



FIRST MARINE INTERNATIONAL

**First Marine International findings  
for the global shipbuilding industrial  
base benchmarking study**

**Part 2: Mid-tier shipyards**

**FINAL REDACTED REPORT**

TURNING IDEAS INTO REALITY





APPROVED FOR UNLIMITED RELEASE

# FIRST MARINE INTERNATIONAL

## FINDINGS FOR THE GLOBAL SHIPBUILDING INDUSTRIAL BASE BENCHMARKING STUDY

### Part 2: Mid-tier shipyards

#### FINAL REDACTED REPORT

*This independent report has been written for the Office of the Deputy Under Secretary of Defense for Industrial Policy (ODUSD(IP)) and the Center for Naval Shipbuilding Technology (CNST). Distribution is approved for unlimited release.*

**FIRST MARINE INTERNATIONAL LTD**

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# Findings for the Global Shipbuilding Industrial Base benchmarking study

## Part 2: Mid-tier shipyards – final redacted report

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**NOTE:**

The information contained in this report is believed to be correct but the accuracy thereof is not guaranteed. First Marine International, its employees and subcontractors cannot accept liability for loss suffered in consequence of reliance on the information contained herein. This report does not obviate the need to make further appropriate enquiries and inspections.



## 0 SUMMARY AND PRINCIPAL CONCLUSIONS

The Office of the Deputy Under Secretary of Defense (Industrial Policy) (ODUSD(IP)) has sponsored a Global Shipbuilding Industrial Base Benchmarking Study (GSIBBS). The study has been carried out in two parts. The findings of Part 1, which focused on the first-tier U.S. shipyards, have already been reported. This report presents First Marine International's (FMI) findings for Part 2 which is focused on the mid-tier yards. The principal output is a list of proposed actions for individual shipyards, industry as a whole and the Department of Defense that will improve the performance of the U.S. shipbuilding enterprise. In order to make the most efficient use of resources and minimize industry disruption, the study was carried out simultaneously with a mid-tier yard capabilities study for the Office of Naval Research (ONR). The capabilities study report is available from the Navy Manufacturing Technology Center of Excellence, the Center for Naval Shipbuilding Technology, which sponsored the study.

FMI used its proprietary benchmarking system to assess shipbuilding technology in nine mid-tier U.S. shipbuilders and five international shipyards. The international yards are a mix of leading commercial builders, builders of complex commercial vessels and naval vessel builders. Both groups contain yards that construct vessels from steel, aluminum and fiber reinforced plastic.

The benchmarking system describes five levels of best practice in each of fifty elements of shipbuilding technology assessed in the survey. At the low end of the scale, Level 1 represents basic technology and, at the high end, Level 5 represents advanced technology which is normally associated with high levels of productivity. As a general rule, lowest cost is achieved by a shipyard having the appropriate level of technology for its product mix, throughput and cost base; therefore a Level 5 is not necessarily best for every yard. The sector averages and the distribution of the averages between the seven element groups studied in both GSIBBS Part 1 and 2 are shown in Table 0.1.

Group		Average rating			
		U.S. Mid-tier 1999/2000 <sup>1</sup>	U.S. Mid-tier 2005/2006	Intl. Mid-tier 2006	U.S First-tier 2004
A	Steelwork production	2.2	2.4	2.9	3.3
B	Outfit manufacturing and storage	2.5	2.6	3.4	3.6
C	Pre-erection activities	2.4	2.5	2.8	3.4
D	Ship construction and outfitting	2.7	3.1	3.3	3.5
E	Yard layout and environment	2.5	2.6	3.6	3.2
F	Design and production engineering	2.7	3.2	3.4	3.6
G	Organization and operating systems	3.2	3.4	3.8	3.9
<b>Overall industry rating</b>		<b>2.6</b>	<b>2.9</b>	<b>3.3</b>	<b>3.6</b>

**Table 0.1 – U.S. and international industry best practice ratings by group and overall**

The average best practice rating for the U.S. mid-tier yards is 2.9. This is an increase of 0.3 since the sector was last benchmarked in 1999/2000. This falls short of the best continuous rate of improvement

<sup>1</sup> This is a slightly different group of yards to the 2005/2006 sample but it is considered to be representative of the industry during 1999.



demonstrated internationally, which is about 0.1 point of best practice rating per annum. The improvement in average rating in the mid-tier yards reflects the recent increase in performance improvement activity including capital investment. Competition in the domestic market and the desire of some yards to increase international competitiveness has provided the motivation to improve. The improvement in the rating of the first-tier yards was 0.5 over a similar period.

The overall average rating of the U.S. mid-tier yards lags significantly behind the international yards average and the gap is larger than that between the first-tier yards and the leading international yards surveyed during GSIBBS Part 1. However, some U.S. mid-tier yards have scored well and lead the international yards in a number of elements. This is reflected in the core productivity of the U.S. mid-tier leaders which appears to be only slightly lower than in equivalent European yards. However, the performance drop-off that can occur on the first vessels in a new series can be a barrier to entry into new commercial markets.

First and mid-tier yards are configured differently for success in their respective market sectors. Therefore, care needs to be taken when comparing the strengths and weakness in the two sectors. For example, due to differences in the nature and volume of their output, there are significant differences between the two sectors in some of the production groups. However, the study has confirmed that in groups such as design, engineering and production engineering, and organization and operating systems, the performance gap between the two sectors should be much smaller. This is in fact the case for the leading mid-tier yards which scored highly in these so-called soft areas when compared to both the first-tier and the international yards. The smaller size of the mid-tier yards makes them easier to manage, inherently more efficient, more flexible and able to adapt more quickly to change than the larger yards. However, as they tend to be lean and have low overhead organizations, they have limited resources to effect change.

Mid-tier yards have an opportunity to further improve performance by making changes in key areas. An industry-wide analysis of the priorities indicates that the top priority areas for improvement are as shown in Table 0.2. The priorities for improvement vary by shipyard.

Rank	Mid-tier (Part 2)	First-tier (Part 1)
1	Production engineering	Ship design and design for production
2	Design for production	Production engineering
3	Master planning, steel and outfit scheduling and production control	Master planning and steel and outfit scheduling
4	Manpower and organization of work	Outfit module building, pre-erection outfitting and onboard outfitting
5	Outfit installation and onboard services	Dimensional accuracy and QC
6	Outfit module building, pre-erection outfitting	Outfit parts marshalling and general storage and warehousing
7	Dimensional accuracy and QC	Pipe shop and other outfit manufacturing activities
8	Outfit parts marshalling	Manpower and organization of work
9	Steelwork and outfit coding system	Steelwork and outfit production information
10	Block assembly	Steelwork and outfit coding system

**Table 0.2 – Top ten industry-wide action areas**



The table clearly shows that the priority areas are similar in both the first and mid-tier sectors which indicates that measures taken to improve one sector are probably applicable to the other.

The degree of benefit the Department of Defense would accrue as a result of the improvements proposed will clearly depend on the value of government work placed in the mid-tier yards in the future. This is likely to increase substantially over current levels as the LCS program progresses and initial indications are that the benefits will be significant. Performance improvement in this sector will also help to enhance competitiveness in commercial vessel building.

There are a number of different organizations providing financial assistance and technical support to shipyards. Effectiveness could be improved if it was better coordinated and targeted towards moving the yards along a performance improvement path that was set out in shipyard-specific long-term improvement plans. The foundations for such plans have been laid in the individual shipyard benchmarking reports.

The following recommendations for the Department of Defense were made in GSIBBS Part 1 to assist with naval shipbuilding program performance improvement. Most of the recommendations are also relevant to naval shipbuilding in the mid-tier sector.

1. Gain a more in-depth understanding of the relationship between ship specification, complexity and work content and work with the design authorities to reduce the inherent work content of naval vessels while not compromising functionality.
2. Work with industry to develop the pre-production processes to reduce first-of-class performance drop-off.
3. Review the acquisition rules, regulations and practices to determine if each adds value and work with the shipyards to find ways to reduce the effect these have on shipyard work content. (i.e., reduce customer factor).
4. Stabilize the ship acquisition program.
5. Improve shipyard incentives.
6. Continue to support performance improvement initiatives such as National Shipbuilding Research Program NSRP.

The Department has taken positive action on several of these recommendations since the publication of GSIBBS Part 1. With regard to the mid-tier sector, issues related to the customer factor should be given priority as these appear to create significant problems for some yards. In particular it is recommended that:

1. The timeliness of the naval technical approval cycle is dramatically improved.
2. The responsibilities of The American Bureau of Shipping (ABS), SupShips and the Naval Sea Systems Command (NAVSEA) are clarified and the interactions between them streamlined.
3. There is continued development of the ABS Naval Vessel Rules with a view to improving productivity and reducing cost.

The strategy of using mid-tier yards for naval construction has many positive features including increased shipbuilder sourcing options available to the Navy and competition in the industrial base.



However, there is a limit to the sector's capability and capacity. Furthermore, the structure of the projects, the steep learning curve and the change in culture required to deal with naval work may result in the ultimate cost savings being lower than anticipated, particularly on vessels early in a series. It is also not necessarily correct to assume that a highly competitive commercial builder will be able to outperform a naval builder on a similar naval vessel.

This strategy also has implications for all naval shipbuilding programs, the majority of which are allocated to first-tier shipyards. Placing work outside the established naval shipbuilding industrial base, already operating well below its physical plant capacity, reduces the ability to spread overhead costs in those yards. Furthermore, the change in culture in commercial mid-tier yards required for success in the naval sector may degrade their commercial competitiveness.



## 1 INTRODUCTION

### 1.1 Background

The Office of the Deputy Under Secretary of Defense (Industrial Policy) (ODUSD(IP)) recently sponsored Part 1 of a Global Shipbuilding Industrial Base Benchmarking Study (GSIBBS) that focused on first-tier U.S. shipyards and leading large international yards. Part 1 had several objectives but the principal output was a proposed list of actions for the Department of Defense and Industry to improve the performance of the U.S. shipbuilding enterprise. Due to the valuable insights gained from Part 1, ODUSD(IP) extended GSIBBS to include the mid-tier yards (Part 2).

At about the same time, the Office of Naval Research (ONR) commissioned a study of mid-tier U.S. shipyards to assess their capability to build medium-size combatants. The study was executed through its Navy Manufacturing Technology (ManTech) Center of Excellence, the Center for Naval Shipbuilding Technology (CNST). The functions of both ODUSD(IP) and CNST are described in Appendix 1.

The capabilities assessment and benchmarking study have common elements and a similar methodology. Therefore, in order to make the most efficient use of resources and minimize industry disruption, the two studies were combined and carried out simultaneously.

The overall objectives of the combined study were:

- Understand the capabilities of mid-tier U.S. shipyards to design and build medium-sized naval combatants made of thin steel or aluminum in accordance with U.S. Navy requirements and American Bureau of Shipbuilding (ABS) Naval Vessel Rules.
- Compare the practices of mid-tier U.S. and selected international commercial and naval shipbuilders in Europe and Australia.
- Identify specific changes to mid-tier U.S. shipbuilding industry processes and to U.S. naval design and acquisition practices that will improve the performance of the shipbuilding enterprise.
- Guide future investment (ManTech, National Shipbuilding Research Program (NSRP), etc.).
- Provide participating shipyards with an independent assessment of the current status of their processes, practices and performance in an international context.

First Marine International (FMI) conducted shipyard surveys to gather the required information with assistance from ODUSD(IP) and CNST. This report records FMI's findings for the benchmarking part of the study. The detailed findings in Appendix 3 are only available in the full report, for which distribution is limited to the participating shipyards, CNST and authorized Government agencies. The capabilities assessments are covered in a separate report.

FMI used its proprietary benchmarking system to assess the technology employed and the performance of the shipyards surveyed. The system is described briefly in Section 1.4 below and in detail in Appendix 4. As the system has been used for both the GSIBBS Part 1 and Part 2, the survey results are directly comparable. They are also comparable to the NSRP Advance Shipbuilding Enterprise benchmarking survey carried out by FMI in 1999/2000.



Each participating U.S. shipyard received three proprietary reports. The first is related to the benchmarking aspects and defines the process and practice observed within the yard, compares them with international best practice and makes suggestions for improvement actions. The second presents the findings of the capability survey and capacity analysis but does not suggest remedies. The third, which was produced after the surveys of all the international and U.S. yards were completed, presents a prioritized list of action areas. The foreign participating yards received a benchmarking report only.

## 1.2 General approach

This report includes a detailed explanation of the methods used in the relevant sections and in the appendices. The overall approach that FMI employed is similar to that adopted for the GSIBBS Part 1 and is as follows:

1. Survey seven groups of manufacturing and business processes and practices (consisting of fifty total elements) of a representative sample of leading international commercial and naval shipyards using the benchmarking system.
2. Survey the same seven groups of processes and practices, and additional aspects related to capability (a further sixty-three elements), in nine mid-tier U.S. shipyards.
3. Compare the technology applied in the international yards to that applied in the U.S. yards to identify technology gaps that present opportunities for making improvement in each U.S. shipyard.
4. Estimate the productivity of the U.S. yards in order to make comparisons with the international yards and to determine how effectively the U.S. yards use the technology applied.
5. Write an individual benchmarking report of the findings in each U.S. yard for the use of the shipyard including a prioritized list of action areas and suggested actions.
6. Write a capabilities assessment report for each U.S. yard gauging their ability to build medium sized naval combatants.
7. Aggregate the benchmarking findings in individual shipyards to an industry level to identify opportunities for industry-wide actions to improve performance and suggest appropriate remedies.
8. Aggregate the capabilities findings in individual shipyards to an industry level to understand the capabilities and capacity of the mid-tier yards as a whole.
9. Review the shipyard findings to quantify the effect of DoD policies on shipyard performance and suggest improvements.
10. Present the general findings in an overall report.

In order to avoid duplication of effort and minimize shipyard disruption, the data to complete both aspects of the study was gathered during a single two-day visit to each yard. The survey team comprised two or three FMI consultants and representatives of ODUSD(IP) and CNST.

Commander Tyler Skarda, the study manager for ODUSD(IP), Kevin Carpentier, the CNST program director, Mr Bob Schaffran and Professor Richard Storch also from CNST, were trained in the application of the benchmarking system. Commander Skarda and one of the three members of CNST accompanied FMI on all the benchmarking surveys. Mr Schaffran, who is the Technical Director of



CNST, and Professor Storch carried out the survey of aspects of both the benchmarking and capabilities assessment in some U.S. yards. The findings in each shipyard visited and the implications for the study were discussed after each visit. However, the FMI members of the team, assisted by the CNST representatives in some yards, independently assessed the benchmarking scores and were not influenced by ODUSD(IP) even though members of ODUSD(IP) participated in the surveys as observers. To provide continuity, the FMI team was selected from the four consultants who took part in the GSIBBS Part 1, each of whom is a specialist in the areas surveyed.

### **1.3 Participating shipyards**

In addition to nine U.S. mid-tier shipbuilders, the team visited five international shipyards during this study. The benchmarking system was applied in all fourteen yards. The international yards were a mix of leading commercial builders, builders of complex commercial vessels and naval vessel builders. The yards construct vessels from steel, aluminum and fiber reinforced plastic. The U.S. yards build commercial, Coast Guard and naval surface vessels and components manufactured from all these materials. Therefore, both the international and U.S. sample are broadly equivalent. One of the U.S. yards surveyed was subsequently considered to be uncharacteristic of the U.S. mid-tier sector and so its scores have been excluded from the results. Other findings from the yard have however been incorporated into the discussion.

### **1.4 The FMI benchmarking system**

The FMI shipyard benchmarking system allows the processes and practices applied in individual shipyards to be compared to others and to international best practice. The system has a number of uses but is most commonly applied in assisting shipyards to develop performance improvement programs. An early version of the system was first used to support the nationalization of the British shipbuilding industry in the mid-1970s. It has since been applied in over 150 shipyards worldwide and has been used as the basis for the following industry studies:

- 1978: U.S. shipyard technology survey
- 1985: U.S. shipyard technology survey
- 1992: EC shipbuilding competitiveness study
- 1993: EC Eastern European shipyard study
- 1995: National Shipbuilding Research Program study (system derivative)
- 2000: U.S., Asian and European shipyard benchmarking study
- 2001: UK shipyard benchmarking study
- 2004: ODUSD(IP)-sponsored Global Shipbuilding Industrial Base Benchmarking Study (GSIBBS) Part 1

The full system contains one hundred and twenty-nine elements of shipbuilding, ship repair and ship conversion technology grouped into eighteen functional areas. The seven functional areas of shipbuilding practice covered by this study are as follows (these areas have a total of fifty elements).

- Steelwork production
- Outfit manufacturing and storage



- Pre-erection activities
- Ship construction and outfitting
- Yard layout and environment
- Design, engineering and production engineering
- Organization and operating systems

The benchmarking system describes five levels of best practice use in each element of each group. In broad terms, the levels correspond to the state of development of leading shipyards at different times over the last thirty years. Those yards that are less advanced remain at the level of technology of an earlier period. On the basis of interviews and inspections carried out during the survey, a “level of technology” mark is assigned to each element. Elements that are subcontracted are noted and if sufficient information is available to evaluate subcontractor performance, then the elements are scored. The scores are aggregated, first, for the individual groups, and second, for the whole yard. The results are presented graphically so the strengths and weaknesses are clearly shown.

## **1.5 First Marine International**

First Marine International Limited was formed in 1991 to provide specialist consultancy services to the marine industry. Principal clients include shipbuilders and ship repairers, UK and overseas government departments and agencies, and national and international maritime organizations. Members of the FMI team have worked on projects in over fifty countries and were first involved together in the 1970s in the design and engineering of some of the largest and most successful shipyards in the world. The company’s expertise includes market research and forecasting; marine industry studies; benchmarking; competitiveness; technology development; upgrading of existing shipyards; design and engineering of greenfield shipyards; and development, implementation and management of shipyard performance improvement programs. Further information is available on the internet at [www.firstmarine.co.uk](http://www.firstmarine.co.uk).



## **2 THE MID-TIER SECTOR**

### **2.1 Sector definition**

There is no generally accepted definition of a mid-tier shipbuilder. Mid-tier yards typically employ more than 200 people but rarely more than 600 to 800. They tend to construct small to medium sized vessels between about 200ft and 650ft length overall (LOA) but many U.S. yards are limited to about 400ft LOA. The yards tend to have lower levels of investment than the large yards and the overhead structure is generally lean with managers often having multiple roles. A high level of subcontracting is a common feature.

Most of the U.S. mid-tier yards included in this study are part of corporations that operate other shipyards. Their output over the last five years has included vessels for the offshore industry, ferries, survey vessels, various Coast Guard vessels and a limited number of cargo carrying and other commercial vessels. Some vessels have been built for international owners but the majority of commercial orders have been for the Jones Act market. The industry is protected from international competition by the Jones Act but there is a high level of domestic competition in this sector. In terms of work content (compensated gross tonnage), over the last five years U.S. shipyards have produced about one percent of the world's commercial output. Eighty percent of this has been built by mid-tier and small shipyards. Over the same period, twenty-five percent of the output of these yards has been for the U.S. Government.

