First Marine International

a company of

Royal HaskoningDHV
Enhancing Society Together

2014 US Naval Shipbuilding and Repair Industry Benchmarking

Part 1: Shipbuilding

DISTRIBUTION A
Approved for public release: distribution unlimited

Assistant Secretary of the Navy
Research, Development & Acquisition

9Y1755

18 March 2016

2014 US Naval Shipbuilding and Repair Industry Benchmarking

Part 1: Shipbuilding

CONTENTS

SUMMARY AND PRINCIPAL CONCLUSIONS

This report presents the findings of the 2014 US Naval Shipbuilding and Repair Industry Benchmarking study carried out by First Marine International (FMI). The study is sponsored by the Assistant Secretary of the Navy for Research, Development and Acquisition (ASN(RDA)). The overall objective is to identify actionable items to improve the performance of the US naval shipbuilding and ship repair enterprise and to assess industry progress in improving its practices and processes over the last ten years. This report presents the findings for shipbuilding and provides international comparisons. The findings for ship repair will be presented in a separate document. A third report will identify Government actions that would help to improve industry performance.

Using the FMI shipyard benchmarking system as a basis, this industry report updates the findings of the Global Shipyard Industrial Base Benchmarking Study (GSIBBS) undertaken by the Office of the Deputy Under Secretary of Defense for Industrial Policy (ODUSD(IP)) from 2004 to 2006. The five large and three mid-tier shipyards (the industry) surveyed in 2014 conduct all current US naval vessel construction. They all participated in the GSIBBS.

The industry has improved its application of shipbuilding technology in the ten years since the last survey. The overall average benchmarking score for the eight shipyards in 2004/2006 was 3.3 out of 5.0. In 2014 it has increased by 0.3 to an overall score of 3.6. The increase in performance improvement activity and investment in facilities and equipment, noted in FMI's findings for the GSIBBS, has continued and the benchmarking team was again impressed by the improvements that have resulted from the recent efforts. In some shipyards the change has been small; in others it has been substantial. Considered by sector, the largest improvement has been in the mid-tier shipyards.

Both sectors now have the same overall average benchmarking score as the international shipyards sampled as part of the GSIBBS almost a decade ago and many of the technology gaps apparent at that time have been closed. However, there are important differences in the technology profiles and the international shipyards have also progressed. FMI has, therefore, proposed benchmarking target scores for the US shipyards which account for each yard's product mix, throughput and cost base. They also account for the fact that the US wishes to have a leading, highly efficient naval shipbuilding enterprise. Sixty-nine processes and practices in ten element groups have been included in the study. The average technology gap between the current scores and the targets for each group is shown in Table 1. The table shows that there is still potential to make further improvements in all the technology groups with larger improvement opportunities indicated by larger gaps.

Group	Description	Average technology gap	
		Large yards	Mid-tier yards
A	Steelwork production	0.4	0.8
B	Outfit manufacturing and storage	0.4	0.9
C	Pre-erection activities	0.8	1.1
D	Ship construction and outfitting	0.5	0.8
E	Yard layout and environment	0.4	1.0
F	Design, engineering and production engineering	0.7	0.9
G	Organization and operating systems	0.5	1.2
H	Human resources	0.5	0.7
I	Purchasing and supply chain	0.6	1.4
K	Performance improvement	0.7	1.3

Table 1 – Average technology gaps

An education and skills survey was included to identify workforce skills gaps and potential skills shortages in the US labor pool. The survey found that 96% of the total shipyard workforce has specific role-related qualifications for their current positions. It also identified roles in which experience levels, in terms of time in the role, were lower than a reference benchmark which could lead to inefficient operations. These were:

- senior and production management
- engineering
- estimating
- planning, production control, and cost control
- production engineering and performance improvement

The shipyards reported difficulties in recruiting skilled and experienced personnel in all production areas, particularly steelworkers, pipe workers, welders and electricians as well as in key technical roles including engineers.

Each participating shipyard has received an individual benchmarking report with a prioritized list of suggested actions to improve performance and close the technology gaps. The prioritization in the individual shipyards has been combined to determine overall priorities for the industry. The highest priority elements have been grouped into the five industry-wide action areas, together with suggested actions, summarized below.

Ship design and design for production: Develop a rationalized standard design approach that includes new methods and reduces design cost. Apply to new designs and the redesign of selected portions of legacy designs with the goal of frequent design upgrades that reduce total costs. Establish design for production standards, including in the earliest design stages. Execute a strategy to maintain core design capability, smooth demand and stabilize employment of the technical workforce.

Dimensional and quality control: Promote awareness of the schedule impacts and true costs of non-value-added work. Fully implement the accuracy control techniques developed by the industry over the last 35 years. Promote the use of statistical analysis as an intrinsic part of the performance improvement process. Conduct an integrated study to improve dimensional and distortion control through ship design, block breakdown, welding and other technologies.

Production and process engineering: Develop a production engineering charter to be in line with those of the world's leading shipyards. Develop a training and certification program that can be a basis for incentives. Introduce a production engineering requirement for future designs. Conduct regular upgrades of legacy designs in selected ship zones to incorporate up-to-date production engineering principles.

Pre-erection outfitting, outfit installation and module building: Optimize the design and pre-production processes to inherently define outfit modules and support advanced outfitting. Increase the use of outfit modules. Improve the conditions and orientation of advanced outfitting. Complete onboard outfitting by zone-by-production-stage, then by system to facilitate testing. Define and measure outfit manning density. Implement outfitting approaches that reduce hot work. Review naval legacy outfitting-related rules.

Manpower, organization of work, and job and skills flexibility: Remove all trade demarcations, increase the levels of flexible working, and make more use of multi-disciplinary teams. Fully implement workstation organization and product-oriented operations. Fully implement area management through the whole organization. Stabilize employment levels. Make more proactive use of subcontractors.

A similar list of actions for the Government is included in the Government actions report.

