily be applied to ocean going ship construction. The resulting significant savings in ship construction costs and the large reduction in overall construction time translate to much higher profits.

Operation	Traditional* Shop	Traditional* Platen	Traditional* Erection	WE WIP IM Shop	WE WIP IM Erection
Number of Panel Butt Welds (Plate to Plate) 65	54	11	0	65	0
Number of Cycles Stiffeners welded to panels	66(1)	12	0	35	0
Number of Tank Top Plate/Plug Welds 22/1056	o 0	17(2) 816	5 240	21 1008	1 48
Number of Plug Weld Cycles	0	816	240	168(3)	48
Number of Main Assembly Units 17	0	17	0	17	0
Number of Erection Units 17	0	0	17	0	5(4)
Number of Erection Welds 37 (24 Sides, 13 Bottoms]	0	o	37	26	11(5)

* Traditional Barge construction assumes panel line welder, stiffener tack station (3/6 stiffeners/tacks) and stiffener welder (3/6 stiffeners/welds).
(1) One cycle = 3 stiffeners v. up to 9 stiffeners.
(2) Plug welds made in Platen areas v. in shop.
(3) Special welding equipment (6 weld at same time).
(4) One Bottom and 2 Sides, plus Rake and Transom.
(5) 3 Bottom welds, and 8 side welds.

Table IX Traditional Barge Construction V. WE WIP lM Concepts

Source: Rack, 1982.

HOW TO CAUSE THE CHAHGE?

Numerous articles and books have been written (Barker, 1992, Drucker, 1980 and Swartz, 1994, etc.], that have provided answers to the two questions discussed previously: What to change and What to change to, but the question: How to cause the change, has only been partially answered.

The common message and overall objective of all of these "Gurus" is essentially the same i.e. , continuous on-going improvement. The actual results in all too many cases of continuous on-going linear improvement programs that have been implemented is shown as the "A" curve in Figure 3 and Figure 9 below.

Theoretically the implementation of continuous on-going non-linear

CONCLUSIONS

The U.S. Shipbuilding industry is a major link in the overall U.S. Maritime industry, but it may well be one of the weaker links. At the global level, a significant contribution to the national economy and to the involved participants can result from continued growth of each and every element in this industry. Leadership to eliminate the traditional adversarial relationships (paradigms) is needed before a concerted effort to develop Win-Win solutions can be implemented.

The vision of each of the elements of the U.S. Maritime industry should be to contribute to the overall sustained growth of this industry. The U.S. shipbuilders can make a major contribution if they become competitive in the world market.

Today's available technology provides an understanding of what has happened, both good and bad, to many industries and nations. This same technology can be used to learn what should be done to improve the future. To make an improvement requires a change. However not all changes are improvements.

The TOC'S Thinking Processes (TPs) provide a "workable tool" that when used in conjunction with "Systems" thinking principles that are directed to implementing the non-linear solution, can result in moving U.S. shipbuilders from the "Reactive Mode" to the "Anticipative Mode" of managing. The following key elements are prerequisites or vital elements of such a process:

1. System Thinking,
2. Outside Knowledge,
3. Communications,
4. Redesign of the System,
5. Assumptions (challenging of),
6. True and Inspiring Goals,
7. Involvement (employees), and
8. Continuous Non-Linear and Linear Improvement.

Proven methods exist to address physical and policy type of constraints. However, how existing technology can be used to address the third type of constraint-behavioral-has been the major obstacle as it involves individuals.

Improvement in existing methods are still needed in: "ways to arouse emotional factors, other than fear, that will motivate people to invest the emotional energy needed to bring about the fundamental changes in behavior, as well as in the structure and functioning of the organization" (Malin, 1992).

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