Some U.S. mid-tier yards build commercial and government vessels in the same facilities but others carry out the work in different buildings or even at different sites. Although some international yards also carry out both types of work in the same facilities, separation tends to be the preferred route. This is because the yards consider the two types of work to be different, as are many of the standards and procedures used. There are many examples of commercial builders performing poorly on naval contracts and, similarly, naval builders often have difficulty building commercial vessels at a competitive price. Therefore, it is not necessarily correct to assume that a highly competitive commercial builder will be able to outperform a naval builder on a similar naval vessel. To achieve the best performance, shipyards have to be configured specifically to design and construct the vessels in their chosen product mix. Companies building both commercial and naval vessels tend to separate production if possible.

### **2.2 International commercial competitiveness**

The international commercial shipbuilding industry is currently experiencing booming orders and the highest rate of new order generation since 1975. There is a shortage of capacity and in some cases owners must wait until beyond 2010 for delivery of orders placed today. This is stimulating the development of new capacity, particularly in China, India and Vietnam.

High shipbuilding capacity utilization, very high earnings in the shipping markets and significant increases in raw material costs have all contributed to higher prices, which are now around 85 percent higher than they were in 2002. The price of a Very Large Crude Carrier (VLCC), for example, has doubled from \$63.5 million to \$130 million and a 1,000 Twenty-foot Equivalent Unit (TEU) container ship has increased from \$15.5 million to \$23.5 million.



The weakening dollar has improved the competitiveness more in the U.S. than in many countries whose domestic costs are not dollar denominated such as Europe and South Korea. This means that international market conditions are more favorable for U.S. yards than they have been for two decades. U.S. mid-tier yards can already offer prices which are internationally competitive on some ship types for which they have extensive experience. These include vessels for the offshore industry and some workboats.

U.S. mid-tier yards appear to be unable to offer competitive prices for ship types with which they are less experienced. Some of the reasons for this are listed below. Several are within the control of the yards; others are not.

1. Yards tend to concentrate on specific markets and become skilled at designing and building those vessels cost effectively. The steep learning curve makes it difficult for entry into new markets.
2. Due to market conditions, U.S. yards often build one-offs or short series commercial vessels and the design costs are therefore amortized over fewer vessels. Far East yards and many European yards tend to build longer series.
3. Short series building means that ships are rarely built at the shipyard's core productivity due to first-of-class performance drop-off, which can be high. This leads to ships built early in a series being much more costly than those built later. Therefore, on a short series, it can be very difficult for yards with high drop-offs to compete against yards that are already well down the learning curve. This is a barrier to market entry. Yards with high best practice ratings in the pre-production areas tend to have lower performance drop-offs.
4. The core productivity of the U.S. mid-tier yards lags behind leading international mid-tier yards although, for the best U.S. yards, this gap is quite small.
5. The rate of output tends to be lower in the U.S. yards and so the proportion of overhead allocated to each vessel is higher.
6. Material costs tend to be higher in U.S. yards due to lower levels of throughput and weaknesses in the supply chain. Non-standardized designs also drive up cost.
7. Although U.S. shipbuilding hourly labor costs are lower than Japan and most of Western Europe, they are significantly higher than in some Asian and Eastern European countries.
8. There are environmental constraints that can lead to higher costs.
9. There is a cost associated with the risk resulting from the litigious culture in the U.S.
10. U.S. yards tend to have higher profit expectations than many international builders.

This said, given rationalized, highly production engineered, market-specific designs and the demand for long vessel series, it is likely that leading U.S. mid-tier yards could be competitive in a range of market sectors. However, to be competitive on a shorter series, a product-orientated approach to design and production would have to be adopted and some subcontracting to lower cost countries may be required. The U.S. yards may also need some assistance to develop international designs.

Although price is generally the predominant consideration when selecting a shipyard to construct a new vessel, there are other important issues that ship owners take into account. These include delivery date, schedule adherence, financing, quality, reputation, track record, shipyard location and the relationship with the customer. The standing of U.S. mid-tier yards on these issues has not been assessed but there is no reason to suppose that they would not score well in many of them.



### 3 SUMMARY OF USE OF BEST PRACTICE

#### 3.1 Overall findings

GSIBBS Part 1 reported that in the period between 1999 and 2004, there has been a significant increase in performance improvement activity in the first-tier yards and that, in some, substantial investments in facilities, plant and equipment have been made. It was suggested that this may have been motivated by pressure from the government to give better value for money, increased competition brought about by the reduction in naval demand and pressure brought to bear by the yards' two parent corporations to produce higher returns. There has also been an increase in performance improvement activity in the mid-tier yards and, although it is at a much lower level compared to the large yards, there has been capital investment. Competition in the domestic market and the desire of some yards to improve international competitiveness has provided the motivation to improve.

The mid-tier yards were last benchmarked during the NSRP Advance Shipbuilding Enterprise benchmarking survey carried out by FMI in 1999/2000. Although the sample of U.S. yards is not the same, both are believed to be representative of the industry sector. Table 3.1 shows the change in the average best practice rating of the U.S. yards and the comparison with the average rating for the international sample in 2006.

Section	Group	U.S. yards average rating 1999/2000 <sup>2</sup>	U.S. yards average rating 2005/2006	International yards average rating 2006
A	Steelwork production	2.2	2.4	2.9
B	Outfit manufacturing and storage	2.5	2.6	3.4
C	Pre-erection activities	2.4	2.5	2.8
D	Ship construction and outfitting	2.7	3.1	3.3
E	Yard layout and environment	2.5	2.6	3.6
F	Design, engineering and production engineering	2.7	3.2	3.4
G	Organization and operating systems	3.2	3.4	3.8
<b>A – G</b>	<b>Overall industry rating</b>	<b>2.6</b>	<b>2.9</b>	<b>3.3</b>

**Table 3.1 – Mid-tier U.S. and international industry best practice rating by group and overall**

The overall average for the U.S. yards has increased from 2.6 to 2.9. The yards were benchmarked in three batches and quite substantial improvements have been made in the initial batch of yards since they were surveyed in the summer of 2005. This is not reflected in the 2005/2006 score and so the current average is likely to be higher than is shown.

The degree of improvement since 1999 varies significantly from yard to yard but the average rate of improvement for the industry as a whole is approximately 0.05 of a point of best practice rating per annum. This is about half the rate of improvement demonstrated by large and mid-tier international builders in the past and by the large U.S. yards. Although the average rating of the highest scoring U.S. mid-tier yard is higher than the lowest rated international mid-tier yard, the gap between the

<sup>2</sup> This is a slightly different group of yards to the 2005/2006 sample but it is considered to be representative of the industry during 1999.



industry averages is about twice the gap that existed between the U.S. first-tier yards and the large international yards in 2004.

Figure 3.1 shows the range of use of best practice observed in the international and U.S. yards in 2005/2006 by element group. The ends of each bar represent the lowest and highest average score in each element group and the black line across the bar is the average for all the yards benchmarked.

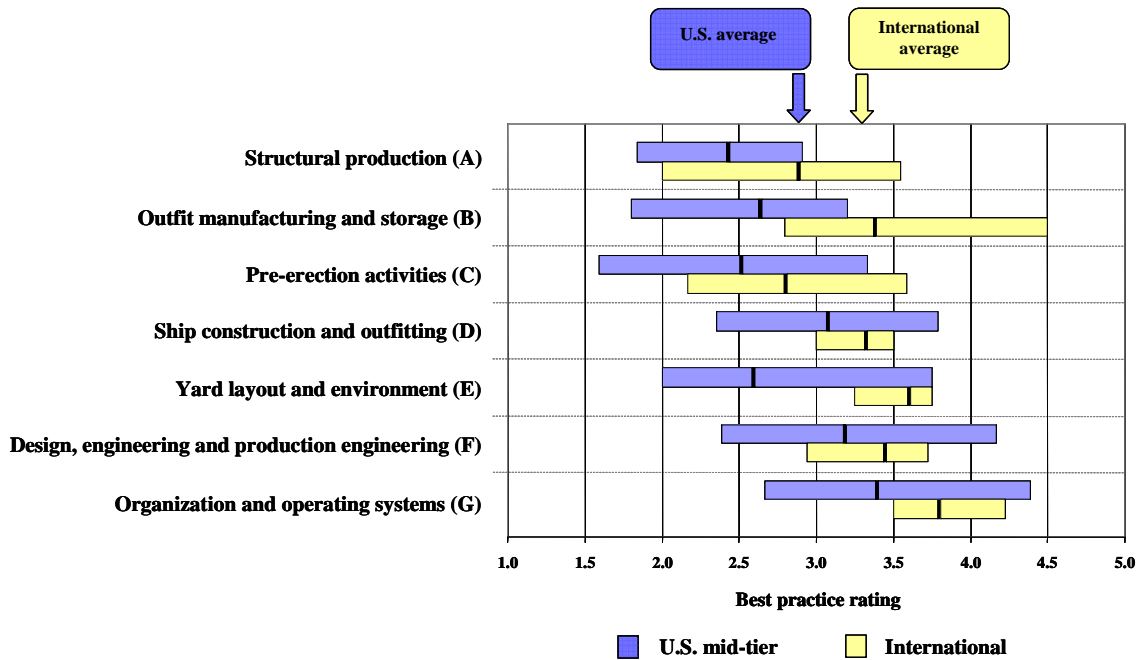


Figure 3.1 – Overall industry use of best practice

Some individual U.S. yards have clear strengths and lead the best international yards in some groups. These are predominately in the soft areas (i.e., not facilities or equipment) which are mainly part of the design, engineering and production engineering, and the organization and operating systems groups. Some have also scored well in ship construction and outfitting and the best have yard layouts and environments on par with the international yards. However, the average best practice ratings for the U.S. industry lag behind the international yards in all element groups. The largest technology gaps occur in yard layout and environment, outfit manufacturing and storage, steelwork production, and organization and operating systems.

Generally, the U.S. facilities are less well developed and there is a lower level of investment in buildings and equipment. With the exception of some aspects of design, and with other notable exceptions in individual yards, there is generally much less emphasis on, and investment in, the soft areas in the U.S. This is in part compensated for by highly skilled supervisors who often undertake a higher level of planning, detailed design, materials control and production engineering than their international counterparts. However, when compared to the international leaders, this approach does not result in the best overall performance, particularly on larger, more complicated vessels and contributes to high performance drop-offs early in a construction series. The gap in some production groups is justified as lower throughput does not warrant the use of costly, high output equipment that leads to high scores.



There is a higher level of subcontracting in the mid-tier yards when compared to the large yards. When the volume of work is not sufficient to justify investing in a process that will result in the high level of productivity, the leading yards tend to subcontract it if they can.

Previous surveys have shown that although there are differences in emphasis related to product mix and throughput, the highest performing shipyards usually have a good balance of technology across all groups and the range within each group is quite small. The group averages for the individual mid-tier U.S. yards generally have a relatively wide range and there is often a broad spread of scores within each group. Addressing these imbalances will improve the performance of individual processes locally and will increase the effectiveness of technology applied in other areas.

GSIBBS Part 1 highlighted the importance of the soft areas in large shipyards and this study has indicated that they are equally important in the mid-tier yards. Leaders in this sector are process oriented and have placed a great deal of emphasis on the aspects of technology that:

1. Provide coordination and control over the operation.
2. Give visibility of the performance of individual processes.
3. Provide high levels of dimensional accuracy.
4. Continually improve performance.
5. Smooth the flow of materials and technical information.
6. Reduce work content.
7. Keep shop-floor workers at their workstations.
8. Reduce work in progress and inventory.
9. Organize work into optimized workstations and maximize the use of the facilities.
10. Ensure that work is done at the most cost effective stage of production (this is usually as early as practicable in the cycle).
11. Reduce cycle time.

Recently, and in some cases with government assistance, several U.S. mid-tier yards have made significant investment in both the soft areas and in new equipment and facilities. Most are planning to make additional investment in the future. Substantial capital expenditure is usually required to make improvements in the hard areas. Therefore, the most progressive yards have tended to develop the soft areas (working smarter) prior to make heavy investments in facilities and equipment.

The following paragraphs summarize the current situation in the U.S. mid-tier yards, the changes that have occurred since 1999/2000, and make comparisons to the practices of the yards in the international sample. A more detailed review at the element level is included in Appendix 3 of the full report. The appendix includes suggestions for industry-wide corrective actions.

### **3.2 Structural production**

The U.S. yards' average score of 2.4 in this group is lower than in any other group benchmarked in the study. In general, the industry employs a low level of technology in structural production, although it may be appropriate for the current low throughput in some of the smaller yards. There is a significant



technology gap when compared to the international yards surveyed although some did not score particularly high either.

U.S. stockyards are generally well-organized although in some yards they are not particularly well located. About half of the yards have combined plate and stiffener treatment lines; most of the remainder work with aluminum or buy steel pre-primed. Plate cutting is now universally high technology and there are a few examples of laser cutting, an advanced technology typically found in shipyards processing light plate. Profile cutting and plate and profile forming, with few exceptions, is low technology and labor intensive. Modest upgrades are required in these areas in almost all yards to improve their efficiency and the accuracy of parts. It is unlikely that significant investment could be justified in any single yard but there may be advantages in collaboration between yards or outsourcing to regional centers employing a higher level of technology. This is also true for the production of metal outfit items.

The technology employed in virtually all the assembly stages in most of the shipyards is basic. Work is often done in random areas (i.e., where space is available) or non-dedicated areas, and sometimes in areas which are not within buildings. With few exceptions there is a lack of workstation organization or process lane approach. This means that structural assemblies are often produced in sub-optimal work areas. The issues here are mainly related to the organization of the work although some investment is required in equipment and processes and to increase the proportion of work completed under building cover.

### **3.3 Outfit manufacturing and storage**

There are some well organized outfit manufacturing shops in the U.S. mid-tier yards that have been arranged on lean principles and have managed to achieve good levels of performance without a high level of investment. Even so, the international yard average leads the U.S. yard average by 0.8. One of the reasons for this is that while a substantial amount of outfit manufacturing is subcontracted, some U.S. yards have adopted a basic approach to most aspects of outfit manufacturing. This is generally because low throughput makes it difficult to justify more sophisticated processes. Although much has been done with a low level of investment, to improve further some shipyards should invest in pipe shop and sheet metal shop technology in particular. An alternative to investing in individual shops would be to subcontract, or to cooperate in establishing high technology regional outfit manufacturing centers.

A high proportion of yards have a jobbing machine shop to support ship repair and shipyard maintenance but where they are also used for new construction they have been scored. Some yards subcontract all machining work associated with new construction which is the norm in the international yards. Most U.S. yards subcontract the manufacture of major electrical items and provide a jobbing workshop to support installation. It is disappointing to see how few cables are pre-cut or have one end prepared for termination or plugged prior to installation. Software that would facilitate this and is compatible with the CAD systems currently used by most yards was being developed at the time of the study.

In general, warehousing operations between the leaders in the two groups are not dissimilar. It is the lower inventory levels in the international leaders that put them slightly ahead. Some of the lower scoring U.S. yards should also make more use of line-side stores and vendor managed/controlled inventory. It is generally recognized that it is advantageous to deliver large or heavy items to the point of use and some U.S. yards manage this quite well where practical. However, the efforts of others are often hampered by poor schedule adherence.



### 3.4 Pre-erection activities

The pre-erection activities group average was one of the lowest of all groups and there was also a very wide range of scores within the group. There are particularly poor scores in module building, and below average scores in outfit parts marshalling, block assembly and materials handling. The best scores were to be found in pre-erection outfitting and unit and block storage. In pre-erection outfitting, the U.S. yards' average score exceeded that of the international yards by a significant margin.

There is limited understanding of the benefits offered from outfit module building (the assembly of functionally related outfit components on to a structural frame) and little effort is made to incorporate the concept in build strategies or to design for module building. In the cases where modules are assembled, they are rarely done in dedicated, purpose-designed workshops.

Outfit parts marshalling (kitting) is not as effective as it should be. Other than in the smallest yards, the practice of allowing shop floor personnel to do their own planning and parts marshalling does not tend to result in minimum production cost. It is important that everything is done to make the necessary material available to the tradesmen at the proper workplace at the proper time. Even though supervisors will be involved, this requires an outfit parts marshalling system which is operated by the supporting logistics operation.

There is a good understanding of the pre-erection outfitting process across most of the yards surveyed and some achieve relatively high levels of pre-outfitting. However, its implementation may be hampered by immature design information, especially on first-of-class vessels. Also, it is impossible to achieve the highest levels of pre-erection outfitting unless the shipyard builds large natural blocks (that is, subdivides the vessel into large structural units and blocks that are self-supporting as far as possible and which minimize the work content at the vessel construction point). Some yards do not build blocks and follow a small unit approach in structural production. This approach extends outfitting cycle time and pushes outfitting to the more costly onboard stage.

Block construction is an important technology in shortening building way cycle time and reducing costs. Some yards have limits imposed on block size by constraints such as crane capacity, access and building size. A high level of investment may be required to improve the use of best practice in this area; however, the benefits can be very significant. All shipyards have sufficient space for the temporary storage of structural units/blocks and most have appropriate handling and transportation equipment. While there is a good range of general materials handling equipment in the yards, a surprisingly large volume of materials and equipment is still man-handled between workstations. This is partly due to weaknesses in the material control systems. Also, many yards could benefit in extending the use of purpose-designed pallets.

### 3.5 Ship construction and outfitting

The ship construction activities scored above the industry average although there is a relatively wide range of scores within the group. Ship construction in the U.S. takes place on either land-level facilities with barge or floating dock launching, or on building ways with side or end launching. About half the yards carry out construction in the covered building halls; the remainder erect the ship in the open. Again, about half the yards have adequate cranage for natural block erection, while the remainder erect small units. Construction cycle times tend to be long. Where cranage is suboptimal, it must be upgraded if large pre-outfitted blocks are to be erected with a consequent reduction of cycle time and onboard man-hours (which are the least productive).



With regard to erection and fairing, some yards have made good progress in improving block accuracy and reducing the extent of fairing required at erection. However, others leave excess material on nearly all structural components, have long crane hanging times and incur significant corrective man-hours at the erection stage. The key focus areas in eliminating this non-value-added activity are accuracy control in part preparation and assembly, and the application of non-welded aids in block alignment and fairing.

The use of semi-automatic welding, and automatic welding with the use of tractors, is well established throughout the sector although the application of one-sided welding with ceramic backing is limited. There is little use of manual metal arc welding. While there is room for welding process improvements, especially on the building ways, and on welding procedures and sequences, the shipyards generally have a good working knowledge of best practice.

In many yards, onboard services are pre-planned and well-organized. In others, they are under the control of the local supervision and are not well coordinated across the vessel. Onboard housekeeping varies from yard to yard and ranges from good to untidy. Unfortunately, there are many examples where hoses and cables can be seen spread around internal spaces in an apparently unplanned and uncoordinated manner.