For the industry as a whole, performance improvement and investment projects that address the technology gaps listed in Table 1 are likely to be worthwhile investments. Fully closing the technology gaps in some of these areas will require investment in hardware and facilities. However, the benefits that can be derived from developing the soft areas are often more cost effective and need to be maximized before investing in equipment and facilities. Also, in some instances, a change in the soft areas is required to fully realize the benefits from facilities development.

Specific FMI facility and equipment suggestions have been included in each shipyard's benchmarking report. To provide an industry overview, the key facility and equipment recommendations are summarized below.

Materials handling and storage: Materials handling and storage improvements of various sorts have been recommended in all the shipyards surveyed.

Unit and block assembly: Investments relating to flat unit, curved unit, superstructure and block assembly, and outfitting have been suggested in a high proportion of the yards.

Welding: Increased levels of mechanized and automated welding and robotic welding in workshops have been suggested in a high proportion of the yards. Welding R&D facilities are also required in some yards. Additional product standardization will be required to justify increased automation in some areas.

Module building: In about half of the yards, high priority facility investment suggestions have included establishing or expanding purpose-designed facilities to assemble outfit modules on current and future designs.

Support and services: Improvements in construction support and services in the grand blocking, construction and post-launch stages of construction have been recommended in a high proportion of the shipyards.

Workstation organization: Improvements in workstation operations in minor assembly, sub-assembly, and outfit steel and aluminum manufacturing have been suggested in a high proportion of the shipyards. This will require some investment in facilities and some equipment such as mechanized material handling, positioning fixtures, manipulators, and automated or robotic welding. In most of the shipyards, an enabler to the improved mechanization/automation is further development of interim product families and design for production.

Pipe shop: Opportunities to improve pipe shop performance through investment in equipment and facilities has been identified in a high proportion of the shipyards. In most, an enabler to the increased automation is the introduction or expansion of pipe piece family manufacturing.

Construction points: A few shipyards require investment in their construction points. This includes increased erection crane capacities, environmental protection and access for people and materials. The capability to launching fine, more heavily outfitted ships also needs to be improved in some shipyards.

1 INTRODUCTION

1.1 Background

This report presents the findings of the 2014 US Naval Shipbuilding and Repair Industry Benchmarking study carried out by First Marine International (FMI). The study is sponsored by the Assistant Secretary of the Navy for Research, Development and Acquisition (ASN(RDA)). The overall objective is to identify actionable items to improve the performance of the US naval shipbuilding and ship repair enterprises and to assess industry progress in improving its practices and processes over the last ten years. The FMI shipyard benchmarking system, which is briefly described in Section 1.3, has been used as the basis for this study. The report presents the combined results of the benchmarking surveys of five large US shipyards and three mid-tier yards undertaken in 2014. Although the performance and practices of individual shipyards are not discussed, the characteristics of the eight shipyards are compared and, as a consequence, performance improvement actions are proposed for the US shipbuilding industry as a whole and the Government. Each participating shipyard has also received a confidential report which defines the use of best practice within the yard and presents a prioritized list of suggestions for improvement actions. Suggestions for Government actions to lower shipbuilding costs are covered in a separate report.

The same system was used in the 1999/2000 National Shipbuilding Research Program (NSRP) study and the 2004/2006 Global Shipyard Industrial Base Benchmarking Study (GSIBBS) undertaken by the Office of the Deputy Under Secretary of Defense for Industrial Policy (ODUSD(IP)). Thus, for shipbuilding, the results of the studies can be compared and changes in the levels of shipyard technology employed identified. The GSIBBS also included a survey of large and mid-tier international yards for additional comparison purposes. The results of the international study are also used as a benchmark in this study.

Productivity was reviewed as part of the GSIBBS but has not been included in this study. The emphasis has been placed on reviewing the practices and processes employed. As has been previously shown, higher benchmarking scores are associated with higher levels of productivity. Therefore, an increase in the average benchmarking score since the GSIBBS means that there should be a reasonable expectation that productivity has improved.

Clearly the skills of the workforce are an important to achieving high levels of productivity and quality. Therefore, at the request of the industry, a workforce skills survey was undertaken concurrently with the benchmarking survey. The results are included in this report.

1.2 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 first collaborated in the 1970s with the design and engineering of the 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 new shipyards; and development, implementation and management of shipyard performance improvement programs.

In February 2008, FMI was acquired by Royal Haskoning, an independent, international engineering and project management consultancy. In July 2012, Royal Haskoning merged with another international engineering company, DHV, to form Royal HaskoningDHV. FMI is the shipyard technology and marine market research advisory group within the Maritime and Waterways business line of Royal HaskoningDHV.

1.3 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. 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:	US shipyard technology survey
1985:	US shipyard technology survey
1992:	EC shipbuilding competitiveness study
1993:	EC Eastern European shipyard study
1995:	NSRP study (system derivative)
1998:	Portuguese shipyard benchmarking
1999:	UK shipyard benchmarking study
2000:	US, Asian and European shipyard benchmarking study
2004/2006:	US ODUSD(IP) GSIBBS
2008/2009:	UK MoD dockyard benchmarking study
2010/2011:	Benchmarking in support of the Canadian NSPS

The full system contains 157 elements of shipbuilding, ship repair and ship conversion technologies grouped into twenty functional areas. This study includes 69 of the 157 elements in the following ten functional areas of shipbuilding practice:

A Steelwork production

B Outfit manufacturing and storage

C Pre-erection activities

D Ship construction and outfitting

E Yard layout and environment

F Design, engineering and production engineering

G Organization and operating systems

H Human resources

I Purchasing and supply chain

K Performance improvement

The benchmarking system describes five levels of use of best practice in each element of each group. 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' rating is assigned to each element. Elements that are subcontracted are noted and if sufficient information is available to evaluate subcontractor performance, the element is rated. The ratings are aggregated, first, for the individual groupings, and second, for the whole shipyard. The results are presented graphically so the strengths and weaknesses are clearly shown.