The concept of minimizing the need for staging and other access equipment is well understood and implemented by some U.S. mid-tier yards. However, others lag well behind industry best practice and, in fact, most yards spend excessive hours and cost on non-value-added staging activities. Those yards which achieve least in pre-erection outfitting and in erecting large, natural blocks have the greatest amount of work remaining to be done on board, all of which requires additional costly electrical and mechanical services, staging and access.

In most yards there is a high proportion of outfitting achieved prior to launch although the lack of a zone-by-stage outfitting methodology in some makes coordination of the outfitting trades difficult. To minimize onboard outfitting work, shipyards should maximize the manufacture of outfit modules, build large structural blocks and achieve high levels of pre-erection outfitting. Onboard outfitting can then be completed in a short duration on an area-managed, zone-by-stage basis.

While much of the industry achieves good integration of painting into the outfitting schedule, painting facilities, processes and quality vary, as does the amount of painting achieved at the less costly, pre-erection stages. This is limited by a lack of purpose-designed (or even temporary) painting facilities that can handle the largest structural units/blocks. The lack of accurate technical information that allows painting to be carried out at earlier stages without having to rework it, following damaging hot work, at later construction stages can also be a constraint in some yards.

### **3.6 Yard layout and environment**

The average score in this group for the U.S. yards is below the industry average and is significantly less than that of the international yards. Few yards have well-designed layouts with good flows, low work-in-progress and short distances between product centers. The layout and material flow in most shipyards suffers from the fact that they have been developed over several decades and/or experienced piecemeal facility evolution as their product mix and rate of output changed. Unfortunately, it is obvious that most developments have not been carried out in the context of a long-range facilities plan. A number of the yards are still being re-developed and there is recognition of the need to improve layout and material flows. It is important that these yards take a long-term view.



With regard to general environment, some yards have scored well and some very poorly. In the best yards, almost all work is done under cover, housekeeping is good and working conditions are comfortable. In the worst yards, the opposite is the case and, additionally, a common feature is unpaved roads and storage areas. A high proportion of work in these yards is undertaken outdoors exposed to the worst effects of the climate. Housekeeping and working conditions are poor. A few yards are between these two extremes. There is a mixture of old and new buildings with most manufacturing work and ship erection carried out undercover within buildings or under temporary structures/covers. Buildings are well maintained and conditions are satisfactory.

In many yards, a continuous focus is required to improve housekeeping and working conditions, particularly in outside assembly areas, ship construction areas and onboard.

### **3.7 Design, engineering and production engineering**

The average score for the design, engineering and production engineering group is the second highest of all groups. Although there is a wide variation in the scores across the industry, there has been a significant improvement since 1999. The U.S. average lags slightly behind the international yards but there are some U.S. yards that are clear leaders in the group and in several elements. The highest scoring elements in which the U.S. averages lead the international yards are ship design process and preparation of production information. However, there are very low scores in key elements that have a major effect on work content and productivity including production engineering, design for production, dimensional accuracy and quality control. Coding systems and parts listing methods are also weak in many U.S. and international yards. These yards are missing an opportunity to easily organize work into product families, reduce work content in the pre-production functions and automate some processes which are currently manual, costly to operate and prone to errors.

Most U.S. mid-tier yards have a strong design capability supported by large libraries of vessel designs but there is limited engineering capacity and limited experience with some international commercial designs. A particular U.S. strength is the industry-wide use of the ShipConstructor CAD system which is shipbuilding-specific product modeling software that is being developed specifically for the small and mid-tier yards with the assistance of NSRP funding. The standard formats for production information embedded in ShipConstructor make it easier to implement the workstation philosophy and transfer information between systems. However, more work is necessary to improve interfaces with some of the more common planning and material control systems. A key weakness in the design process is the reliance on a traditional system-based organization rather than a more efficient product-oriented, area-based organization. In some yards there is a low level of awareness of the degree to which production engineering and design for production can reduce cost and cycle time. Also, the accuracy control activity is given insufficient prominence.

### **3.8 Organization and operating systems**

This group of elements has shown an improvement of 0.2 in use of best practice since 1999 and even though some U.S. yards now lead the international yards, the U.S average lags by 0.4. The U.S. shipyards tend to have a relatively flexible, skilled core workforce and place considerable responsibility on supervisors. This is similar to the international yards, except that the supervisors in the international yards usually have more support from the center in terms of planning and material control. Even though the U.S. yards subcontract a substantial proportion of the work, the proportion of work subcontracted by the international yards is higher.



The extent to which workstation organization has been implemented is variable in both the international and U.S. mid-tier yards and in general it is not implemented to the same degree as it is in larger yards. Even so, some U.S. mid-tier yards have recently put a great deal of effort into workstation organization and have benefited substantially. Area management has also been partially implemented but production is often organized by trade with a limited amount of onboard coordination for outfitting. There would be benefit in increasing the level of coordination of the work carried out in each area on some larger, more complicated vessels. Some of the international yards are also highly trade orientated but they have the volume of work to keep people working within their trade. The work also tends to be organized differently with common tasks such as hot work completed at one stage.

Aspects of the approach to planning and the planning systems are currently under development in most in U.S. yards. Some already have first class systems that are comparable to those in leading international mid-tier yards, while others are still in the early stages and require much further development. There also appears to be a shortage of experienced planners in some areas. Structural scheduling tends to be carried out more efficiently than outfit scheduling, which is often heavily reliant on the supervisors concerned and does not benefit from a comprehensive set of performance metrics to the same degree as structural scheduling. There is also a reliance on supervisors to carry out production control, the approach to which is variable but generally it is not done as efficiently as it is in the international yards. It is not unusual for overhead-sensitive small organizations to resist investment in planning and production control, but it is notable that the leading yards have all made considerable investments in these processes.

As with the first-tier U.S. yards, performance and efficiency calculations are often focused on the budget for a particular vessel rather than the productivity being achieved by individual processes. This is because the yards tend to be project rather than process orientated. In contrast, the leading international yards are strongly process orientated. Quality assurance systems are generally very good in the U.S. mid-tier yards with a few exceptions which are normally due to a lower level of throughput and the desire to reduce overhead. The higher scoring mid-tier yards make effective use of their quality assurance systems to improve performance and some do this more effectively than the international yards. Quality assurance was also identified as being a very important element in leading yards in both groups. Most yards make management information available internally on-line, however much of the information is produced manually from data extracted from the shipyard systems. Ideally, focused management information should be available online without the need for manual reconfiguration, as it is in the leading yards in both groups.



## **4 U.S. INDUSTRY PRODUCTIVITY**

### **4.1 Measurement of productivity**

This section has been repeated from the Section 3.1 of the GSIBBS Part 1 report as it contains important definitions that are central to the analysis of productivity.

Compensated Gross Tonnage (CGT) is the measure of work content that forms the basis of the productivity estimate. CGT is the international gross tonnage (a measure of internal volume) of the vessel multiplied by a compensation coefficient which represents the complexity of the vessel design. It allows the productivity of different shipyards to be compared even though they may be building different types and sizes of ships. This is because the work content is based on the characteristics of the subject vessel and is not expressed in terms of man-hours. The man-hours required by a particular shipyard to execute the work content are determined by multiplying the CGT for the vessel by the productivity of the yard in terms of man-hours per CGT.

There are internationally agreed CGT coefficients for commercial vessels but none for naval vessels. A recent study carried out by FMI on behalf of the UK Ministry of Defence (UK MoD) has provided the basis for the coefficients used in this project.

In the U.S. and other developed nations, naval design and construction projects require the shipbuilder to commit proportionately more management, technical and administrative resources than would be the norm on a commercial vessel. This is because the customer requires the shipbuilder to adopt practices that are not normally necessary in commercial shipbuilding and there is simply more work involved in dealing with, and responding to, the customer. To be able to make a fair comparison between the work content of commercial and naval vessels, the additional effort needs to be taken into account in the CGT coefficient. This correction has been called the customer factor. It is expressed as a percentage and applied to the vessel's base CGT coefficient to account for the additional work content. The method used to calculate the factor for the U.S. is explained in Appendix 2.

The measure of shipyard productivity is man-hours per CGT. The man-hours used in the calculation are the hours of the workforce, direct and indirect, involved in shipbuilding plus the subcontracted man-hours. It is therefore a measure of the efficiency of the whole organization.

Three aspects of shipyard productivity have been considered: core productivity, rate of improvement in core productivity, and first-of-class performance drop-off. Core productivity is the best productivity a shipyard can achieve with its current production technology and a mature design. Shipyards do not always work at this level of productivity because first-of-class effects, interference between contracts, facilities development and other disruptions cause the actual productivity to be less. First-of-class performance drop-off is the degree to which actual productivity drops off on a new first-of-class. Less effective pre-production processes and complex vessels tend to result in higher first-of-class performance drop-offs.

### **4.2 U.S. mid-tier shipyard productivity**

Only a limited analysis of productivity has been carried out for GSIBBS Part 2. Although some shipyards provided data, alternative methods have been used to estimate the productivity in some others.



The core productivity of the majority of yards surveyed has been estimated to fall in the range of 20 to 50 man-hours per CGT. First-of-class performance drop-off is likely to be quite low in the higher scoring yards but, in others, it appears to be in excess of 50 percent which is similar to some of the first-tier yards. The indications are that the best rate of improvement in core productivity since 1999 is less than 5 percent per annum.

### 4.3 Customer factor

In order to assess U.S. shipyard productivity, the customer factor as it relates to U.S. naval shipbuilding contracts was estimated in GSIBBS Part 1. The analysis concluded that there was an increase of about 10 percent in man-hours for naval auxiliaries over and above an equivalent commercial contract but that it is likely to be much higher on more complex vessels. The appropriateness of the acquisition practices and processes that result in this premium were not assessed but the premium was presented as a possible opportunity for the Navy to reduce costs.

Following the GSIBBS Part 1 report which discussed the reasons for this factor in general terms, Congress, the Navy and other government agencies have requested specific examples of their practices that increase shipyard man-hours. The items below are representative of the issues highlighted by several of the shipyards benchmarked. The list, which includes several independent observations made by the benchmarking team, is presented in descending order of importance. Not all items listed are within the scope of the customer factor as it was defined in Part 1.

1. Incomplete specifications at contract signing and a low level of design maturity at the start of construction driven by a requirement to start construction early.
2. The time taken by the Navy to make technical decisions relating to the vessel design.<sup>3</sup>
3. The time taken by the Navy to approve production processes.<sup>4</sup>
4. Lack of technically qualified on-site naval supervisors who are empowered to make decisions.
5. Inconsistent and sometimes excessive naval supervision (this may be a reflection of the varying levels of confidence the Navy has in different builders).
6. Duplication of responsibilities and conflict between inspection agencies.
7. Naval supervisors overruling the classification society.
8. ABS Naval Rules that do not produce projected cost savings and appear to impose unwarranted specifications in some cases.
9. Compromised build strategies to meet political milestones.
10. Significant differences in the interpretations of specifications and the interpretation of commercial standards between industry, Navy and the inspection authorities.
11. A lack of flexibility to accept production engineered modifications that would reduce work content.

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<sup>3</sup> & <sup>4</sup> These are related to the reduction of specialist technical expertise and capacity at NAVSEA and the transfer of some technical authorities to industry.



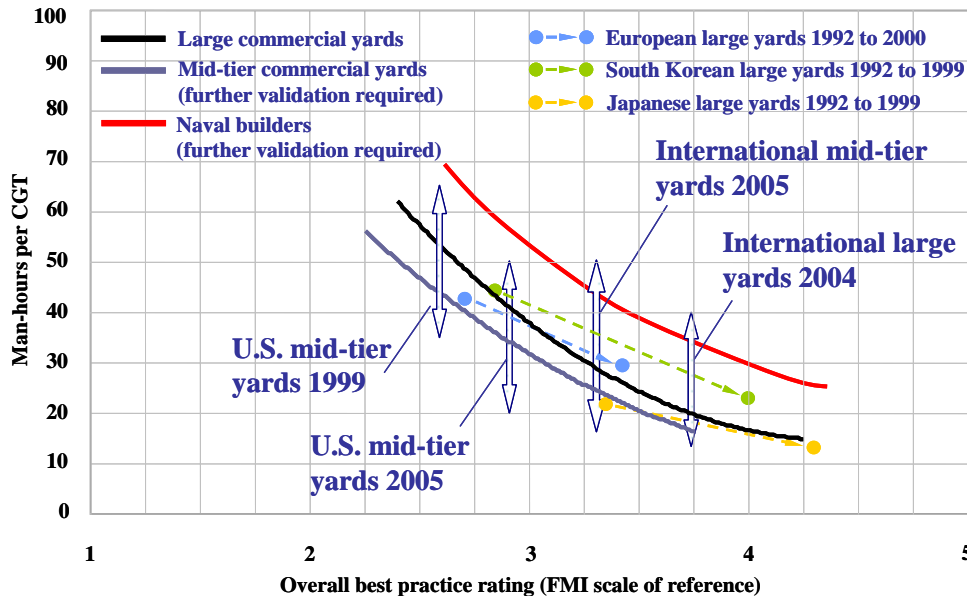
12. An imposed purchasing regime that results in much higher management costs, results in practices that are often contrary to good commercial practice and does not always provide best value.
13. Progress payment regimes that reward increased shipyard inventory.
14. Naval restrictions on the use of ship systems to assist with the construction of the vessel.

Some of the issues listed above have a very significant impact on the time and cost of construction. The list is not exhaustive and does not cover the full scope of acquisition practices and processes that contribute to the customer factor. While there may be sound reasons for many of the practices, the list indicates that there would be considerable merit in the Navy continuing to review its practices and to make changes. In particular, it appears that the relatively newly formed relationship between ABS, Supervisor of Shipbuilding, Conversion and Repair (SUPSHIP), the Naval Technical Authority, Naval Sea Systems Command (NAVSEA) and the shipyards would benefit from revision. The shift in technical responsibility and the availability of personnel to deal with day-to-day technical issues within NAVSEA also appear to be factors.

A further observation is that cost-plus contracts are likely to result in a lack of discipline, especially on the first-of-class, which will increase cost. There is a tendency to overlook good practice relating to design maturity at start of construction, design freezes, optimum build strategy and so on. This is likely to account for some of the recently reported cost increases on the Littoral Combat Ship (LCS) built in U.S. mid-tier shipyards.

#### **4.4 International comparison**

Past competitiveness studies have established a correlation between use of best practice, performance and profitability. One of the most thorough of these was the 1992 European Commission Study of the Competitiveness of European Shipyards carried out by KPMG (UK) and FMI. This study proposed that each yard must maximize its use of resources by ensuring that it is using best practice appropriate to its size, type and individual business objectives. The research program and analysis demonstrated the link between the use of best practice and output performance. The results are shown in Figure 4.1, together with the results from subsequent studies for which trend lines for the large commercial yards and naval builders have been derived. The overall position of the mid-tier U.S. yards has been plotted to provide a comparison with the international mid-tier shipyards.



**Figure 4.1 – Best practice and core productivity**

Although more data would increase the level of confidence, this study has indicated that there is a further trend line for commercial mid-tier yards which falls beneath the commercial large yards line. The difference between the two is driven by differences in shipyard output, the size of vessels produced and the relative size and structure of the organizations.

From a productivity standpoint, the most effective shipyards tend to lie close to or below the trend line that represents their particular business focus. Yards which are above the line make less effective use of their applied technology. This means that shipyards with higher best practice ratings do not necessarily have high productivity.

Several U.S. mid-tier yards appear to fall relatively close to the mid-tier line and the organizations are relatively lean and effective. This indicates that there is limited opportunity to improve by making more effective use of their existing technology and that they need to raise their technology levels (best practice ratings) to significantly improve core productivity.

Mid-tier naval builders tend to fall above the mid-tier line. This is a further illustration of the productivity differences that occur between the commercial and naval shipbuilding environment that was highlighted in GSIBBS Part 1. It emphasizes the point that commercial acquisition practices result in better shipyard productivity. Commercial practices are characterized by competition between builders, fixed price contracts, clear specifications, very few change orders, appropriate construction oversight and no restrictions on profit.

The core productivity of the leading U.S. mid-tier yards still appears to lag slightly behind leading international mid-tier yards. However, the average productivity gap appears to be much less than it was found in the 1999 study.



## 5 COMPARISON WITH FIRST-TIER U.S. SHIPYARDS

### 5.1 Overall characteristics

As previously stated, to achieve the most competitive position, a shipyard needs to have appropriate best practices for its throughput, product mix and cost base. The first and mid-tier yards address different market sectors and therefore need to be configured differently to be successful.

The first-tier yards design and construct complicated naval vessels and some large commercial vessels. Government work is often allocated and fixed-price contracts are not often used. The yards all have high corporate overheads and a large staff in place to deal effectively with the requirements in the government sector. Staff numbers include large purchasing, legal, production support, administrative and engineering departments. There is a relatively high level of investment in facilities and equipment, and production processes are geared towards higher throughputs than the mid-tier yards. They retain a broad capability in-house and there is a relatively low level of subcontracting.

Although the mid-tier yards do some government work and the proportion is increasing, there is a high degree of focus on the design and construction of simpler, small to medium-size commercial ships. As the product mix does not wholly comprise of naval work, the yards are generally less exposed to the effects of changes in naval demand than some of the first-tier yards. The commercial market is highly competitive, it is not subjected to a high degree of political influence and fixed-price contracts are the norm. Most yards have minimized overhead and have adopted processes that support a lean structure. This is reflected in the investment in facilities and equipment in the yards which, although significant, is much lower than in the first-tier yards and production processes are geared towards lower throughputs. The mid-tier yards generally have more flexible, cross-trained employees with a good range of skills and they tend to retain a core workforce and subcontract a much higher proportion of the work. In contrast to the first-tier yards, a high proportion of the workforce is non-unionized. Members of the management team often have multiple roles and supervisors are normally required to work far more autonomously with less support than in the first-tier yards.

### 5.2 Best practice rating

The average best practice rating of the mid-tier yards is 2.9. The average for the first-tier yards in 2004 was 3.6. However, the leading mid-tier yards have an overall best practice rating which is much closer to the first-tier average. Figure 5.1 shows the range of use of best practice observed in the first and mid-tier yards by element group. The ends of each bar represent the lowest and highest average score in each element group and the black line across the bar is the average for all yards. As explained in earlier sections, it is expected that there should be some significant differences in groups such as structural production, but in others such as design, engineering and production engineering, and organization and operating systems, the gap should be much smaller. This is in fact the case and it is interesting to note that the leading mid-tier yards score highly in these so-called soft areas. The paragraphs following the chart explain some of the reasons for the differences in averages.