Groups H, I and K were not included in the 2004/2006 benchmarking surveys so, in order to make a direct comparison between this study and the previous study, the overall score for groups A through G (A-G) is quoted in addition to the A-K overall score. Other elements that have been added are:

- E3: Environmental control
- F10: Test and trials and setting to work

Further details of the benchmarking system are available in the FMI Shipyard benchmarking system description, a copy of which can be supplied by FMI on request.

1.4 General approach

A more detailed explanation of the methods used has been included in the relevant sections and appendices of the report. The overall approach was as follows:

1. Survey the 69 manufacturing and business processes and practices in the eight US shipyards using the benchmarking system. Carry out an education and skills survey and interview shipyard personnel to identify what changes the Government could make to help improve shipyard productivity.
2. Review the findings for the international yards in the GSIBBS, consider US shipbuilding trends and circumstances, and suggest target technologies and hence target benchmarking scores for the US yards.
3. Compare the technology applied in each yard to the suggested targets to identify technology gaps that represent opportunities for making improvements.
4. Write a report on the findings in each yard that includes a prioritized list of action areas and suggested actions. Provide a shipyard characteristics report that gives a generic description of the target processes and practices.
5. Aggregate the findings to an industry level to identify opportunities for industry-wide action to improve performance. Summarize the findings of the education and skills survey.
6. Review the shipyard findings to identify the effects of Government policies and contract incentives on shipyard performance and suggest improvements.
7. Present the general industry findings and suggestions for Government actions in two separate reports.

As with the GSIBBS study, to provide continuity the same team of four FMI consultants carried out the surveys in each shipyard, each of whom are specialists in the areas surveyed. Several members of the FMI team were also involved in the GSIBBS and earlier US and international studies. The NAVSEA NSRP program manager accompanied the team on the surveys of seven of the eight shipyards but did not influence the benchmarking scores assigned. It is assumed that the industry, for example through the NSRP, will use this report as the basis for an action plan to further improve performance.

1.5 Participating shipyards

The three mid-tier and five large shipyards surveyed during this study predominantly build surface ships but one builds both surface ships and submarines and another builds submarines only. The participating shipyards represent eight of the fifteen US shipyards that participated in the GSIBBS. In order to determine where changes in applied technology have occurred, the 2004/2006 averages have been recalculated to include only the shipyards surveyed in 2004/2006 and again in 2014. No international shipyards were benchmarked as part of the 2014 study. The 2004/2006 international averages quoted here have been duplicated from FMI's findings for the GSIBBS report.

1.6 Proposed best practice targets

Lowest cost is achieved by having a best practice rating which is appropriate for the product mix, throughput and cost base of the shipyard. The most appropriate score in each element is therefore not necessarily 5.0. It is possible to calculate the most appropriate target best practice ratings from an analysis of productivity and the structure of ship cost. These analyses have not been included in FMI's scope of work for this study. Therefore, a realistic target has been proposed for each element on the basis of FMI's international experience applied to the circumstances in each US shipyard. Accordingly, some of the suggested targets for submarine builders, naval surface ship builders, commercial ship builders and mid-tier shipyards differ.

FMI has proposed the target for each element based on its individual merits and its balance with other relevant elements rather than on the basis of the overall shipyard best practice rating. This has resulted in the overall shipyard target scores being relatively high when compared internationally. There may not be a single shipyard with the same technology profile or overall best practice rating as that proposed. The targets for some elements exceed the 2004/2006 international shipyard highest scores. This is because international shipbuilding technology levels have progressed since the last study and the US is aiming to have a highly developed and efficient naval shipbuilding industry.

The characteristics of the processes and practices that match the proposed target best practice ratings are described in the individual shipyard characteristics reports. In some elements, similar target ratings have been proposed for large and mid-tier yards. The operational details will vary with the size of the shipyard but the overall characteristics will be similar. In essence, the ideal overall shipyard characteristics would be as described in the following paragraph:

> The whole operation would be compact, lean and progressive with a relatively simple management structure. The workforce would be highly skilled, flexible and motivated with an emphasis on research and continuous development. There would be a documented shipbuilding strategy that balances strong core competencies with an effective outsourcing strategy. A strong pre-production organization would support production and provide effective coordination of all activities with low inventory. Information and communications technologies would be leveraged to the maximum possible extent to automate the processes and reduce man-hours. Production engineering and purchasing would have a significant influence on design. Design and manufacturing would be product-oriented. Facilities would be modern and contain equipment and production processes that optimize labor cost and capital expenditure to achieve minimum cost. A high proportion of the work would be carried out during early production stages with a minimum amount of work done after launch. There would be strong schedule adherence and an emphasis on dimensional accuracy and quality.

There needs to be an appropriate balance in the applied technology that reflects the relative differences in throughput and justifiable investment. The relatively low throughput in some areas of production means that it may not be possible to justify high levels of technology in all areas; thus, the targets proposed for some elements are lower than might be expected. Naval acquisition processes and practices, vessel complexity and high outfit ratios mean that many of the pre-production functions need to be strong. These functions include design, engineering and production engineering; organization and operating systems which includes planning; and the approach to outfitting and test and trials.

The targets for each element vary for each shipyard depending on the circumstances in the yard. The average targets for each element across all the yards are shown in Appendix 1. The group targets are shown in Tables 2.1 and 2.2 in the following section. In some elements in some shipyards, the current score is already higher than what would be proposed as a target. In these instances the target score has been increased to match the current score.

The technology gap is the difference between the current benchmarking score and the proposed target. For the industry, the average technology gap for an element is the difference between the average current score and the average proposed target for that element.