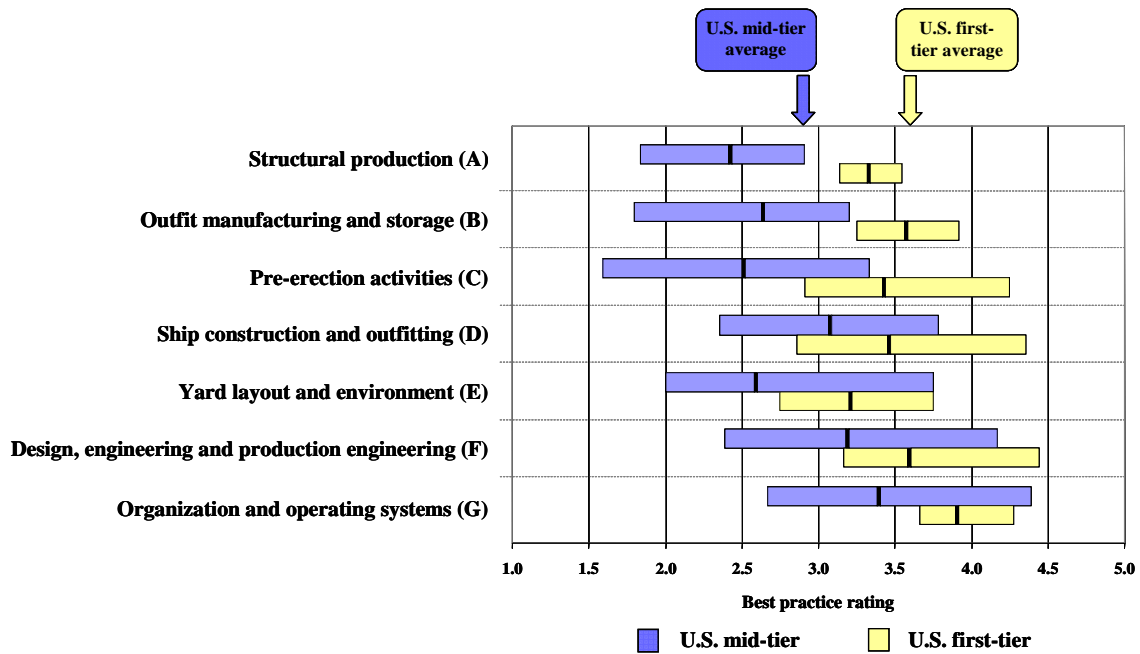


Figure 5.1 – Mid-tier / first-tier comparison of ratings by group

**Structural production – difference in average score 0.9:** Although some mid-tier yards do not store large quantities of structural material and arrange for just-in-time delivery, in those cases where it is stored in-house, there are only small differences in the approach to stockyards. Plate cutting arrangements are similar in the highest scoring yards with an emphasis on high accuracy in both first- and mid-tier yards. There is a much larger gap in profile cutting technology because many of the mid-tier yards have adopted fairly basic profile cutting techniques. Mid-tier yards also utilize a much lower level of technology for plate and profile forming and often subcontract portions of this work. All the assembly areas score lower in the mid-tier yards. This is due in part to the fact that the lower throughputs do not justify costly mechanized assembly lines. However, it is also due to the fact that most of the first-tier yards have organized this work more effectively into workstations.

**Outfit manufacturing and storage – difference in average score 0.9:** Many mid-tier yards subcontract the manufacture of outfit items. There are exceptions but where the work is done in-house it is often not as well organized as in the larger yards and the equipment used is generally not as sophisticated. First-tier yards tend to cut cables to length prior to installation and can prepare one end for connection in a workshop which is not the norm in the mid-tier yards. The storage of large or heavy items is minimized in many mid-tier yards as they often arrange for just-in-time delivery. However, the approach to general storage and warehousing is variable and insufficient emphasis is placed on keeping tradesmen supplied with materials at their workstations. Inventory levels are generally much lower than they are in the first-tier yards.

**Pre-erection activities – difference in average score 0.9:** Pre-erection outfitting can be a major strength in the mid-tier yards. Many do this work more effectively than some of the first-tier yards, however, less use is made of outfit modules than is the norm in the first-tier. The responsibility for outfit parts marshalling is often placed on supervisors without the support of the sophisticated centralized system that is a feature of the majority of the large yards. The approach to block



construction is variable in the mid-tier yards and, in general, the first-tier yards make much more use of this process. This is, in part, related to the fact that the mid-tier yards build smaller vessels and many cannot see benefit in adopting block construction techniques.

**Ship construction and outfitting – difference in average score 0.4:** There is a wide range of ship construction approaches in both first and mid-tier yards. Some of the best yards have protected, level construction points, large block sizes and good dimensional control. There is an equally wide spread of scores in erection and fairing with the mid-tier yard average lagging only slightly. Generally, welding techniques are more developed in the large yards and are oriented towards higher throughputs. These yards also tend to adopt a more organized approach to onboard services; however, some mid-tier yards are likely to adopt very progressive strategies for this work on future new construction. When compared to the large yards, many mid-tier yards have done surprisingly well in minimizing the use of staging, which is non-added-value. The approach to onboard outfit installation is variable in both first and mid-tier yards and although the lowest scores are the same in both, on average the mid-tier yards do not organize this part of the work as well. The approach to painting is equally varied with the highest scoring yards making good use of purpose-designed paint cells.

**Yard layout and environment – difference in average score 0.6:** The layout and material flow in the first-tier yards is generally better than in the mid-tier yards and has benefited from a higher level of investment. Although there are good working environments in both, the mid-tier benchmarking group average is lower and some yards have relatively poor working conditions.

**Design engineering and production engineering – difference in average score 0.4:** The single element that relates to ship design within this group is notable in that it scored an average of 3.9 in the mid-tier yards compared with 3.8 in the first-tier. This is because many of the mid-tier yards have excellent, appropriate design software and frequently produce new designs. As they have been building long-series legacy designs, many of the large yards have limited opportunity to produce new designs. It should be noted however, that the mid-tier yards have limited design capacity.

Production information tends to be well focused and appropriate in the mid-tier yards and is generally produced easily from the ShipConstructor 3D design software. Although coding systems can be quite basic in the mid-tier yards, some have adopted a highly product-orientated system and have achieved a higher score than any of the first-tier yards. Some mid-tier yards have developed a rational and efficient parts listing procedure. However, on average, the first-tier yards, which deal with a larger number of parts, have adopted a more efficient approach. Production engineering and design for production were both identified as representing major opportunities for improvement in the first-tier yards. The gap between the first and mid-tier yards in design for production is smaller but the mid-tier yards lag significantly behind in production engineering. A few of the mid-tier yards have done an excellent job of implementing dimensional accuracy and quality control and lead many of the first-tier yards. Sector-wide, however, this is not generally the case and many mid-tier yards have a long way to go in effectively implementing dimensional accuracy and quality control.

**Organization and operating systems – difference in average score 0.5:** In contrast to the first-tier yards, mid-tier yards generally have a non-union, flexible workforce but both still tend to be organized on a trade basis. The mid-tier yards do not make as much use of workstation organization as the larger yards and are inclined to keep their production operations flexible to deal with the lower volume of varied work. Although aspects of planning, scheduling and production control are all well advanced in some mid-tier yards, the large yards have a higher average score. The reasons for this include the fact that the mid-tier yards have a lower throughput and the supervisors often carry out a substantial part of



this work. The first-tier yards often dedicate a large number of people to planning, scheduling and production control. This is not the case in the mid-tier with some yards being close to international manning norms.

Due to lower throughput and the supervisors taking more responsibility, stores control tends to be less sophisticated in the mid-tier yards. Not all the mid-tier yards have accredited quality assurance systems as some cannot justify the overhead cost. However, both first and mid-tier leaders have sophisticated, accredited systems which are used as a vehicle to improve performance. There is a fairly consistent approach towards performance and efficiency calculations in the first-tier yards that tends to be project rather than process orientated. There is a much wider range of scores in the mid-tier yards with the information available ranging from extremely basic to being highly product and process oriented. Production management information systems in the first-tier yards are generally more comprehensive. This is due to a higher level of investment in this area resulting from the need for increased visibility on larger projects. However, there are examples of first-class, on-line systems in both sectors and innovative low-cost but effective systems in the mid-tier yards.

### 5.3 Productivity

The productivity estimate for the first-tier yards made in GSIBBS Part 1 was based largely on data which was available in the public domain. The basis of the mid-tier estimate has been explained in Section 4.2. The reliability of the productivity estimates therefore need to be kept in mind when considering the comments in this section. The origins of the chart in Figure 5.2, which shows the relationship between best practice rating and productivity of the first-tier yards in 2004 and the mid-tier yards in 2005/2006, have been explained in Section 4.4. It should be noted that all direct and indirect employees and subcontractors are included in the measure of productivity (man-hours per CGT) so that the efficiency of the whole operation is measured.

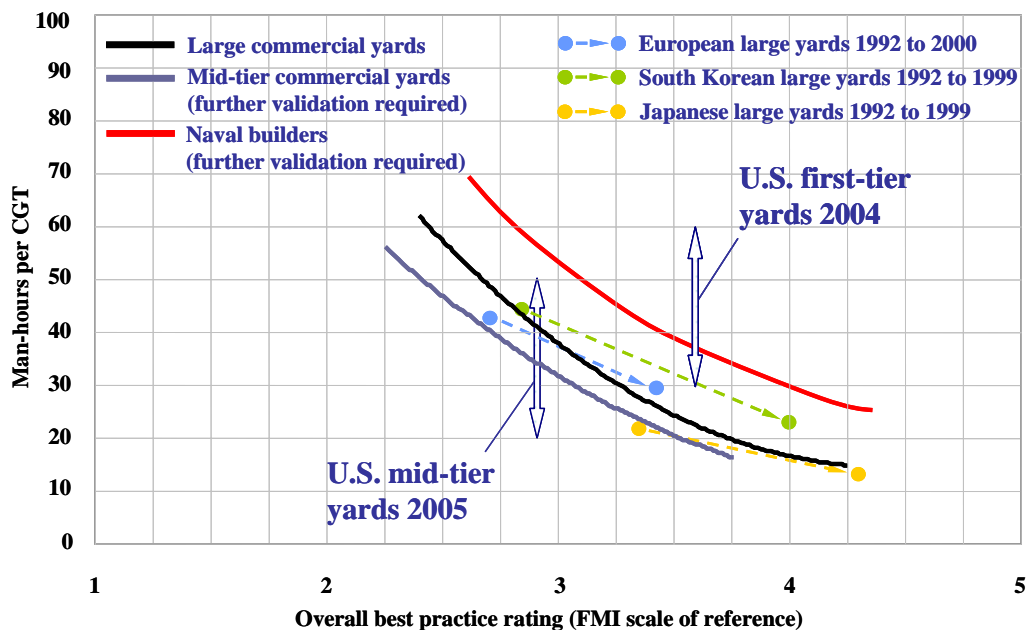


Figure 5.2 – Mid-tier / first-tier productivity comparison



There is an overlap between the first and mid-tier yards' productivity and the leading mid-tier yards appear to achieve a higher level of productivity than some of the first-tier yards. The benchmarking scores are higher in many of the production elements in the first-tier yards and productivity in those areas should be higher than in the lower scoring mid-tier yards. However, leading mid-tier yards tend to:

- have fewer employees and lower overheads per unit of output
- be configured for success in the commercial sector
- be smaller organizations that can be more efficient



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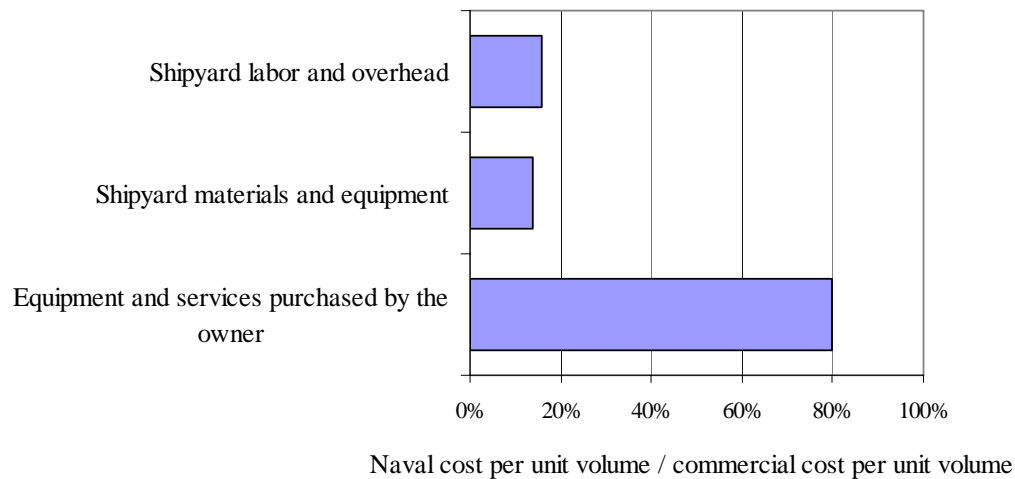


## 6 MID-TIER YARDS AND NAVAL BUILDING

### 6.1 Commercial and military cost drivers

There are different cost drivers in commercial and military vessels that affect the structure of ship cost and the configuration and operation of the shipyard. The purpose of this section is to explain some of principal differences.

A typical medium-sized combatant could be expected to cost about three times as much to build as a typical mid-size tanker built for the Jones Act market. However, the commercial vessel is much larger, having about seven times more internal volume. Therefore, when compared on the basis of internal ship volume, the combatant costs about twenty times (3 x 7) more than the commercial ship per unit of volume. The relative differences between the principal costs are shown in Figure 6.1.



**Figure 6.1 – Relative cost per unit of volume**

#### 6.1.1 Shipyard labor and overhead cost

The reasons for the labor cost being proportionately higher on naval vessels include:

1. Combatants are necessarily more complex. Proportionately more materials and equipment, often with a higher level of complexity, must be manufactured, installed, integrated and tested.
2. They have higher outfit densities and smaller compartment sizes which make it more difficult to work on them.
3. Naval acquisition rules, processes and practice increase overhead costs.

Table 6.1 below has been derived from a large number of studies into the relative work content of commercial and naval vessels. For four groups of work that account for the majority of the direct construction man-hours in a typical combatant, it shows:



1. The typical differences in the quantity of material and equipment built into typical combatants and commercial vessels. The comparison is based on the weight of equipment and materials per unit of internal ship volume.
2. The degree to which complexity increases construction man-hours in typical combatants when compared to typical commercial vessels.

<b>Work group</b>	<b>Typical relative quantity of materials and equipment in terms of weight per unit of internal ship volume</b>	<b>Additional man-hours required per ton weight of material and equipment manufactured, installed and tested</b>
Steel	1	3 to 4 times
Metal outfit	10	1 to 2 times
Piping systems	5	2 to 3 times
Electrical cable and fittings	3	3 to 4 times

**Table 6.1 – Comparison of material quantity and complexity of manufacture and installation**

This table illustrates how man-hours are proportionately higher on combatants. For example, there is about five times the weight per cubic foot of ship internal volume of piping systems in a typical combatant than there is in a typical commercial vessel. In addition to there being proportionately much more material and equipment in the combatant's piping systems, the differences in complexity can mean that the systems take 2 to 3 times more man-hours per ton to install. Therefore, between 10 and 15 times more man-hours are required to install the piping systems in a cubic foot of combatant than in the commercial vessel.

A review of the relative weights in Table 6.1 also illustrates that there is much more outfit in the combatant. This has an influence on the trade mix in the shipyard. Shipyards building these vessels need to employ many more outfitting personnel, some of which must have a high level of skill, or be very specialized. If the specialist outfit trades are not available, subcontractors must be employed and managed.

The overhead cost is proportionately higher on naval vessels because operating in the naval sector is simply more complex than the commercial sector. The absolute overhead costs also tend to be higher because the cycle time for the production of naval ships is proportionately longer than for commercial ships and the burden of establishment costs carried by naval ships is higher.

### **6.1.2. Shipyard materials and equipment**

Clearly, the total cost of materials and equipment is determined by the quantity used, its specification and the cost of the individual components. Table 6.1 has shown that a proportionately much greater quantity of outfit materials and equipment is installed in combatants. This is reflected in Table 6.2 which shows the relative proportions of equipment and material costs in both vessels types. The cost of outfitting materials will be much higher if government furnished equipment (GFE), which often includes some or all weapons systems, is taken into account.



Cost	Commercial	Naval
Hull structure	25%	6%
Propulsion	20%	12%
Outfit	55%	82%

**Table 6.2 – Breakdown of shipyard material costs in mid-tier shipyards**

The cost of similar individual components also tends to be higher on combatants. The reasons for this include:

1. The individual pieces of material and equipment could have a higher specification on the naval vessel. For example, structural steel may be higher strength and certain equipment will have shock or other additional requirements. However, many pieces of equipment are identical but because they are bought to a naval specification, they often cost more.
2. Legacy equipment is often specified by the Navy which tends to be more expensive than modern equivalents. More unique items are specified and less “off-the-shelf” equipment is used.
3. The certification and approvals required for materials and equipment on military ships, which often require additional testing, adds significantly to the cost.
4. The purchasing process which naval builders are required to follow is dictated by government. It requires more shipyard labor than typical commercial shipbuilding processes and so shipyard overheads in purchasing are higher. The government process does not always result in the best value for money when compared to commercial shipbuilding. The reasons for this include restrictions on sources, the difficulty in partnering easily with individual vendors and the ability to purchase equipment without running a competition.
5. The supply base adopted by naval builders is not structured solely on the basis of commercial imperatives as it is influenced by Congressional lobby.
6. The supply base for marine equipment in the U.S. is diminishing and this, in association with buy-America requirements for military ships, leads to increased cost.

### **6.1.3 Equipment and services purchased by the owner**

For military contracts, about one-third of the cost is typically incurred directly by the Navy rather than the shipyard. This may include prime contractor program management, systems integration and GFE. GFE is procured by the Navy and issued to the yard for installation, or is installed by a third party or the Navy after the vessel has been delivered. GFE can include weapons, sensors, platform equipment, and military or specialist equipment. Purchasers of commercial vessels also incur non-shipyard costs including, for example, finance, classification, contract supervision and owner-supplied items. The total proportion of commercial non-shipyard cost generally does not exceed about 10 percent of the total cost of the vessel.



## 6.2 Strategy

Typical mid-tier shipyard facilities are configured to build small to medium-size vessels with moderate outfit and have relatively low output compared to the large yards. They do not have the facilities nor the overhead staff required to compete for and handle large projects. Even though some changes to the facilities, equipment, skills mix and manning levels are required to build naval vessels, the basic configuration of the yards should offer cost advantages on projects that suit their capabilities. However, as they typically have limited experience in naval design and construction to undertake such projects effectively, mid-tier yards may need to be part of a contractor team in which other members provide specialist expertise and additional capability. The cost advantages could therefore be partially negated, especially as teaming arrangements inevitably have additional organizational and geographic costs associated with them. The yards could also be expected to incur high performance drop-off early in a series.

By encouraging mid-tier yards that have not previously built medium-size naval vessels to enter the market, the Navy is better utilizing available facilities and is increasing both available options and the level of competition in the U.S. industrial base. This strategy, however, also has implications for all U.S. naval shipbuilding programs, the majority of which are allocated to first-tier shipyards. Placing work outside the established naval shipbuilding industrial base, already operating well below its physical plant capacity, reduces the ability to spread overhead costs in those yards over a larger number of contracts.