2 SUMMARY OF USE OF BEST PRACTICE

2.1 Overall findings

The increase in US shipyard performance improvement activity and investment in facilities and equipment noted in FMI's findings for the GSIBBS has continued. As was recognized at that time, some US yards have clear strengths and the benchmarking team was again impressed by the improvements that have resulted from the recent efforts. Approximately 40% of the individual yard target scores suggested as part of the GSIBBS have been reached. However, when compared to the 2014 targets which are generally equal to, or higher than, the targets established a decade ago, there are a large number of technology gaps, which indicate that there is potential for further improvement.

Figure 2.1 shows the range of use of best practice observed in the US yards in 2004/2006 and 2014 by element group. The 2004/2006 international range is also shown. The ends of each bar represent the lowest and highest shipyard average score in each group and the black line across the bar is the average for all yards. The average 2014 targets proposed by FMI are shown as an orange line for each group. There are no 2004/2006 US or international scores shown for the last three groups shown on the figure as these were not assessed in the GSIBBS.

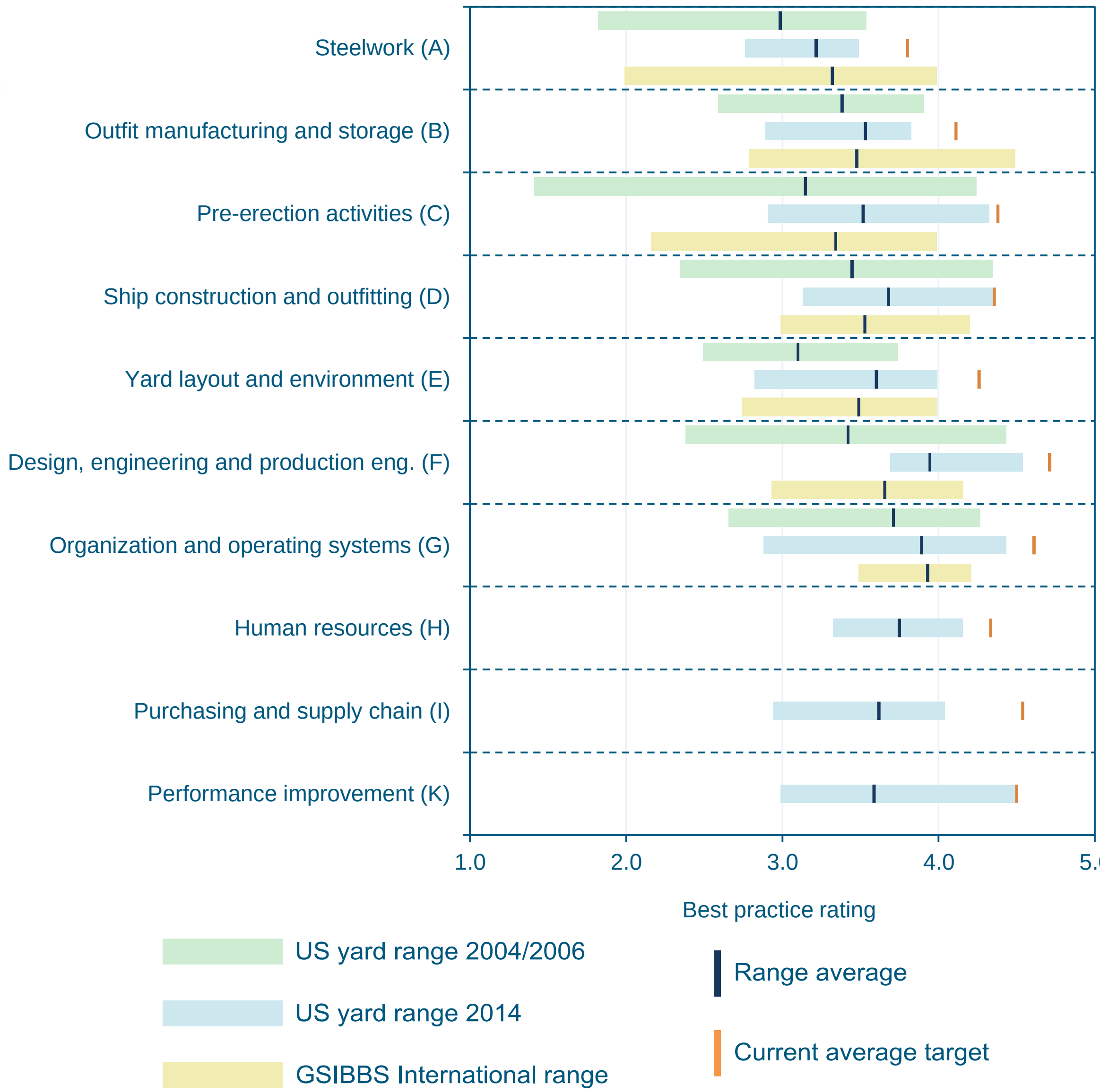

Figure 2.1 – Overall change in best practice rating and targets

Since 2004/2006, the overall average best practice rating for groups A-G across all shipyards benchmarked has increased from 3.3 to 3.6. In some shipyards the change is small; in others it is substantial. When considered by sector, the larger improvements have been in the mid-tier yards. In both sectors, though, there appears to have been a concerted effort to close the technology gaps identified in FMI's findings for the GSIBBS.

While there are individual elements within each group that are still low scoring, the group averages have increased significantly and the very low group averages that were seen in some US yards have been eradicated. Although there remain some important technology gaps, a number of the US averages now exceed the 2004/2006 international averages.

However, the international yards have advanced since that time and care needs to be taken when making comparisons between industries and sectors. Differences in the product mix, throughput and cost base need to be taken into account as do the challenges of constructing high quality, complex naval vessels for a demanding customer.