There is no doubt that dealing effectively with the burden of current naval acquisition processes and procedures would require a considerable culture change at some mid-tier yards. This will increase cost and is likely to be detrimental to hard-won commercial competitiveness. An alternative is for the Navy to take the opportunity to thoroughly review its acquisition processes and practices with a view to minimizing the burden on the mid-tier yards, thus assisting them to retain the commercial advantage they offer. This could have a positive effect on other programs as well.



## 7 CONCLUSIONS AND RECOMMENDATIONS

### 7.1 Principal conclusions

The overall average best practice rating of the U.S. mid-tier yards lags significantly behind the international yards average. However, some U.S. yards have scored well and lead the international yards in a number of elements. There are opportunities for U.S. yards to improve their productivity by increasing their use of best practice in key areas. As in the first-tier yards, there are some significant gaps in the important soft areas although further investment in facilities and equipment is also required to close the technology gap.

Commercial ships currently dominate the product mix in the mid-tier sector. However, any processes and practices that are developed to improve commercial competitiveness, provided they are acceptable to the Navy, will also reduce the cost of naval shipbuilding. Therefore, the actions proposed by this study are relevant to both commercial and naval mid-tier shipyard output.

The overall range of core productivity is similar in the U.S. and international yards but the leading international commercial yards are ahead. Those yards that have a high first-of-class performance drop-off and wish to expand into new markets should, in addition to improving core productivity, prioritize improvements in the areas that reduce drop-off. This will reduce the cost of vessels built early in a series and help facilitate market entry.

The first and mid-tier yards are configured differently so they can succeed in their respective market sectors. Therefore, care needs to be taken when comparing the strengths and weakness in the two sectors as the comparison may not necessarily be valid. The size of the mid-tier yards makes them easier to manage, more flexible and able to change more quickly than the larger yards. However, they have limited spare resources to effect change.

The scope of the initiatives suggested in this study is limited to the elements of the benchmarking system which were included. The capabilities analysis has indicated that there are other areas that require attention such as those relating to human resources, purchasing, and contract management that are not discussed here. It is also recommended that the various existing performance improvement initiatives and programs are reviewed to take account of the findings and recommendations of the study.

The assistance provided to shipyards would be most effective if it was targeted towards moving them along a performance improvement path that was set out in shipyard-specific, long-term improvement plans. The foundations for such plans have been laid in the individual shipyard benchmarking reports.

The following recommendations for the U.S. Government and Navy were made in GSIBBS Part 1 to assist with naval shipbuilding program performance improvement:

1. Gain a more in-depth understanding of the relationship between ship specification, complexity and work content and work with the design authorities to reduce the inherent work content of naval vessels while not compromising functionality.
2. Work with industry to develop the pre-production processes to reduce first-of-class performance drop-off.



3. Review the acquisition rules, regulations and practices to determine if each adds value and work with the shipyards to find ways to reduce the effect these have on shipyard work content. (i.e., reduce customer factor).
4. Stabilize the ship acquisition program.
5. Improve shipyard incentives.
6. Continue to support performance improvement initiatives such as NSRP.

Positive action has been taken on several of the points raised since the publication of the Part 1 report. Most of the recommendations are also relevant to naval shipbuilding in the mid-tier sector but issues related to the customer factor should be given priority as these appear to create significant problems for some yards. In particular it is recommended that:

1. The timeliness of the naval approvals cycle is dramatically improved.
2. The responsibilities of ABS, SupShips and NAVSEA are clarified and the interactions between them streamlined.
3. The ABS Naval rules are continued to be developed with a view to improving productivity and reducing cost.

The strategy of using mid-tier yards for naval construction has many positive features. However, there is a limit to the sector's capability and capacity. Furthermore, the structure of the projects, the steep learning curve and the change in culture required to deal with naval work may result in the ultimate cost savings, particularly on vessels early in a series, being lower than anticipated. This strategy also has cost implications applicable to all U.S. naval shipbuilding programs, the majority of which are allocated to first-tier shipyards. Placing work outside the established naval shipbuilding industrial base, already operating well below its physical plant capacity, reduces the ability to spread overhead costs in those yards over a larger number of contracts. The change in the culture in commercial mid-tier yards required for success in the naval sector may also adversely affect their commercial competitiveness.

## **7.2 Priority areas for industry improvement**

It is possible to set best practice rating targets on the basis of the need to achieve a specific, market-driven level of productivity. To be internationally competitive building a vessel for which it does not already have a high level of expertise, it is likely that a U.S. mid-tier yard would need to have a best practice rating between 3.5 and 4.0, depending on the product mix and the circumstances in the yard. With this in mind, generic targets for best practice rating have been proposed for each element based on a review of international benchmarking data.

In some production elements, due to the lower volumes, the targets set are lower than those proposed for the first-tier yards in GSIBBS Part 1. However, as Part 2 has confirmed the importance of the soft areas in all yards regardless of size, many targets relating to these, and to some of the production elements, are the same or higher than those proposed for the first-tier yards. Plate cutting is an example of this. As dimensional accuracy is paramount in achieving high productivity and as the mid-tier yards generally deal with lighter plate, more sophisticated machinery is required for accurate cutting. For some elements, the target proposed is higher than any of the U.S. or international yards surveyed are currently achieving. The reason for this is that in these elements, even the highest scoring yards would benefit from upgrading their processes and technology. The targets set are considered to be realistically achievable in a 3 to 4 year period. In some cases such as production engineering, the



target has been moderated from the optimum as the technology gap is considered to be too wide to close in that time.

The following criteria have been used to produce a prioritized list of elements for action in each yard:

1. The size of the gap between the current and target level of use of best practice (high priority given to large gaps).
2. The impact that the activity has on ship cost (high priority given to high impact).
3. Contracts (current or future) on which the benefits would be realized (high priority given to current contracts).
4. The typical dollar cost of raising the level of technology in the area concerned (high priority given to lower cost items).

The individual shipyard priority lists were combined and the number of shipyards that need to take action in each area was added as a fifth prioritization criteria. This resulted in a prioritized list for the mid-tier yards as a whole. The highest ranking items are those which were ranked the highest in all, or a majority of, the shipyards.

Table 7.1 summarizes the results of the analysis and compares it to the rankings derived for the first-tier yards.



Element description	Rank: mid-tier	Rank: first-tier	Element description	Rank: mid-tier	Rank: first-tier
Production engineering (F6)	1	2	Metal outfit (A11)	26	41
Design for production (F7)	2	1	Erection and fairing (D2)	26	15
Outfit scheduling (G4)	3	3	Layout and material flow (E1)	26	34
Manpower and organization of work (G1)	4	13	Profile cutting (A4)	29	32
Outfit installation (D6)	5	18	Pipe shop (B1)	29	12
Module building (C1)	6	28	Ship construction (D1)	29	24
Production control (G5)	7	19	Flat unit assembly (A8)	32	37
Dimensional accuracy and QC (F8)	8	7	Storage of large heavy items (B6)	33	35
Outfit parts marshalling (C2)	8	9	Painting (D7)	34	16
Pre-erection outfitting (C3)	10	5	Minor assembly (A6)	35	42
Structural scheduling (G3)	11	3	Plate and profile forming (A5)	36	22
Master planning (G2)	11	5	Profile stockyard and treatment (A2)	37	28
Steelwork (and outfit) coding system (F4)	13	10	Sub-assembly (A7)	37	39
Onboard services (D4)	14	27	Production management info systems (G9)	39	48
Block assembly (C4)	15	28	Plate cutting (A3)	40	48
Electrical (B4)	16	44	Staging and access (D5)	40	32
Quality Assurance (G8)	17	43	Machine shop (B2)	42	47
Materials handling (C6)	18	11	General environment (E2)	43	22
Outfit production information (F3)	19	14	Plate stockyard and treatment (A1)	44	35
Performance and efficiency calculations (G7)	20	20	Superstructure unit assembly (A10)	45	40
Welding (D3)	21	38	Unit and block storage (C5)	46	45
Parts listing procedure (F5)	22	20	Steelwork production information (F2)	46	26
Curved and 3D unit assembly (A9)	23	31	Stores control (G6)	46	48
General storage and warehousing (B5)	23	16	Lofting methods (F9)	49	25
Ship design (F1)	25	8	Sheet metal working (B3)	50	45

**Table 7.1 – Industry summary of elements requiring action, in order of priority**



Although there are differences in the targets suggested for the first and mid-tier yards, and the gaps between current and proposed targets are generally different, the highest ranking elements are similar in both sectors. Production engineering and design for production have the highest priority even though most of the benefits are not realized until a new vessel is designed. Planning, scheduling, dimensional accuracy and QC, pre-erection outfitting and outfit parts marshalling are also ranked highly in both sectors. Elements that have been ranked more highly in the mid-tier analysis include manpower and organization of work, outfit installation and module building. One of the reasons for the high ranking of the manpower and organization of work is that although the mid-tier yards scored quite well, they are better placed to more easily achieve a higher use of best practice than the large yards, therefore, a higher target is proposed. There are still important improvements that can be made in ship design but it is interesting to note that this element has a much lower priority in the mid-tier yards. The main reason for this is that the technology gap is smaller.

The following sections contain suggestions for industry-wide, shipyard-specific, government and collaborative initiatives to make the necessary improvements in high priority areas. These are based on the findings and recommendations made in Appendix 3 of the full report. Some initiatives will affect more than one high priority element so the actions have been grouped into the top ten priority areas. These are shown in Table 7.2 which also shows the top ten focus areas proposed for the first-tier yards in Part 1.

Rank	Mid-tier	First-tier (Part 1)
1	Production engineering	Ship design and design for production
2	Design for production	Production engineering
3	Master planning, steel and outfit scheduling and production control	Master planning and steel and outfit scheduling
4	Manpower and organization of work	Outfit module building, pre-erection outfitting and onboard outfitting
5	Outfit installation and onboard services	Dimensional accuracy and QC
6	Outfit module building, pre-erection outfitting	Outfit parts marshalling and general storage and warehousing
7	Dimensional accuracy and QC	Pipe shop and other outfit manufacturing activities
8	Outfit parts marshalling	Manpower and organization of work
9	Steelwork and outfit coding system	Steelwork and outfit production information
10	Block assembly	Steelwork and outfit coding system

**Table 7.2 – Top ten industry-wide action areas**



### **7.3 Production engineering**

The GSIBBS Part 1 report proposed the Navy should address production engineering and design for production at an industry level and within the individual shipyards to reduce the cost of naval shipbuilding. These activities are also of vital importance in commercial shipbuilding where cost is the dominant element of competitiveness and there is a commercial imperative to reduce work content and maximize process efficiency. The industry should understand the importance of a strong production engineering function and the best way to develop it in mid-tier yards. As recommended in Part 1, this should be encouraged by:

1. Developing a shipbuilding industry production engineering charter defining the role and functional responsibilities of production engineering in U.S. yards to be in line with those of the world's leading shipyards.
2. Introducing a production engineering requirement for future naval ship acquisitions. This could be introduced as part of the design process to demonstrate the developing production methodology at each stage of design.

At the shipyard level, production engineering should assume a leading role in performance improvement, and facilities and methods development.

### **7.4 Design for production**

Although the mid-tier yards already consider producibility during ship design, there is an opportunity to increase effectiveness through a more formalized approach and by increasing design for production skill levels in engineering. Each yard should have a formalized and consistent shipbuilding strategy from which design rules and guidelines are developed for each stage of the design process in order to optimize production performance. The NSRP Design for Production Manual is an excellent reference and already explains the basic techniques. This document should be updated to reflect recent developments and should be extended to include guidelines for implementation in specific shipyards to suit particular product mixes and facilities. This could be supported by a series of workshops.

### **7.5 Master planning, structural and outfit scheduling and production control**

The highest ranking priorities in this category are outfit scheduling and production control but they need to be improved within the context of the system as a whole, hence the inclusion of master planning and structural scheduling. Evaluating and reorganizing outfit work and the development of metrics for outfit work content are likely to be part of this effort. The responsibility to improve their systems clearly lies with the shipyards. However, as recommended in Part 1, it would be possible to assist by producing a model planning framework that would provide guidance to the best shipbuilding approaches. The framework could include:

1. The overall planning process.
2. The development of the vessel design and approvals.
3. Exploitation of the full capabilities of design modeling software with respect to planning and scheduling.



4. The organization of the planning and scheduling function including manning levels.
5. Sequencing planning and scheduling to include time fences and design freezes.
6. Planning and scheduling outputs.
7. The organization of production to facilitate effective planning.
8. Work content measures, especially for outfit.
9. Progress monitoring.
10. Data collection.
11. Tools and systems, including simulation.

## **7.6 Manpower and the organization of work**

GSIBBS Part 1 identified the reasons why the first-tier yards lagged behind the international large yards. These included:

1. There is often a high level of trade demarcation.
2. There is limited flexible working between the trades.
3. Limited use is made of multidisciplinary teams.
4. Only a small number of yards have managed to successfully implement area management through the whole organization.
5. Re-training for flexibility is not widespread.
6. Employment levels are relatively unstable (but this is improving).

Part 1 also pointed out that successful implementation of best practice requires the full cooperation of the workforce and the unions. It was also suggested that the government and Navy could assist by working in partnership with the industry to smooth demand in order to provide more stable employment. This in turn would allow the yards to focus more on the wellbeing and long-term development of their employees. The boom and bust in the technical areas was also of particular concern.

The situation is similar in the mid-tier yards except that they do not generally have problems with trade demarcation and restrictive practices. Also, the workforce tends to be more flexible and retraining for flexibility is common. In general, the mid-tier yards should improve the organization of work into workstations, fully implementing zone by stage outfitting techniques, introducing area management into the later stages of production, and reorganizing engineering on the basis of ship zones. The level of trade flexibility required depends on the balance of work between the trades and this will vary from yard to yard.



## 7.7 Module building and pre-erection outfitting

Module building<sup>5</sup> and pre-erection outfitting<sup>6</sup> are important because both these techniques transfer outfitting work away from the ship to more cost-effective earlier production stages. With a few exceptions, the extent of module building in U.S. yards is disappointingly low. In the first-tier yards, this was largely attributed to building legacy designs where the vessel design did not incorporate outfit modules. However, in the mid-tier yards, the frequency of new designs provides more opportunity to incorporate outfit modules in each new design. Unfortunately, few yards are familiar with the spatial design techniques that make module building efficient and effective.

Although there are some notable exceptions, the low level of pre-erection outfitting achieved is also disappointing. As with module building, the frequency of new designs presents an opportunity to design for pre-erection outfitting but the design process must produce the technical information in time to use the technique effectively on a short build series of vessels. Although most yards have the CAD tools to do this, generally the design techniques need to be developed to facilitate this. Again the proposed solutions are similar to those proposed in GSIBBS Part 1, and are:

1. Carry out training and familiarization of design, planning and production personnel to increase the understanding and to quantify the savings from advancing outfit to earlier build stages.
2. Develop the production engineering process; incorporating product analysis, process engineering, methods engineering and industrial (facilities) engineering, to provide the design process with specific design for production guidance.
3. Encourage funding of purpose-designed module building facilities or other facility developments that would facilitate a higher level of advanced outfitting.
4. Investigate the feasibility of regional module assembly facilities. This could be based in an existing yard which would serve others, or be a joint venture between yards.

## 7.8 Outfit installation and onboard services

With regard to the installation of outfit onboard, low levels of module building and pre-erection outfitting have the consequence of pushing outfitting work to the more costly onboard stage. In addition, the lack of a zone-by-stage outfitting methodology and lack of area management makes the co-ordination of the various outfitting trades more difficult to manage. Excessive onboard outfitting is often characterized by too much staging, poor housekeeping and workers competing for limited working space. As this is one of the most expensive stages of construction, it is primarily important to minimize the work done at this stage through a build strategy that maximizes pre-erection outfitting and module building, and then to effectively organize the outfit work that remains. Part of this is the provision of onboard services. Best practice for onboard services involves accurate and detailed planning and organization combined with very good housekeeping. Ship systems should also be used wherever possible, although this is not always an option for naval construction.

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<sup>5</sup> The assembly of functionally-related outfit components onto a steel frame.

<sup>6</sup> The fitting of outfit components and assemblies onto structural blocks prior to erection at the construction point.



Improving the organization of onboard outfitting and services is simply a management issue. Planning support is necessary, however, and some changes are required to the organization of work which are discussed in previous sections. There is guidance on these topics available from NSRP so it is suggested that this material is reviewed prior to developing additional industry-wide guidance. It is also proposed that naval restrictions on the use of the ship's systems to assist with the construction of the ship be reviewed.

## **7.9 Dimensional accuracy and quality control**

Since the early 1980s, NSRP has done much work on accuracy control (AC) and quality control (QC), as have Professor Storch and others more recently, but there is still a disappointing low level of implementation. Although there are examples of good implementations in the U.S. industry, there is a wide range of benchmarking scores and the averages significantly lag behind the international mid-tier yards and the U.S. first-tier yards. A lack of understanding of the benefits of AC often gives it a low priority and it is not generally recognized as being a key aspect of performance improvement. This is in complete contrast to leading yards. There is also a general acceptance of rework, such as removing excess material and distortion removal in the assembly processes, as being an inherent part of the shipbuilding process. A prerequisite to good accuracy control is good workstation organization and the two aspects should be addressed together. The solutions proposed in Part 1 are also relevant to the mid-tier sector and these are:

1. Promote awareness of the true costs of non-added-value work through training, seminars and workshops for all levels of the workforce.
2. Fully implement the AC control techniques that have been developed by the industry over the last 25 years.
3. Promote the use of statistical analysis as an intrinsic part of the performance improvement process.

It is also suggested that a compelling cost/benefit analysis is developed in the hope that this helps to break the historical resistance to investment and implementation.

## **7.10 Outfit parts marshalling**

The approach to outfit parts marshalling varies widely in both the international and U.S. yards but the average score is considerably lower in the U.S. yards. There is a tendency in all these yards, which are focused on minimizing overhead cost, to place the responsibility for outfit parts marshalling onto the supervisors or, in some cases, onto the tradesmen themselves. This may be appropriate in the smaller mid-tier yards; however, it is clear that the leading yards do everything they can to make the necessary material available to the tradesmen at the work place at the right time. This inevitably requires an outfit parts marshalling system that:

1. Palletizes kits of ship-specific parts by work package.
2. Kits the parts for multiple-systems.
3. Ensures that the kits contain 100 percent of the parts that are not available line-side.



4. Delivers the kits to well-defined delivery addresses throughout the yard and onboard.
5. Ensures that kits are pulled into production based on requirement rather than being pushed by planning.

The material control software operated by most shipyards could probably support this activity but it would be best if it were developed alongside the approach to planning and parts listing. Again this is considered to be a matter for the individual shipyards and no industry-wide collaborative initiatives are proposed.