The extent to which the use of best practice influences productivity is related to the proportion of man-hours spent on the activity or its effect on other aspects of the operation. For example, in a complex surface combatant there are at least twice as many man-hours in outfitting as there are in structural steelwork so, from a productivity viewpoint, priority should be given to achieving a high use of best practice in outfitting. Conversely, some of the South Korean yards process in excess of one million tons of steel to produce 50 to 60 less-complex ships per annum. Thus it is extremely important for them to have the equipment and technologies that facilitate a high output of low-cost steelwork. As discussed in Section 1.6, the targets developed for each yard vary according to the yard's product mix and other relevant factors. Therefore, because the proposed targets take into account the factors that are currently important in the US yards, they are a better reference than the 2004/2006 international scores.

Although the average scores are generally at a lower level than the proposed targets, their profile tends to match the profile of the targets. The so called 'soft areas', which are groups F onward, tend to be higher scoring than some of the production groups. This is because, as stated above, to successfully construct complex, high-outfit ratio vessels, the soft areas need to be strong and the low volume means that it can be difficult to justify the investment in some production areas. The exceptions to this are those production elements associated with outfitting.

Table 2.1 shows the change in the average best practice rating of the US large yards between 2004 and 2014 and the comparison with the average rating for the international large yard sample in 2004. The average proposed target is also shown, as is the technology gap, which is the difference between the current average and the target.

Group	Description	US yards average rating		International large yards average rating 2004	Average proposed target	Average technology gap
		2004	2014			
A	Steelwork production	3.4	3.4	3.7	3.8	0.4
B	Outfit manufacturing and storage	3.7	3.7	3.6	4.1	0.4
C	Pre-erection activities	3.6	3.7	3.8	4.5	0.8
D	Ship construction and outfitting	3.6	3.9	3.7	4.4	0.5
E	Yard layout and environment	3.3	3.8	3.4	4.2	0.4
F	Design, engineering and production engineering	3.7	4.0	3.8	4.7	0.7
G	Organization and operating systems	4.0	4.1	4.0	4.6	0.5
H	Human resources	-	3.8	-	4.3	0.5
I	Purchasing and supply chain	-	3.9	-	4.5	0.6
K	Performance improvement	-	3.8	-	4.5	0.7
A-G[1]	**Overall yard rating**	**3.6**	**3.8**	**3.8**		
A-K	**Overall yard rating**	**-**	**3.8**	**-**		

Table 2.1 – Large yards best practice rating by group and overall

For the groups A-G, the overall average for the US large yards has increased from 3.6 in 2004 to 3.8 in 2014. The average rate of improvement for the large yards as a whole is approximately 0.02 points of best practice rating per annum. Although some yards have achieved a high rate of improvement, the average rate has slowed when compared to the five-year period preceding the GSIBBS. FMI's findings for the GSIBBS noted that the rate of improvement at that time was similar to that demonstrated by leading international builders in the past. This was about 0.1 per annum as compared to the current rate of 0.02. However, as technology levels increase, it becomes more difficult to improve and a slowdown to some degree in some of the higher scoring large yards could be expected.

[1] For 2014 the A-G overall yard rating has been calculated excluding the new elements E3 and F10. This ensures the A-G average is comparable with FMI's findings for the GSIBBS. E3 and F10 have been included in the average rating shown for Groups E and F.

The largest technology gaps are in three groups that have a significant influence on productivity in large US yards. The Pre-erection activities group includes pre-outfitting and related elements. Design engineering and production engineering includes elements that are important enablers of higher levels of productivity. The Performance improvement elements measure attitude to change and how the shipyard improves its own processes and practices. The large technology gaps suggest that improvement in these three groups would be highly beneficial. Summaries of each group are provided in Sections 2.2 through 2.10 and the details by element are in Appendix 1.

Table 2.2 is a duplicate of Table 2.1 but for the mid-tier yards. The international reference score was determined in 2006.

Group	Description	US yards average rating		International mid-tier yard average rating 2006	Average proposed target	Average technology gap
		2006	2014			
A	Steelwork production	2.3	2.9	2.9	3.7	0.8
B	Outfit manufacturing and storage	2.9	3.2	3.4	4.1	0.9
C	Pre-erection activities	2.3	3.1	2.8	4.2	1.1
D	Ship construction and outfitting	3.1	3.4	3.3	4.2	0.8
E	Yard layout and environment	2.8	3.3	3.6	4.3	1.0
F	Design, engineering and production engineering	2.9	3.8	3.4	4.7	0.9
G	Organization and operating systems	3.3	3.4	3.8	4.6	1.2
H	Human resources	-	3.6	-	4.3	0.7
I	Purchasing and supply chain	-	3.2	-	4.6	1.4
K	Performance improvement	-	3.2	-	4.5	1.3
A-G[2]	**Overall yard rating**	**2.8**	**3.3**	**3.3**		
A-K	**Overall yard rating**		**3.3**	**-**		

Table 2.2 – Mid-tier yards best practice rating by group and overall

For the groups A-G, the overall average for the US mid-tier yards surveyed has increased from 2.8 in 2006 to 3.3 in 2014 with increases in the average benchmarking score in all groups. The overall rate of improvement for the mid-tier yards as a whole is approximately 0.06 points of best practice rating per annum. Given the low starting score, the rate could have been higher but this is still a very positive achievement and some of these yards have had a much higher rate of improvement.

The largest technology gaps in the mid-tier yards are in the soft areas, which is indicative of the lean production-led approach that has been a feature of these yards in the past. The groups with the largest gaps include Organization and operating systems, Purchasing and

[2] For 2014 the A-G overall yard rating has been calculated excluding the new elements E3 and F10. This ensures the A-G average is comparable with FMI's findings for the GSIBBS. E3 and F10 have been included in the 2014 average rating shown for Groups E and F.

supply chain, and Performance improvement. There is also a significant gap in Design, engineering and production engineering. As can be seen from Table 2.2, there are other important gaps that would benefit from closure. These are discussed in Sections 2.2 onward. The details by element are in Appendix 1.

The following sections summarize the current situation in US yards, the changes that have occurred since the GSIBBS and some of the reasons for the technology gaps. A more detailed review at the element level is provided in Appendix 1. The appendix includes proposed actions for industry-wide improvements.

2.2 Steelwork production

The yards in both sectors have increased their average scores for the steelwork production group. The large yard average has increased to 3.39, a small increase of 0.03 from 2004. This is 0.3 below the 2004 average of the large international yards and 0.4 below the 2014 target average. The mid-tier average has increased by 0.6 to 2.9, which is equal to the 2006 mid-tier international average and 0.8 below the 2014 average target.

The level of applied technology in plate cutting is high across the US industry as it was in 2004/2006. In both sectors it is the highest scoring element in the group. The yards tend to have modern equipment, good dimensional controls and low work in process in the cutting areas. There has also been a large improvement in stiffener cutting at the mid-tier yards with higher levels of automation commonly being applied. It appears the need to split or de-flange rolled members has been reduced by design in both sectors and it is often outsourced.

Minor assembly and sub-assembly processes would benefit from increased application of production engineering. The level of technology is mixed across the industry and often within individual yards. There are separate instances of automation within a majority of more conventional methods. There are isolated good examples of mechanized lines, automated welding and well-designed work centers. However, there appears to be a lack of effective standardization and use of interim product families, resulting in a lower expectation for automation than would actually be justified. Accordingly, there is only limited use of purpose-designed fixtures, automated welding, mechanized fairing aids and manipulators.

There are moderate to high levels of mechanization in the large yard panel lines. However, unit assembly methods are more conventional in both sectors with low levels of mechanization in most yards and substantial work being done outdoors in some. Both sectors appear to have increased early outfit installation and most yards have an increased focus on dimensional and distortion control. Further efforts could be made to reduce and eliminate the allowances made for inaccuracies. These include excess materials cut at erection and various forms of work left undone until later stages due to dimensional and distortion issues.

Almost all the international shipyards surveyed as part of the GSIBBS subcontracted the fabrication of outfit steel and aluminum items such as foundations, hatches, doors, ladders, walkways, and railings. Many US shipyards still do this work in house using a wide range of technology. There would be benefit in simplifying and standardizing the items currently produced and, if improved manufacturing technology cannot be justified, developing additional outsourcing alternatives.

2.3 Outfit manufacturing and storage

Both US yard sectors have increased their average scores for the outfit manufacturing and storage group. The large yard average score has increased slightly, by 0.04, to 3.70. This is above the 2004 large international yard average of 3.6 by a small amount and below the 2014 target average of 4.1. The mid-tier yard average has increased by 0.3 to 3.2, which is below the 2006 mid-tier international average of 3.4 and well below the 2014 target average of 4.1.

Within this group, the large yard averages are above the 2004 international averages in all four of the workshop elements but below them in the two storage elements. This indicates an opportunity to focus on material-related issues. Mid-tier yard averages are also above their 2006 international counterparts in two of the three workshop areas surveyed. However, both sectors are well below the targets which take into account the factors that are important in the US yards.

Most of the shipyards run proficient but conventional warehouse operations. The use of barcoding and parts kitting have increased and quality assurance and preventive maintenance processes appear to be well established in most yards. However, inventory levels vary from medium to very high which can result in large staffs and added external warehouse space. The reasons for this likely include poor schedule adherence and contractual arrangements that encourage early deliver or require extended storage of GFE. Material also tends to be handled a large number of times and there is limited use of just-in-time deliveries and supplier deliveries direct to the point of use. Some of these factors are discussed in the Government actions report.

For pipe and sheet metal manufacturing, the yards tend to use moderate to high technology in preparation. However, lower technology is typical in the downstream assembly and welding processes. Leading international yards outsource more of this manufacturing work than large US yards, especially in sheet metal, and the US mid-tier yards outsource a majority of their sheet metal work. The enablers of major US advances are to reduce the variety and complexity of pipe and sheet metal work and to organize it by interim product families, which would benefit both in-house and outsourced work. It would benefit the industry to increase the implementation of production engineering, design for production and pipe piece family manufacturing. These are all subjects of prior NSRP work.

2.4 Pre-erection activities

There has been improvement in the pre-erection group of elements for both the large and mid-tier yards. While the large yard average has increased to 3.7, it still slightly lags the 2004 international average. However, the mid-tier average of 3.1 now exceeds the 2006 international mid-tier average of 2.8. The most important improvements in the large yards have been in module building (pre-assembled units of outfit), block assembly and pre-erection outfitting. All of these move outfit work to more cost-effective, earlier stages of construction and reduce construction time. However, both sectors are well below their target averages with this group having the largest technology gap of all the large yard group averages.

A limited number of outfit modules have been introduced on some new designs and a number of legacy designs are being re-engineered to take advantage of this approach. The mid-tier score for module building has not changed. In general both sectors could make more use of this technique and produce better optimized module designs. Consideration should also be given to re-engineering additional selected areas of legacy designs with module construction in mind.

A respectable level of pre-erection outfitting had been achieved in many yards at the time of the last survey and, although there are some exceptions, there has been improvement in both sectors since then. That said, some shipyards are still having difficulty in achieving the anticipated high levels on a first-of-class. The resulting shift of outfitting work to later stages of construction can result in unexpected increases in cost and schedule which are difficult to forecast. There is still potential to make further improvements in the level of pre-erection outfitting and the related processes, but painting strategies need to be complimentary. .

Block assembly and unit and block storage have both shown a further improvement. This is principally due to a general increase in block size, the introduction of a number of very good block construction facilities, and a developed scheduling rationale,. However, the size and configuration of blocks is still sub-optimal in some yards due chiefly to erection cranage limitations. Unit and block storage is generally well organized and is compatible with overseas standards. Although the levels of in-process storage are now generally lower than they were, they are still excessive in some yards.