### **7.11 Coding systems**

With an average score of 2.6, the U.S. mid-tier yards lag behind the international average score of 3.0; however, some U.S. yards lead the international yards. Although there are examples of industry-leading coding systems in the U.S., most yards have basic parts identification codes that do not support automated data extraction from CAD systems, facilitate data sharing between systems or result in the design of a rationalized set of interim products. As such, opportunities are being lost to reduce technical work content and automate downstream processes such as the generation of production information, work package information, workstation loadings and workstation and build progress accounting. To be effective, the coding system must embrace all areas of ship pre-production and production operations. Only in this way can the various databases within a shipyard be effectively and efficiently utilized without extensive manual intervention.

Each yard should adopt a standard, hierarchical coding system that enables the clear definition of parts, interim products, product family types, steelwork and outfit systems, and shipboard zones. The cost of developing such coding structures and implementing the systems can be a barrier for some of the smaller yards. Therefore, it is recommended that the industry cooperates to develop a consistent, relational coding structure that can be independently developed into a yard-specific coding system.

As proposed in GSIBBS Part 1, an industry-wide common coding structure would best support an acquisition strategy characterized by a lead shipyard designing a vessel that will be built in whole or in part by several other shipyards. This initiative would also serve as a framework to facilitate industry-wide cooperation.

### **7.12 Block assembly**

There is a wide variation in the approach to block assembly throughout the mid-tier sector, both in the U.S. and international groups. The average in the international group is a little higher. Leading shipyards are characterized by the following:

1. Block assembly is seen as an opportunity to reduce work content at the construction point.
2. All ships have a natural block breakdown which facilitates early outfitting and allows short crane hanging times at the construction point.
3. Blocks are assembled and outfitted undercover in purpose-designed workstations.



Some U.S. mid-tier yards have made good use of the block construction method and are achieving close to best practice, particularly on superstructure blocks. However, in others there is little or no use of the concept. Some yards have grown to a size where block assembly is appropriate but they have not modified their approach; others consider it inappropriate for the size of vessel in their current product mix. Where block assembly is undertaken in mid-tier shipyards, however, significant cost and cycle time gains result.

For yards that do not have dedicated block assembly facilities or have facilities that are not adequately supported, the rationale for investments that improve productivity at the construction point (e.g., undercover facilities with integral workshop, stores and amenities), and those that bring work forward (e.g., dedicated block assembly and outfitting facilities) varies from yard to yard. Thus the issues in block assembly are principally related to yard-specific process development and facilities investment and no industry-wide actions are proposed.

### **7.13 Shipyard incentives**

Shipyard incentives in naval building were discussed in GSIBBS Part 1. The principal points made were:

1. An effective way to improve shipyard performance, reduce cost and provide a climate for investment is to stabilize the naval procurement program as this will create an environment conducive to investment and performance improvement.
2. One of the keys to encouraging performance improvement in the industry is to build appropriate incentives into contracts.
3. Ideally, contractual incentives focused on performance improvement should promote profitability through higher efficiency and should not reward the shipyard for simply spending more man-hours.
4. Profit limitations imposed on the contractor are considered to be a barrier to formulating effective incentive schemes because, ultimately, the only way for a shipyard to make more profit is to spend more man-hours.
5. As a general principle it was suggested that it is far more effective to improve shipyards by creating an appropriate commercial environment rather than becoming involved in their day-to-day management.
6. Incentives, including agreed rates of annual performance improvement are likely to form a more important part in guaranteeing good value for money in the future.

These points are equally applicable to naval construction in the mid-tier sector. However, an additional point is that some yards clearly find the cultural shift between commercial and naval shipbuilding to be seriously demotivating. This is mainly because they feel that they are required to take actions which they believe to be wasteful of money and/or time. Although the shipyards are not subject to the full force of international competition in the commercial sector, competition within a limited Jones Act market appears to be providing good motivation for the mid-tier yards to improve performance. However, it is questionable if this will be sufficient to achieve international competitiveness in a broader range of market sectors.



## 7.14 Support for performance improvement

A number of government-sponsored initiatives have provided industry with information and financial assistance to support performance improvement efforts. In general the initiatives have two main drivers at their core. The first is to reduce the cost of naval shipbuilding and the second is to continue providing employment in local areas. As the first-tier yards have been building most of the naval vessels and employ the majority of people in the industry, they have been the main focus of most of these initiatives. While the mid-tier yards have also benefited, it is surprising to see that not all mid-tier yards are actively involved in performance improvement initiatives such as those sponsored by NSRP. The mid-tier shipyards are now well represented on the NSRP Executive Control Board which should further encourage these yards to take part.

At a national level, in addition to NSRP, the Office of Naval Research, ManTech and the Center for Naval Shipbuilding Technology provide assistance. There are also several local programs addressing specialist areas. Provided they are properly funded, there appears to be sufficient support for industry performance improvement. However, the efficiency of this assistance could be improved through overall coordination of the activities. The shipyards that have an overall long-range performance improvement plan and have used these programs to provide assistance to move through the plan step by step, have achieved the most benefit from them. As suggested in Section 7.1, it is recommended that future assistance be made in the context of an individual shipyard performance improvement plan.

## 7.15 Cost benefit

The degree of benefit the government would accrue as a result of the improvements proposed will clearly depend on the value of government work placed in the mid-tier yards in the future. Although this is likely to increase substantially as the LCS program progresses, as stated in Section 2.1, over the last five years about 25 percent of the output, in terms of CGT, has been for the government (this typically represents about 7 percent of the government output of the first-tier yards). Therefore, in addition to reducing government costs, the improvements will reduce the cost of U.S.-built commercial vessels which will stimulate demand. In addition to the direct cost reduction in labor and materials that would occur, there would be a significant improvement in cycle time which could substantially reduce the overhead charges accrued by each vessel constructed.

Assessing the cost and benefit of the proposals to improve the industry is a complex problem that should ideally be the subject of separate further analysis. In GSIBBS Part 1, a high level estimate of the benefit to government was made by considering the savings that would occur in the five principal areas that the study recommendations were focused on. The potential savings have not been estimated in Part 2. The focus areas, which are listed in Table 7.3, are the same for the mid-tier yards, and appropriate mid-tier targets have been proposed in the table together with comments on the relative cost of making changes.

It is important to note that as the top ten priority areas listed in Section 7.2 are similar in both the mid-tier and first-tier yards, any initiatives to make improvements will be applicable to both.



Focus area	Targeted change	Relative cost of achieving targets
Increase the use of best shipbuilding practices	0.5 to 1.0 increase in best practice rating depending on the yard and the product focus	It will be possible to improve the use of best practice with low capital expenditure in 4 elements, a modest expenditure in 24 elements and relatively high expenditure in 22 elements. Therefore, to fully close the technology gap, capital expenditure will be required.
Make more effective use of the technology employed	The yards are already quite effective but 5% improvement in effectiveness of shipbuilding practices employed should be possible	Generally this is low cost as it relates to the organization and operation of the shipyard. Initiatives in this area will include such things as lean manufacturing.
Optimize ship designs to reduce work content in U.S. naval vessels	U.S. naval vessels generally have more work content than equivalent international vessels. Target is to reduce work content by 15%	In a commercial yard this would be a relatively low cost initiative but as this will involve naval vessels and the various facets of the DoD, the cost of achieving this could be quite high.
Reduce customer factor	This has been estimated to be 10% to 15% on U.S. conventional naval vessels. Target is a reduction to 5% to 10%	This will require a complete review and reconfiguration of naval acquisition processes and practices. The cost of achieving this could be quite high.
Reduce first-of-class performance drop-off	This could be as high as 50% in some yards. A reduction to 25% should be possible.	Making these changes will require initiatives in the shipyards and a change of approach in the Navy. Substantial gains could be made for relatively low cost.

**Table 7.3 – Improvement targets and relative cost**



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## **APPENDIX 1 – ODUSD(IP) AND CNST**

### **The Office of the Deputy Under Secretary of Defense (Industrial Policy)**

The Office of the Deputy Under Secretary of Defense (Industrial Policy) is part of the U.S. Department of Defense. ODUSD(IP) ensures that an adequate defense industrial base exists and remains viable for defense production to meet current, future and emergency requirements. The office also advises the Under Secretary of Defense (Acquisition, Technology & Logistics) on defense industry mergers, acquisitions and consolidation. This includes global investment in U.S. defense firms and other related globalization topics. The office also counsels Defense Acquisition Boards on industrial base and production readiness issues. Further information is available on the internet at [www.acq.osd.mil/ip](http://www.acq.osd.mil/ip).

### **The Center for Naval Shipbuilding Technology**

The Center for Naval Shipbuilding Technology (CNST) is the Navy ManTech Center of Excellence for shipbuilding and ship repair manufacturing technologies. The CNST mission is to identify, develop and deploy advanced manufacturing technologies in U.S. shipyards that will reduce the cost and time it takes to build and repair Navy ships. ATI in Charleston, SC, manages CNST under a contract with the Office of Naval Research (ONR). Further information is available on the internet at [www.cnst.us](http://www.cnst.us).



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## APPENDIX 2 – CUSTOMER FACTOR

This appendix is a repeat of Section 3.2 of the GSIBBS Part 1 report.

The customer factor was estimated by analyzing shipyard data and by interviewing shipyard managers. The industry provided a limited amount of data necessary to carry out a numerical analysis for naval auxiliaries. The man-hours spent in each area of the shipyard were expressed as a proportion of the blue collar man-hours for a range of commercial vessels and a range of naval vessels built by the same shipyard. The average proportions for the commercial and the naval vessels were then compared to determine if there were any consistent differences between the two sets of data. Significant differences in the effort required were found in the following areas:

- Engineering not associated with first-of-class design
- Administration
- Master planning
- Industrial engineering
- Program management
- Material procurement and warehousing
- Production and support services
- Quality assurance

The interviews explained some of the reasons for the differences. They were also used to verify the order of magnitude of the differences indicated by the calculation. In addition to the requirements placed on the shipyard relating directly to the design and construction of the vessel, a disproportionate amount of effort is required to deal with the number of people involved in the acquisition process, the number of reviews and reports required, and the effects of such things as integrated logistics support (ILS), Federal Acquisition Regulations (FAR), Prime Contracts Flow Down, material procurement, International Trafficking in Arms Regulations (ITAR) and the Truth in Negotiating Act.

The analysis concluded that there was an increase of about 10 percent in man-hours for naval auxiliaries. A customer factor of 1.1 has therefore been assumed for these vessels. The factor appears to increase with vessel complexity and function. The higher the level of classification, the higher the factor tends to be. The shipyards provided no data that could be used to calculate customer factor for surface combatants, submarines or aircraft carriers. However, based on experience in the UK and comments made by shipyards and NAVSEA, it has been assumed that the factor for surfaces combatants is 15 percent. However, this may be a relatively conservative estimate. The factor is likely to be higher for submarines and aircraft carriers.



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### **APPENDIX 3 – USE OF BEST PRACTICE IN U.S. SHIPYARDS**

This appendix is only available in the full report, for which distribution is limited to the participating shipyards, CNST and authorized Government agencies.



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## APPENDIX 4 – THE FMI BENCHMARKING SYSTEM

### 1 INTRODUCTION

As is well known, benchmarking is a tool by which a company can compare its practices with those of others to determine its strengths and weaknesses with a view to improving performance.

There are several ways to do this. Perhaps the most simple is to visit another company and review its practices. Proprietary benchmarking systems, however, provide a more structured approach which generally makes a comparison against a scale of reference. Some systems can be applied to industry in general; others are more specific.

The First Marine International (FMI) benchmarking system is shipyard specific and provides the foundation for developing a performance improvement program that has the following steps:

1. Evaluate the applied technology and practices against international best practice.
2. Assess the shipyard's current best practice rating.
3. Identify the gaps and imbalances in the applied technology.
4. Establish the shipyard's current performance and competitive position.
5. Identify the areas that require attention if overall performance is to be improved.
6. Determine product focus and required performance through market analysis.
7. Set future performance targets.
8. Define the overall characteristics of the shipyard that will allow it to compete in chosen markets.
9. Describe the processes and practices that will yield the required performance.
10. Generate a prioritized performance improvement plan.

Formulating a performance improvement plan using this methodology ensures that the plan is driven by market requirements and that the shipyard has adopted appropriate processes and practices to succeed in its chosen markets, hence the term "Market-Led Benchmarking".

The benchmarking system has been applied in more than 150 shipyards world-wide and has formed the basis of industry studies in the US, Japan, South Korea and Europe. This provides a significant database.

This document explains the system and explains what is involved in a full benchmarking study.



## 2 THE SYSTEM ELEMENTS

The FMI system is applicable to shipbuilding, ship repair and conversion. Different elements of the system are used in each case and where a yard is involved in more than one activity, shipbuilding and repair, for example, an appropriate mix of elements is employed.

The table below shows the groups of elements available in the FMI benchmarking system and how they relate to each sector.

Section	Sector	Group	Number of elements
A	Shipbuilding	Steelwork production	11
B	Shipbuilding	Outfit manufacturing and storage	6
C	Shipbuilding	Pre-erection activities	6
D	Shipbuilding	Ship construction and outfitting	7
E	Shipbuilding	Yard layout and environment	2
F	Shipbuilding	Design, engineering and production engineering	9
G	Shipbuilding	Organization and operating systems	9
H	All	Human resources	8
I	All	Purchasing and supply chain	10
J	All	Marketing	7
K	Repair/conversion	Commercial	8
L	Repair	Production infrastructure and equipment	8
M	Conversion	Production infrastructure and equipment	3
N	Repair	Production methods	9
O	Conversion	Production methods	11
P	Repair	Organization and operating systems	4
Q	Conversion	Organization and operating systems	2
R	Conversion	Design/technical	9

**Table A4.1 – Groups of elements**

The benchmarking system describes five levels of use of best practice in each element of each group. An example of the description of the levels in one of the human resources elements is shown in Table A4.2.



Level	Description
1	<i>No formal training plan or budget. Training is mainly in response to requirements of regulation or legislation and is carried out only as required. Skills' training is ad hoc and limited in scope and employees follow no specific training program.</i>
2	<i>The shipyard recognizes the benefits of training and has gone some way to putting a training scheme in place for new employees. This may not include off-the-job training and is likely to involve the trainee being assigned to a skilled man for training on-the-job. Responsibilities for training have not been formally assigned within the management team.</i>
3	<i>Apprenticeship scheme, or equivalent, in place. Some skills training for mature shop floor workers and management training for supervisors but probably no middle and senior management training. Small training budget. Probably some students and graduate trainees on site. Management responsibilities for training identified and assigned. Regular formal appraisals of employees and required areas for improvement identified.</i>
4	<i>Skill requirements defined in the business plan. Individual training needs analysis carried out for each employee to ensure that the overall business requirements are met. To some extent learning is self-directed. Employees are released from normal duties for training purposes. Training materials and library available on site. Appraisals lead to identification of specific training needs and a personal action plan.</i>
5	<i>More than 5% of each employee's time devoted to training, with strong emphasis on quality. Structured post-training assessment and evaluation procedures in place. Continuous personal development of all employees is company policy. A high proportion of learning is self-directed, with support from the management team.</i>

**Table A4.2 – H2: Training and education policy**

In broad terms, the levels of use of best practice correspond to the state of development of leading shipyards at different times over the last forty years. Those yards that are less advanced remain at the level of technology of an earlier period. On the basis of interviews and inspections carried out during the survey, a “level of technology” mark is assigned to each element. These are aggregated, first, for the individual groupings, and second, for the whole yard.

Each element reviewed is rated according to the description that most closely matches its situation. If it falls between two descriptions, an intermediate mark is given, leading to nine possible scores: 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5 and 5.

It is important to note that the higher levels of technology are not intrinsically “better”. The highest technologies often imply a high capital cost and, where wage levels are low or savings limited, their application may not be appropriate.

Many shipyards do not need to score 5 to be competitive. The important thing is to have an appropriate balance of technology across all of the elements at the level dictated by the shipyard's cost base and target market. In general, having isolated areas at a significantly higher level than others is not good. The adjacent areas may not adequately support the higher technology areas and thus the investment in the high technology areas alone may not yield the intended benefit.



### 3 LEVELS OF TECHNOLOGY

The broad definitions of the levels of technology relating to shipbuilding are as below. The same principles apply to the ship repair and conversion yards.

**Level 1:** reflects shipyard practice of the early 1960s. The shipyard has several berths in use, low capacity cranes and very little mechanization. Outfitting is largely carried out on board ship after launch. Operating systems are basic and manual. In summary, the yard is characterized by the most basic equipment, systems and technologies and outdated ways of working.

**Level 2:** is the technology employed in the modernized or new shipyards of the late 1960s and early 1970s. There would be fewer berths in use, possibly a building dock, larger cranes and a degree of mechanization. Computing would be applied for some operating systems and for design work. Level 2 is better than basic but is significantly below world industry norms.

**Level 3:** is good shipbuilding practice of the late 1970s. It is represented by the new or fully re-developed shipyards of that time in the U.S., Europe, South Korea and Japan. There would be a single dock or level construction area with large capacity cranes, a high degree of mechanization in steelwork production and more extensive use of computers in all areas.

**Level 4:** refers to shipyards that have continued to advance their technology during the 1980s and 1990s. Generally a single dock, with good environmental protection, short cycle times, high productivity, extensive early outfitting and integration of steel and outfit, together with fully developed CAD/CAM and operating systems. Level 4 is better than industry averages but not up to leading standards.

**Level 5:** represents state-of-the-art shipbuilding technology. It is developed from level 4 by means of automation and robotics in areas where they can be used effectively, and by integration of the operating systems, for example, by the effective use of CAD/CAM/CIM. There would be a modular production philosophy in design and production. The level is also characterized by efficient, computer-aided material control and by fully effective quality assurance. In summary, state-of-the-art use of technology and industry-leading business processes, facilities, systems, management and workforce.

The marking of each element is based on a combination of what the consultants/assessors see (e.g., activity on the shop floor or examples of planning and engineering outputs) and what they are told. The scoring system does not necessarily reflect effectiveness or productivity, except that level 5 is concerned with the effectiveness of the technology in use, as well as the hardware and software in place.

### 4 OVERALL PERFORMANCE

The overall measure of financial competitiveness used for shipbuilding yards is break-even cost per CGT. In this case, break-even cost is defined as the amount of income that the yard needs to break even after it has purchased equipment, materials and other bought-in items. Man-hours per CGT are used as the overall measure of productivity. The man-hour calculation includes hours spent by all direct and indirect staff and employees who contribute to the shipbuilding effort.



These measures allow the performance of individual shipyards to be compared even though they may be building different types and sizes of ships. They also allow the performance of a yard to be easily related to the current and future requirements of the market.

CGT is a normalized measure of work content that is calculated by multiplying the gross tonnage by a factor that is representative of the complexity of the vessel. Ships that have a low level of complexity, such as bulk carriers, have lower factors than more complex vessels such as cruise ships and warships. The system has been developed and refined over more than thirty years by leading shipbuilding organizations under the umbrella of the OECD. Factors have been developed for the main commercial ship types and FMI, working in partnership with the UK MoD, US DoD and international shipyards, has developed factors for naval vessels. However, when a yard has been building unusual vessels, new factors may need to be calculated to support the benchmarking process.