There has been very little change in the approach to materials handling in the large yards but there has been some improvement in the mid-tier. Materials handling in US yards still lags the international yards by a significant margin and has the second largest gap in the group for the large yards. There is limited use of conveyor systems, specialist and automated transport systems and purpose-designed pallets. The mid-tier yards have made significant improvements in their approach to outfit parts marshalling, which is now far more structured and focused on keeping the trades on the job. Although the large yards generally have outfit parts marshalling systems that get most of the parts to the right place at the right time, in several there is a great deal of storage and multiple handling. This reduces the effectiveness and consequently the benchmarking score.

2.5 Ship construction and outfitting

The overall score for Ship construction and outfitting has increased in the large shipyards. The principal improvements have been in onboard services, outfit installation, painting and, to some degree, welding. These are all important areas that account for a large number of man-hours in ship construction. There has also been an increase in the score for this group in the mid-tier yards. The group average for both sectors is now ahead of the 2004/2006 international averages and the proposed targets, although only slightly for the mid-tier yards. However, there are still important deficiencies in some US yards such as limited erection crane capacities and other sub-optimal features at the construction points.

In the large yards, ship construction takes place on a mixture of land-level facilities, inclined ways and in building docks. Some facilities are at or near state-of-the-art but most are not. There are instances of work being moved off the construction points to undercover block assembly areas but, other than this, there have only been minor changes in the construction points themselves. Conversely, investment in some of the mid-tier yards and a closer alignment of the product mix to the facilities has meant that construction is now conducted in good undercover facilities. Construction cycle times are still long in some cases but this can be a consequence of naval requirements.

The large yards have a significantly higher average score for erection and fairing than the mid-tier yards, which have regressed since the last survey due to a re-emergence of scribing blocks at erection. Both sectors still lag behind the 2004/2006 international averages. Accuracy control is not yet fully implemented across the industry and erection rates tend to be slow. There has been some reduction in the use of welded fairing aids but these, rather than non-welded fairing aids, are still the norm.

There has been further progress in the application of more efficient and productive welding processes with a greater proportion of mechanized and robotic welding in the large yards accounting for their higher score. There are fewer opportunities for these techniques in the mid-tier yards but more could still be done. Both US averages are now similar to the 2004/2006 international averages.

In general, the amount of staging used in the industry has reduced somewhat and its application improved slightly. More fixed platforms and mezzanine floors are in use, particularly in the mid-tier yards. The organization of outfit installation has generally improved, which has increased the scores but more could still be done. There has also been significant improvement in the approach to onboard services which now tend to be better organized and planned.

There has been a substantial investment in paint facilities in the US yards over the last few years, with the majority of paint cells being state of the art. Painting practices still vary across the industry and paint rework is generally quite high. Outfit complexity and structural distortion of light scantling designs make painting difficult on many naval vessels. This is made more complicated by stringent naval preservation requirements which are still an area where research and development is required to produce a wholly satisfactory approach.

2.6 Yard layout and environment

The Yard layout and environment group included only two elements in the last survey and now includes three. Therefore, a comparison at the group level is less useful here than in other groups. Instead, each element is summarized below.

There have been some small improvements in the layout and material flow in the large yards and a substantial improvement in some of the mid-tier yards. Most US yards are composed of facilities which have evolved over a long period. With one or two exceptions, their shapes are less than ideal (for example, long and narrow) and they are generally constrained by roads or other adjacent facilities. Despite this, the material flows are mostly unidirectional although they can be convoluted in local areas. Materials handling distances between production centers are sometimes very long (several miles or more). Many foreign yards visited during the last survey were purpose-designed within the last forty to fifty years and are therefore more logically and efficiently laid out.

The General environment averages have increased in both US sectors; they are above the 2004/2006 international averages and are approaching the 2014 average targets. Almost all yards have a mixture of old and new buildings and factory-like conditions are achieved in the newest buildings. Housekeeping is often good although work in process levels tend to be high and detract from the working environment. A large amount of work is done outdoors in some yards and most yards would benefit from increased use of purpose-designed service towers in ship construction areas and on board.

Environmental control was not assessed in 2004/2006 but has achieved consistently good scores across the large yards in 2014 with an average rating of 4.2. ISO14001 accreditation is commonplace, environmental infringements are rare, and the adoption of forward-looking, proactive policies is growing. The mid-tier yards scored considerably less well. There are opportunities across the industry to maximize the public relations benefits gained from good environmental policies, particularly in the labor markets.

2.7 Design, engineering and production engineering

The Design, engineering and production engineering group of elements has scored an average of 4.0 for the large yards and 3.8 for the mid-tier yards. This is an increase of 0.3 and 0.9, respectively, since the last survey. Both shipyard sectors exceed the average 2004/2006 international scores but fall short of their proposed average targets, with a technology gap of 0.7 for the large yards and 0.9 for the mid-tier yards.

In general, the shipyards continue to use a system-oriented approach to ship design. The development and introduction of product-oriented design is ongoing. Unfortunately, the opportunity to introduce new design and engineering methods is hampered by the continued use of legacy designs, long cycle times and large series. This leads to designs being adapted to improve producibility rather than being optimized for production performance. One of the barriers to changing the design is the design cost, so there would be benefit in reviewing the approach to the naval design process with a view to minimizing cost. That said, for the large shipyards there has been significant improvement in the Production engineering, Design for production and Dimensional and quality control elements. In the mid-tier shipyards, there has been improvement in all elements but the largest improvements are in the Coding system, Production engineering and Dimensional and quality control elements.

Since the last survey, the profile of production engineering has increased and there has been greater emphasis on introducing production engineering principles into the design and engineering process. However, in the large yards, the use of best practice in production engineering and design for production continue to lag behind the international yards and the proposed targets.

Despite statistical accuracy control programs having been established in most shipyards, there remains a reluctance to rely on statistical evidence to reduce in-process rework by, for example, reducing the use of excess material in steelwork. The significant improvement in

Coding systems in the mid-tier shipyards is reflected in the increase of 1.6 in best practice rating. For this to advance further, the individual product families need to be identified through the development of a product-oriented design philosophy. The same can be said for the large shipyards.