In general, the performance assessment is based on aggregated output over a three-year period. However, in some cases, it is not possible to do this and the performance achieved on an individual ship is calculated and taken to be representative of the performance of the yard as a whole.

As performance measurement based on CGT is inappropriate for ship repair and conversion, overall performance for these sectors is expressed in terms of a number of measures that relate to a yard's competitiveness and profitability. The choice of measures is influenced by the availability of data for comparison purposes. The measures address output, enquiry response times, customer service, tariffs, manpower issues and overall profitability. They include such factors as:

- labor cost
- charge-out rate
- time taken to prepare bids
- cost of carrying out various routine work
- time taken to carry out routine work
- key financial ratios
- utilization of manpower
- output
- delivery reliability
- quality
- customer satisfaction
- time taken to prepare invoices
- ability to keep within budget



## 5 THE BENCHMARKING SURVEY

An FMI team will visit the shipyard to gather data and assign the benchmarking scores. Individual members of the team visit the relevant offices and facilities and interview department or area managers and/or their nominated representatives. Some of the interviews are done while walking around the yard, others are office based. Interviews may last up to thirty minutes per element, depending on the subject.

The yard is sent a proposed timetable prior to the visit together with a description of the scope of each survey element and a suggestion of the person in the shipyard the team would like to discuss the element with. The survey normally begins with a short presentation on the project (about forty minutes including discussion) to senior managers and other appropriate staff. This is followed by a guided tour of the facility that allows the team to orient itself, before splitting up to carry out the individual interviews.

A confidential questionnaire is used to collect the information required to calculate the overall performance of the shipyard. The yard usually completes this in advance of the survey so that the team can collect it while they are in the yard. In some cases it is necessary for the yard to complete an additional questionnaire that will allow CGT factors for unusual ship types built by the yard to be validated.

The survey normally takes one or two days with a team of two to four people depending on the size of the yard. Subject to receiving the required information in good time, FMI submit the benchmarking report within three to four weeks of completing the visit.

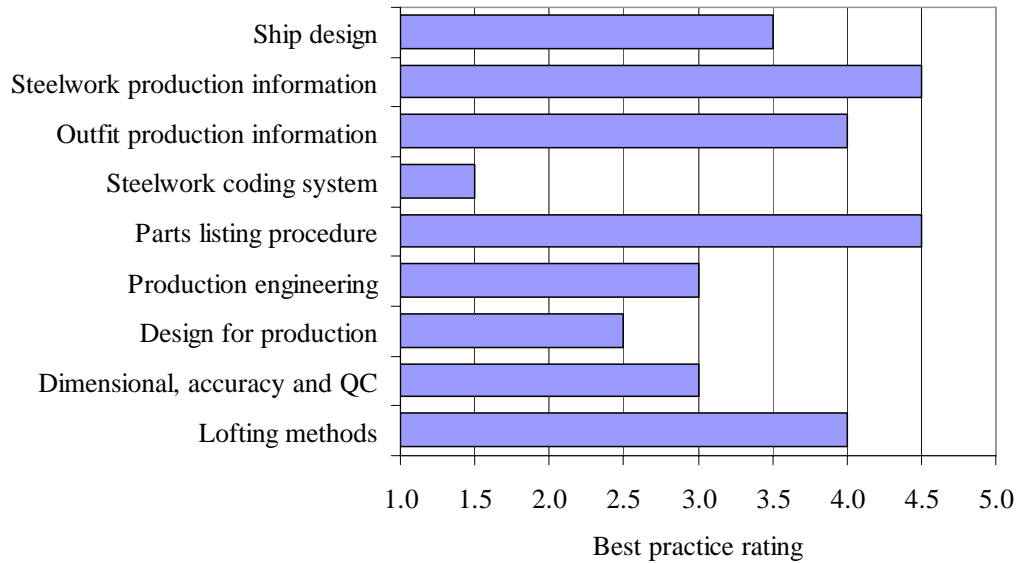
No information acquired by FMI relating to the shipyard is disclosed to any other party and the shipyard report is considered to be wholly company confidential.

## 6 THE SURVEY REPORT

Clearly the contents of the report are dependent on the scope of work carried out by FMI. However, the benchmarking survey report usually combines graphical representations of the survey results with commentary on the processes used. Typically the report contains:

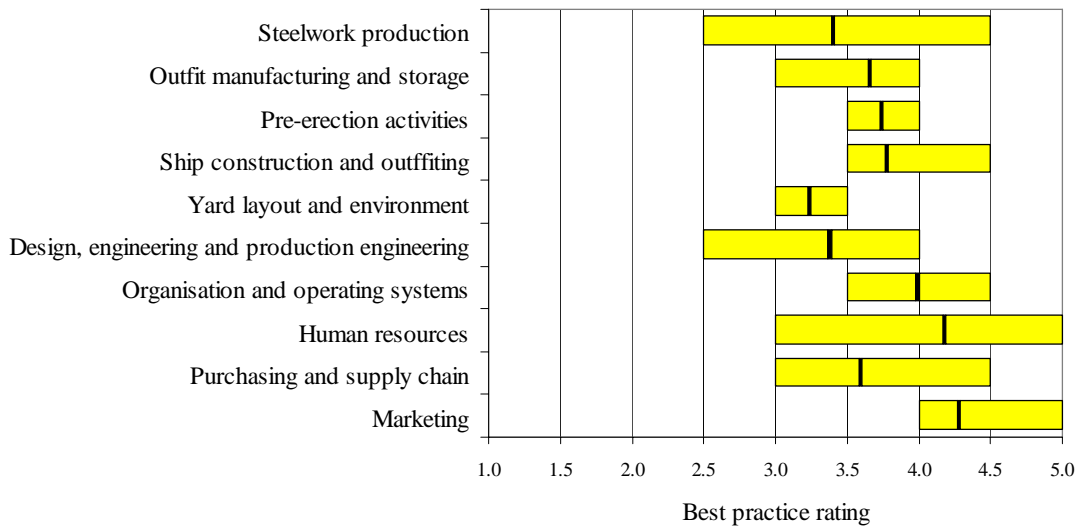
1. Best practice rating by individual technology element, organizational area, and overall.
2. Overall performance in terms of man-hours per CGT and cost (\$) per CGT.
3. A short written interpretation of the results.
4. Comparison between the yard's best practice / performance rating against international standards.
5. Suggestions for improvements that will yield benefit in the short term.

If appropriate, the yard is positioned on the graph shown in Figure A4.3. The graph used to present the benchmarking scores is shown in Figure A4.1 below. This is an example for the Design, engineering and production engineering group.



**Figure A4.1 – Presentation of the results for one group of elements**

The strengths and weaknesses in the use of best practice and the balance across the group can be clearly seen from this representation. Figure A4.2 shows a typical example of the results across all the groups in a shipbuilding yard.



**Figure A4.2 – Presentation of the results for all groups**

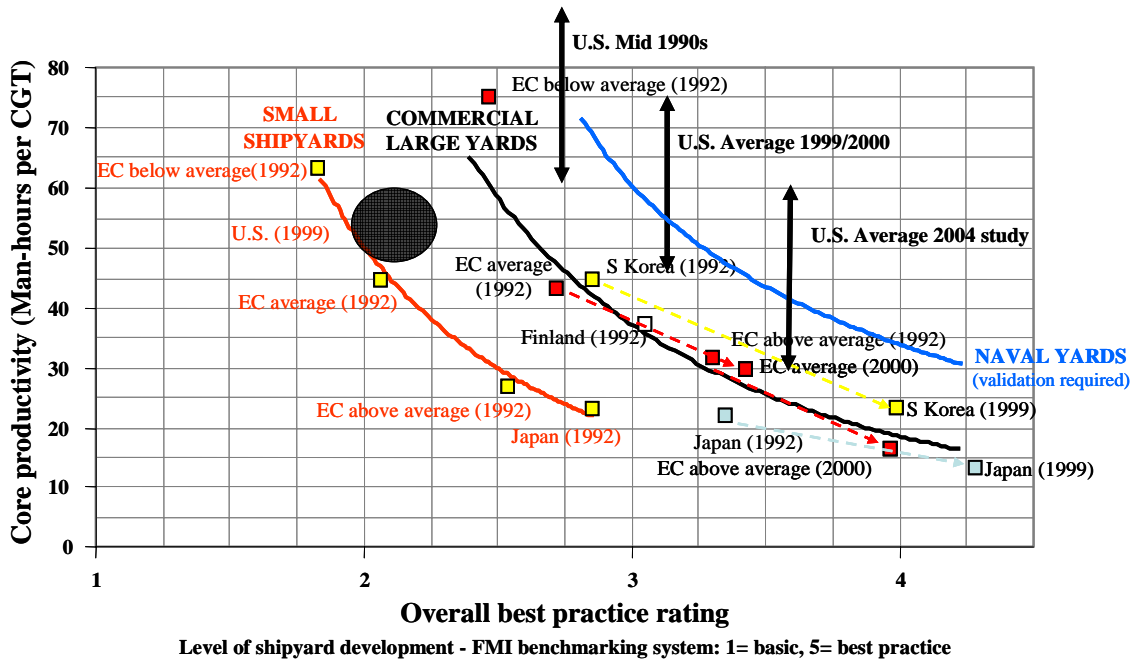
The results of the technology survey in terms of level of use of best practice in each group of elements and the differences between the groups can be clearly seen. For each group, the left end of the bar gives the score of the lowest scoring element(s) and the right hand end of the bar gives the score of the highest scoring element(s). The thick vertical line is the average score of all elements within the group.



Previous benchmarking studies have shown that the shipyards making the most effective use of their applied technology and having high levels of performance tend to have a similar use of best practice across all groups. Furthermore, the range of use of best practice applied within each group tends to be quite low.

## 7 BEST PRACTICE AND PROFITABILITY

Past competitiveness studies have established a correlation between use of best practice, output performance and profitability. One of the most thorough of these was the 1992 EC Study of the Competitiveness of European Shipyards carried out by KPMG (UK) and FMI. This study proposed that each yard must maximize its use of resources by ensuring that it is using best practice as appropriate to its size, type and individual business objectives. The research program and analysis demonstrated the link between the use of best practice and output performance. The results are shown in the figure below, together with the results from subsequent studies.



**Figure A4.3 – International competitive performance**

The figure shows that there is a different relationship between the use of best practice and overall performance for shipyards operating in different market sectors. In general terms, for a yard to be competitive it must be operating close to and below the line relating to its sector. The naval builders' line still requires validation and is the subject of on-going work.

The 1992 study also showed a clear relationship between use of best practice, performance and profitability. Although this table relates to newbuilding, the principle applies also to ship repair and conversion.

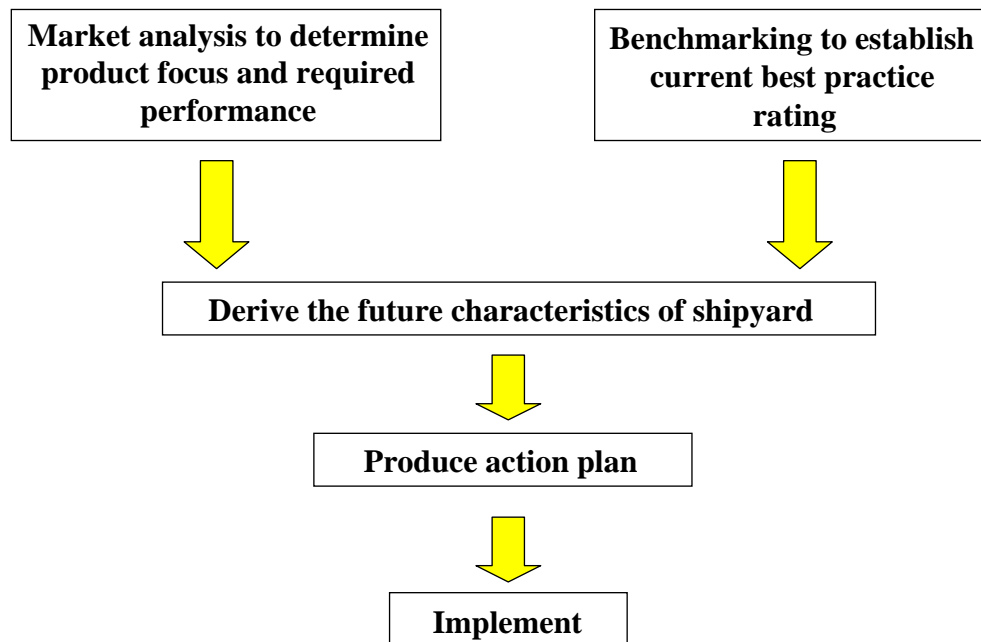


Shipyards type	Best practice measure	Performance measure	Profitability measure
EC Above average	117	150	91
EC Average	96	105	70
EC Below average	88	65	23

**Table A4.3 – Relationship between best practice, performance and profitability**

## 8 SETTING FUTURE TARGETS

The overall method used to determine the required target performance for a shipyard and define the characteristics that will allow it to reach the required level of performance is shown in Figure A4.4. A key element in this part of the work is the application of relationships, such as those shown in Figure A4.3, which have been derived from the assimilation of data gathered from previous benchmarking studies.



**Figure A4.4 – Overall methodology**

This is an integrated approach with each stage building on the results of the previous stage. Although these modules are complementary, they can be carried out in isolation. FMI is able to provide expertise to assist with all stages of this process. However, some yards choose to carry out part of the work themselves. A description the procedure applicable to shipbuilding is given below. A similar procedure is followed for ship repair and conversion.

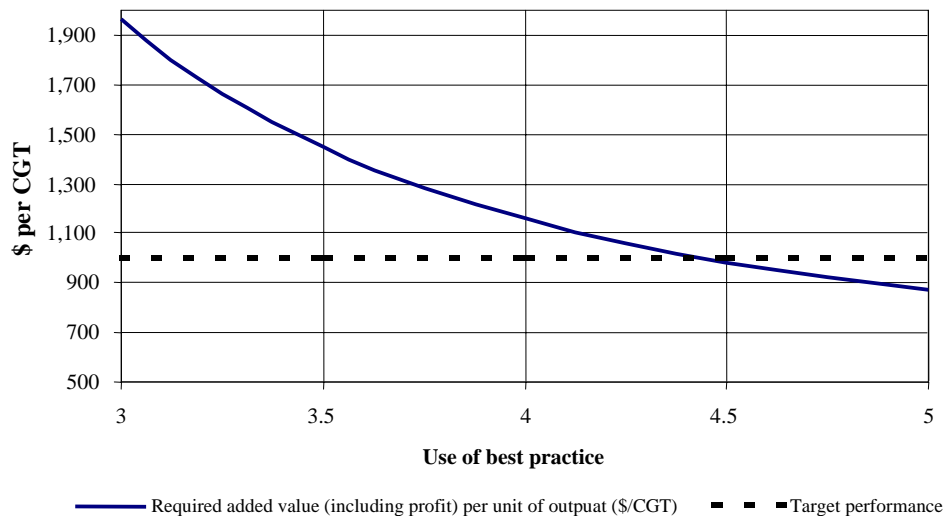


A market study or market review is undertaken to identify a compatible product mix, the prices for ships in target market sectors and hence the levels of performance that have to be achieved to succeed in these sectors. It is essential that the shipbuilding facilities and supporting processes and practices are matched in a technical sense with the chosen market sectors. Choice of technologies and equipment must be clearly related to the size, type and number of ships to be built.

Overall performance targets are specified in the form of added value per unit of work (\$/CGT), where added value is defined as price less equipment, material and other bought-in items and the unit of work used is compensated gross ton (CGT). In effect, this unit specifies the available income per unit of work to cover shipyard labor, overhead and profit.

The benchmarking system is used to establish the current use of best practice and the break-even cost in terms of \$/CGT that is achieved by the yard. The gap between this value and the added value available in the target market is known as the “performance gap”. The objective is to develop and implement a performance improvement program to close this gap and subsequently stay ahead of the main competitors.

The shipyard should be configured to be capable of profitably building the ship in the product mix that has the lowest level of added value (\$/CGT). Using the relationship between the use of best practice and overall productivity shown in Figure A4.3, and the cost structure information gathered from the shipyard, the added value per CGT for incremental changes in the use of best practice is determined. The minimum required use of best practice occurs at the point where the break-even added value that can be achieved by the yard is the same as the added value that is available in the market sector. This is illustrated in Figure A4.5.



**Figure A4.5 – Minimum use of best practice**

The minimum level of use of best practice, required performance, manning levels and high level financial targets are determined by running different product mix and financial scenarios on a computer-based model that takes the following factors into account:



- output
- wage rates
- facility related costs
- operating expenses
- current best practice rating
- current performance
- incremental cost of improving the best practice rating

The gaps between the current levels of use of best practice and the required minimum can be seen by marking the minimum use of best practice onto the results of the benchmarking survey, as shown in Figure A4.6.

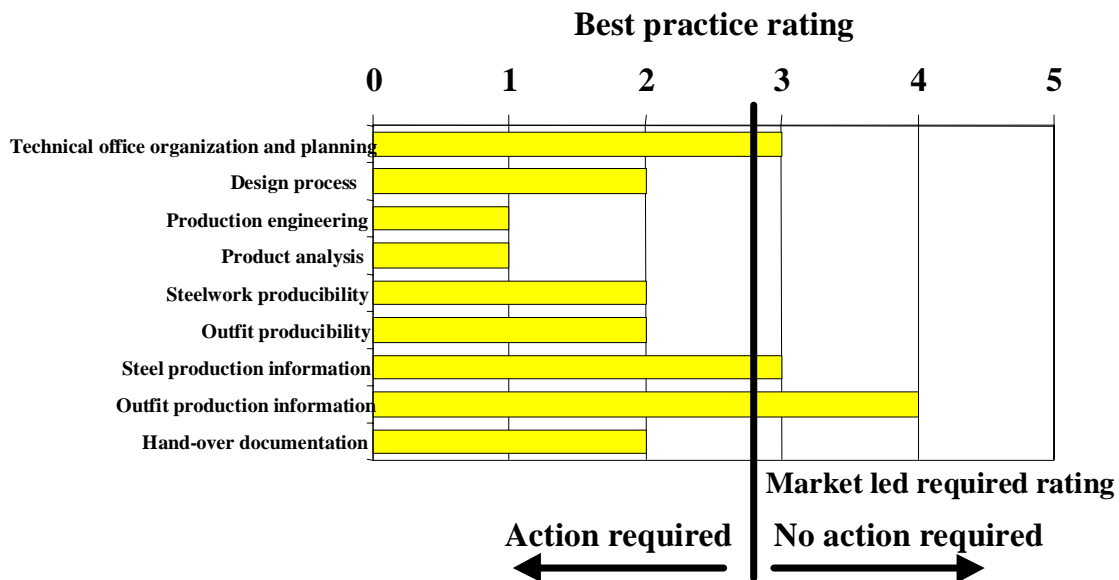


Figure A4.6 – Identifying the gaps in the use of best practice

This identifies the deficient areas of the organization and gives a clear indication of the focus areas for the performance improvement effort.

A description of the processes and procedures that will yield the required level of performance is then written. This is generated by overlaying the minimum required use of best practice onto the descriptions of the levels of use of best practice in the benchmarking system. This gives an extremely useful high-level indication for shipyard managers of the required physical characteristics of the shipyard and the systems, methods and technology which should be applied in order to reach the necessary performance level. It is also possible to determine target levels of productivity for discrete stages of production.

The next step is to develop a performance improvement program to close the gap.



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## **APPENDIX 5 – GLOSSARY OF SHIPBUILDING TERMS**

The shipbuilding industry is quite diverse in nature and widespread in location, it is therefore inevitable that some terms will be used differently by different people. The glossary is designed to help in this situation.

### **ACCURACY CONTROL (A/C)**

Statistical process control that is focused on reducing rework through the continuous improvement of production processes.

### **ADVANCED OUTFITTING – see PRE-ERECTION OUTFITTING**

### **AREA MANAGEMENT**

The management of the workforce organized by workstation, workshop area and/or onboard zone rather than organized by individual crafts.

### **ASSEMBLY**

The process of joining together items (structural or outfit) prior to erection at the ship.

### **ASSEMBLY, OUTFIT (also OUTFIT MODULE)**

The process, or end product, of joining together outfit items. The end product may also be referred to as an outfit module.

### **ASSEMBLY, STEEL**

The process, or end product, of joining together steel items.

### **ASSEMBLY, STRUCTURAL**

The process, or end product, of joining together structural items.

### **ASSEMBLY, MINOR**

The process, or end product, of joining two or more parts into a product, which will then be joined to other products to form a sub-assembly.

### **ASSEMBLY, SUB-**

The process, or end product, of joining parts and minor assemblies into a product, which will then be joined to other assemblies to form a unit or block.

### **ASSEMBLY, PANEL**

The process of assembling flat or curved plates together with associated stiffening.

### **ASSEMBLY, UNIT**

The process of joining sub-assemblies and parts to form units.

### **ASSEMBLY, BLOCK**

The process of joining units to form blocks.



**ASSEMBLY, GRAND BLOCK**

The process of joining two or more structural blocks. The largest grand blocks may be complete ring sections of a ship.

**ASSEMBLY LINE**

A set of workstations linked by conveyors for the sequential assembly of similar products.

**BLOCK**

An assembly formed by joining together two or more structural units.

**BLOCK BREAKDOWN**

The process, or end result, of determining how a vessel will be subdivided into structural units and blocks.

**BLOCK BREAKDOWN, NATURAL**

The subdivision of a vessel into large structural units and blocks that are self-supporting as far as possible, and which minimize the work content at the vessel construction point. Examples are complete superstructure blocks and, in the case of cargo-carrying ships, blocks that span from one transverse bulkhead to the next.

**BUFFER STORAGE**

A storage area for the products of a workstation before they are transported to the next workstation in their manufacturing/assembly sequence.

**BUILD CYCLE**

The time from start of production (e.g., steel cutting) to delivery for a particular vessel.

**BUILD PROGRAM**

An overall program showing the timing of key events in the build cycle of a vessel.

**BUILD STRATEGY**

A document outlining the overall plan for building a particular vessel. For example, it defines programs, processes and levels of quality and accuracy to be achieved. It is a day-to-day reference for production management and supervision.

**CELLULAR MANUFACTURING (also GROUP TECHNOLOGY)**

A method of organizing production equipment with the goal of producing items from start to finish in one sequential flow in a cell, as opposed to a traditional job shop (functional) arrangement that requires moves and queues between each operation. The cell is considered as one work center for capacity planning purposes.

**CENTRAL PLANNING**

The strategic and tactical phases of planning that are carried out in a centralized location.

**COMPENSATED GROSS TONNAGE (CGT)**

A normalized measure that allows the work content per unit volume of different types of vessel to be compared on the same basis.



**COMPONENT**

Any single item that is vendor furnished rather than shipyard manufactured.

**COMPOSITE DRAWING**

A drawing which depicts, simultaneously, the arrangements of all the individual ship systems within one zone.

**COMPUTER-AIDED DESIGN/COMPUTER-AIDED MANUFACTURING (CAD/CAM)**

The application of computers to facilitate the design, engineering, lofting and manufacturing processes.

**CONSTRUCTION (also ERECTION)**

The process of installing structural and outfit assemblies to form the vessel at the erection or construction site.

**CONSTRUCTION CYCLE (also ERECTION CYCLE)**

The time between the start of construction on the erection site (e.g., inclined building way, land-level facility or building dock) up to the point when the vessel is ready for launch.

**CONSTRUCTION SITE (also ERECTION SITE)**

The inclined building way, land-level facility or building dock from where the vessel will be launched.

**CONSTRUCTION STAGE**

The stage when the vessel is being constructed at the erection site. May also be referred to as the erection stage.

**CONTRACT CYCLE TIME**

The time from contract signing to delivery of the finished vessel.

**CORE PRODUCTIVITY**

The best productivity that a shipyard can achieve with its current processes and practices and a mature design. Core productivity does not include the loss of productivity that occurs early in a series of vessels and is regained through ship learning.

**CURVED PANEL – see PANEL, FLAT or CURVED**

**CUSTOMER FACTOR**

The factor which is applied to the CGT coefficient to correct for additional work content caused by the acquisition processes and practices of a non-commercial customer.

**DATUM LINE**

A reference from which assembly and installation dimensions are measured. The datum relates to water lines, buttocks or hull stations rather than structure.

**DESIGN**

The process of defining the specification or relationship of any part of a vessel. Divided into stages.



**DESIGN, CONCEPTUAL**

The establishment of the overall features of a design to meet functional/mission requirements.

**DESIGN, CONTRACT**

The establishment of the features of a design sufficient to provide the basis of a contractual arrangement.

**DESIGN, DETAIL**

The establishment of the features of a design in sufficient detail to allow parts manufacturing and subsequent assembly and installation to be carried out.

**DESIGN, FUNCTIONAL**

The establishment of the functional features of a design for the purpose of classification and other approval, and complete material specification.

**DESIGN, PRELIMINARY**

The process of defining the specification or relationship of any part of a vessel at an early stage of the ship definition process.

**DESIGN, TRANSITION**

The translation of the features of a design from the system orientation necessary to establish functional performance to a planning unit orientation necessary to establish production requirements.

**DESIGN FOR PRODUCTION**

Design methods that lead to a product design with minimum production costs while satisfying all functional requirements.

**DESIGN LEAD TIME**

The time, nominally between contract award and start of production, available to designers to prepare sufficient information to support efficient production.

**DIMENSIONAL CONTROL (D/C)**

The process of ensuring that parts, assemblies and other components are the correct size before moving to the next production stage.

**ENGINEERING (also TECHNICAL)**

Part of the design organization that develops the detailed design of a vessel up to and including the production information.

**ENVELOPE**

A volume which is sufficient to contain parts of the ship system, or systems, and which can be used to define the location of those parts at the preliminary design stage.

**ERECTION – see CONSTRUCTION**

**ERECTION CYCLE – see CONSTRUCTION CYCLE**

**ERECTION SITE – see CONSTRUCTION SITE**



**FACILITIES**

The buildings, production and materials handling equipment, and other plant and equipment available to the shipyard.

**FAMILY**

A set of parts or assemblies related by geometry and specification, which can be produced by the same workstation.

**FIRST-OF-CLASS (FOC)**

The first in a series of vessels to be built by the same shipyard.

**FIRST-OF-CLASS PERFORMANCE DROP-OFF**

The difference between the estimated or achieved productivity on a first-of-class vessel and the core productivity of the shipyard. It is represented as a percentage of the core productivity.

**FLAT PANEL – see PANEL, FLAT or CURVED**

**FUNCTIONAL SPACE**

A volumetric envelope on a vessel which contains related items from one or more ship systems and which is dedicated to a specific aspect of vessel operation.

**GRAND BLOCK ASSEMBLY – see ASSEMBLY, GRAND BLOCK**

**GROUP TECHNOLOGY – see CELLULAR MANUFACTURING**

**HOUSEKEEPING**

The tidiness and cleanliness of facilities. Housekeeping is one indicator of the quality of production organization.

**INDUSTRIAL ENGINEERING – see PRODUCTION ENGINEERING**

**INSTALLATION ANALYSIS**

Analysis of the zones on the vessel to determine at what stage of production the installation of various outfit items should take place.

**INTERIM PRODUCT**

Any part or assembly that is the output of a workstation, is complete in itself, and the completion of which can be used as a measure of progress.

**INTERNATIONAL GROSS TONNAGE**

International gross tonnage is a measure related to the internal volume of a vessel.

**KEY EVENT PROGRAM**

A program which shows the most significant events between contract award and delivery of a vessel.

**KIT MARSHALLING – see PARTS MARSHALLING**



**LEAD TIME**

The time between an event and another related event, during which all preparation for the second event must take place.

**LEAD TIME, DESIGN – see DESIGN LEAD TIME**

**LEGACY DESIGN**

A vessel design that has not been kept up to date in terms of best production engineering practices and producibility.

**MASTER PLANNING – see PLANNING, STRATEGIC**

**MATERIAL CONTROL**

The process of determining how materials should be marshalled and controlled to ensure that production objectives are realized in an efficient manner

**MATERIAL TAKE-OFF**

The process of identifying and listing the materials, equipment and fittings required to construct a vessel.

**MATURE DESIGN**

When the design of a vessel is sufficiently complete to allow the structural and outfit production processes to start in an efficient manner.

**METAL OUTFIT – see OUTFIT STEEL**

**MINOR ASSEMBLY – see ASSEMBLY, MINOR**

**MODULE – see OUTFIT MODULE, SHIP MODULE**

**MULTI-DISCIPLINARY TEAM**

A team working on the same work package where the skilled team members do not all have the same core skills.

**MULTI-SKILLING**

The use of one employee to carry out tasks that require more than one core skill. The term implies that the employee has been trained accordingly.

**NATURAL BLOCK BREAKDOWN – see BLOCK BREAKDOWN, NATURAL**

**NETWORK**

The representation of a set of logically connected events, or activities, which shows the sequence and interdependence of those events or activities.

**NON-ADDED-VALUE**

A process or activity that does not add value to the product. Typically this includes such as materials handling and transportation, staging and the provision services on board. While these processes or activities are essential in facilitating production, the objective is to minimize them.



**OPERATING SYSTEMS**

Inter-related activities which organize and control the operations of a shipyard.

**OUTFIT ASSEMBLY – see OUTFIT MODULE**

**OUTFIT INSTALLATION**

The process of adding outfit items to the steelwork/structure of the vessel during the assembly stages, or to the vessel at the construction site or after launch.

**OUTFIT MODULE**

An outfit assembly consisting of banks of piping or trunking, or functionally related components and connecting parts mounted on a steel frame, which are assembled off the vessel and then installed in one lift. Especially applicable in machinery spaces.

**OUTFIT SCHEDULING – see PLANNING, DETAILED**

**OUTFIT STEEL**

Non-structural steel/metal parts and assemblies (e.g. ladders, foundations, small hatches, doors, etc.) usually related to outfitting, often outsourced. Also referred to as metal outfit.

**OUTSOURCING (also SUBCONTRACTING)**

The process of buying in manufactured or assembled products rather than manufacturing or assembling them in the shipyard.

**PANEL, FLAT or CURVED**

An assembly of flat or curved plates, together with associated stiffening.

**PANEL ASSEMBLY – see ASSEMBLY, PANEL**

**PANEL LINE**

A mechanized assembly line dedicated to the production of flat steel assemblies (plate panels and associated stiffening).

**PARTS LIST**

A list of all items required to complete a particular work package.

**PARTS MARSHALLING (also KIT MARSHALLING)**

The collection of parts, components and assemblies into sets which meet the requirements of the next production stage.

**PIECE PART**

Product of the preparation or pre-fabrication stage of production.

**PIPE BANK**

An outfit assembly comprising pipes from one or more ship systems mounted on supports, installed on an assembly or at the ship in a single lift.



**PLANNING**

Process of determining the sequence of events in design, production and other shipyard functions in advance of those events occurring.

**PLANNING, DETAILED (also SCHEDULING)**

Short term planning with a time horizon of about two weeks. Planning of events at individual workstations.

**PLANNING, STRATEGIC (also MASTER PLANNING)**

Long term planning, beyond the current order book.

**PLANNING, TACTICAL**

The preparation of an overall program for each contract and a corresponding program for each department.

**PLANNING UNIT**

A steel block (or pair of blocks), large outfit assembly or installation zone. The planning unit is the basis for more detailed planning and engineering activity.

**PRE-ERECTION OUTFITTING (also ADVANCED OUTFITTING)**

The process of installing outfit items during assembly of the structural units/blocks rather than during later stages of construction.

**PRE-FABRICATION (also PREPARATION)**

The initial production process consisting of layout, cutting and forming to create outfit or structural piece parts.

**PRELIMINARY DESIGN – see DESIGN**

**PREPARATION – see PRE-FABRICATION**

**PROCESS LANE**

A group of workstations designed to produce a family or families of products which require similar processes.

**PRODUCIBILITY**

An attribute of a vessel design or product which determines whether or not it can be manufactured effectively with the available facilities.

**PRODUCT ENGINEERING**

The process encapsulated during design and engineering which ensures that a vessel and its constituent parts and assemblies are capable of efficient and economical production within the constraints of the available facilities, equipment and processes.

**PRODUCT FAMILY**

A family of parts or assemblies that may be geometrically different but which require the same production process and are within a similar range of weight and size.



**PRODUCT WORK BREAKDOWN STRUCTURE (PWBS)**

The subdivision of work into logical production categories. These categories organize shipbuilding into discrete products which are used to plan and control production.

**PRODUCTION**

Any aspect of the process of making a vessel.

**PRODUCTION ENGINEERING (also INDUSTRIAL ENGINEERING)**

The application of systematic methods to analyze and determine the requirements of production, to develop production methods to meet those requirements and, in general, to improve the efficiency of production. This includes the integration of design and production.

**PRODUCTION STAGE**

A particular stage of the ship production process.

**PRODUCTIVITY**

The ratio of output to input. Often expressed as a quantity of work achieved for a given expenditure of man-hours.

**QUALITY ASSURANCE**

A system for repeating the required performance on every contract by the use of documented procedures that are known, understood and operated by all personnel. The system can also be used to identify and prioritize performance improvement opportunities.

**QUALITY CONTROL**

A process that ensures products are designed and produced to meet customer and regulatory requirements. This generally relies on a statistical approach involving random sample testing for compliance within margins that ensure the quality of the whole output is acceptable.

**SCAFFOLDING – see STAGING**

**SCHEDULING (also OUTFIT SCHEDULING, STEELWORK SCHEDULING) – see PLANNING, DETAILED**

**SHIP DEFINITION STRATEGY**

A formal document describing the methodology applied by the shipyard for the development of a ship's functional design and production definition. It includes a clear description of each stage in the design and engineering process together with the key decision-making criteria and the format and content of inputs and outputs.

**SHIP LEARNING**

The productivity improvements that a shipyard does or may achieve over a series of vessels that is not transferable to other series. Ship learning does not result in changes to processes and practices that improve core productivity.

**SHIP MODULE**

A complete cross section of a vessel assembled from steel units and blocks and associated items of outfit.



**SHIP SYSTEM**

Set of equipment and inter-connecting service runs which carry out a particular function in the finished vessel.

**SHIPBUILDING STRATEGY**

The formal definition of how the shipyard builds ships. It includes a description of the vessels in the product range, the product work breakdown structure, and the attributes and constraints of the facilities, processes and workforce. It also includes the company standards and a set of design and engineering guidelines.

**SOFT AREAS**

The supporting areas related to the shipbuilding process including planning, design and engineering, purchasing, quality assurance, human resources and marketing.

**SPATIAL ANALYSIS**

The process of defining at the preliminary design stage, a vessel's internal layout as a series of envelopes.

**STAGING (also SCAFFOLDING)**

Upright supports and working platforms giving access to a vessel, internally and externally, during assembly and construction.

**STANDARDS**

Products or processes that are specifically designed to be used many times over. Their purpose is to reduce repetition in the technical process and to enhance production efficiency.

**STICK BUILDING**

The assembly of piece parts and components into a vessel with no intermediate stages of assembly.

**STRUCTURAL SCHEDULING (also STEELWORK SCHEDULING) – see PLANNING, DETAILED**

**SUB-ASSEMBLY – see ASSEMBLY, SUB-**

**SUB NETWORK (also NETWORK or SUBNET)**

A detailed network showing the sequence and dependence of events or activities leading to one particular event or activity on an overall network.

**SUBCONTRACTOR**

An individual or company outside the shipyard which supplies products or services to the shipyard.

**TACTICAL PLANNING – see PLANNING, TACTICAL**

**TECHNICAL – see ENGINEERING**

**TECHNICAL (also DESIGN, ENGINEERING)**

Functions of shipbuilding related to design, engineering and the development of production information.



**TRANSITION DESIGN** – see **DESIGN, TRANSITION**

**TYPE PLAN**

A description of how the shipyard produces a type of vessel or interim product. It includes a consolidated schedule in relative time, and facility and labor utilization.

**UNIT (also STEEL UNIT and OUTFIT UNIT)**

An assembly (structure and/or outfit) forming part of the vessel which will be joined to others to form a block or be taken to the construction site to be joined to the ship under construction.

**UNIT ASSEMBLY** – see **ASSEMBLY, UNIT**

**UNIT BREAKDOWN** – see **BLOCK BREAKDOWN**

**VENDOR FURNISHED INFORMATION (VFI)**

Information supplied to the shipyard by an external supplier or subcontractor.

**WORK AREA**

Any part of the production facilities with a specific function. A group of related workstations.

**WORK BREAKDOWN STRUCTURE (WBS)**

Any method of classifying the tasks involved in a construction project into systematic groupings.

**WORK CONTENT**

The quantity of work in a job. Can be converted to man-hours by applying a productivity ratio.

**WORK PACKAGE**

A given task involving a discrete quantity of material or time.

**WORK STAGE**

The division of the shipbuilding process into a hierarchy of stages of manufacture and assembly. Normally defined by significant change in the size and type of product and the production processes and equipment. For example: part preparation, minor assembly, sub-assembly, unit assembly, block assembly, construction, zone completion, commissioning.

**WORKSTATION**

The physical space or location where a particular type of work is performed. The workstation concept is a direct application of group technology where similar types of work are performed in the same locations allowing for an efficient allocation of workers, time, tools and materials.

**WORKSTATION DRAWING (also WORKSTATION INFORMATION)**

A drawing and/or complete set of work instructions related to a work package for a specific workstation containing only the information needed at that workstation.

**ZONE**

A defined geographical sub-division of a ship.



**ZONE BY STAGE**

The systematic step-by-step process of completing outfitting work onboard a ship.

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