2.8 Organization and operating systems

The group average score for Organization and operating systems has improved in both sectors since the previous survey. It remains the highest scoring group for the large yards and is the third highest for the mid-tier yards. The Production control, Quality Assurance, and Production management information systems elements have all scored well. In the large yards, these elements scored highly at the time of the GSIBBS and have improved the least since 2004. This is because the industry has rightly focused on areas with the best opportunities for improvement such as Planning, Steelwork scheduling, Outfit scheduling, Stores control and Performance and efficiency calculations.

Generally, the industry has developed good planning systems. However, poor schedule adherence is common, often exacerbated by a tendency to develop detailed planning unnecessarily early; something that naval contracts demand or encourage. This contributes to high planning rework levels and the need for department sizes to remain large.

The Manpower and organization of work element stands out as a significant hurdle for performance improvement. Although union agreements tend to facilitate trade flexibility, the arrangements can be cumbersome and in practice there are still some union-imposed trade demarcations and other restrictive practices. Middle management can also be resistant to moving away from rigid trade demarcations. The degree of negative union influence on productivity improvement varies widely but it appears more prevalent than was recorded in 2004/2006. In several yards, there needs to be increased emphasis on planning product families by workstation and zone. However, progression toward full workstation-oriented production requires workforces to be appropriately re-organized and currently this may be a barrier in a proportion of shipyards.

For stores control, there is a common tendency to protect production schedules by encouraging the early delivery of materials. Knowledge of the full costs associated with carrying inventory is rare and bringing equipment and materials in early can also be incentivized by naval contracts. The resulting inventory levels observed during the survey have varied from medium to very high.

2.9 Human resources

The human resources group was not included in the 2004/2006 survey. Three elements of the group were surveyed for this study; scoring an average of 3.8 for the large yards and 3.6 for the mid-tier yards. Both sectors fall short of the proposed average target, with a technology gap of 0.5 for the large yards and 0.7 for the mid-tier yards.

A large proportion of the trade workers are union members, with the majority of the large yards being unionized. The mid-tier yards are generally non-union. Although there are union-driven restricted working practices in some of the yards, generally trade union collective bargaining agreements, training procedures and facilities allow for flexible working between trades. However, in most yards there appears to be no drive to advance to a more flexible, multi-skilled production operation and there are limited multi-skill trained workers.

There are well-established training and education policies and procedures within the yards and this is reflected in a good overall job-related skills base across the industry. That said, for continuous improvement an industry-wide skills and qualifications requirement matrix should be considered. In addition to a good skills base, experience is essential and a good proportion of the total industry workforce has an appropriate number of years of experience. However, the education and skills survey highlighted a number of key areas where there is a lower percentage of experienced personnel than is considered optimum for efficient operations. These include senior management, engineering, estimating, planning and cost control, production supervision, test and trials, and quality assurance and inspection. Full details of the survey are discussed in Section 4.

2.10 Purchasing and supply chain

The Purchasing and supply chain group was not included in the previous survey. Vendor recruitment, Relationships with suppliers, and Purchasing procedures are the top rated elements. This is not surprising given the maturity of the supply base and the high standards applied to procurement practices in the US. However, the supply base is mostly limited to domestic suppliers and, depending on the sector, it is static or shrinking. Relationships tend to be transactional, that is relying on hard negotiation rather than partnering. The use of long-term supplier agreements is often driven only by the need to tie suppliers in for a series of vessels. Supplier performance is measured in most yards but is often manual and is not routinely shared with the suppliers themselves.

Although there are a number of successful individual initiatives driving down the cost of equipment and materials, these are mostly based on incentivizing buyers to negotiate harder. The organizational status afforded to procurement activities is low when viewed in the context of the dollar value being controlled, and few yards have developed comprehensive supply chain strategies. This means that procurement personnel can lack senior management buy-in to performance improvement initiatives and are usually unguided for issues such as ideal inventory levels; the target size, location and sector-focus of the supply base; the types of contracts to use; and the logistics of getting the equipment and materials to the point of use.

The Inventory and logistics and Subcontract policy elements have rated the most poorly. Inventory levels vary from medium to very high comprising a mixture of work-in-progress, contractor-furnished equipment and government-furnished equipment. Materials buffer times are high and multiple handling is the routine in many yards. Despite this, the success rates for on-time materials supply into production remain significantly below international standards. Failure points are difficult to identify, as supply chain responsibility is commonly handed across departments between the supplier and delivery into production. Procedures for Vendor furnished information are complex and could be improved.

Subcontracting[3] levels have grown but remain low by international standards. In some yards there continues to be embedded cultural resistance to subcontracting, supported by the unions. Well-founded, company-wide subcontracting strategies are rare with many yards still making decisions on a case-by-case, project-by-project basis. There is more flexibility for the mid-tier shipyards regarding subcontracting, particularly where union influences are low.

2.11 Performance improvement

The performance improvement group of elements was not included in previous US benchmarking studies, so there is no reference against which to measure change. The scores in the US yards, which are strong in these elements, tend to be similar to equivalent international shipyards; however, there is a wide variety in the scores across the group. All yards have some type of performance improvement function but, as expected, the approach in the large yards tends to be more structured than in the mid-tier yards. Most yards have a positive attitude toward change but a few members of management teams and the workforce are still relatively conservative. Unfortunately, union behaviors in some shipyards can make performance improvement difficult. One or two yards are making good progress towards achieving a culture of continuous performance improvement. Performance measurement tends to be on the basis of earned value management but there is also some limited use of the preferable output and process performance measures. Generally, better use could be made of metrics to monitor performance and set targets.

[3] Subcontracting includes the decision to buy rather than make products and the use of 3rd party subcontractors to complete specific scopes of work, such as painting.

2.12 Technology gaps

As previously discussed, the technology gap is the difference between the average current score and the average proposed target. In Table 2.3, the technology gaps have been grouped into four color-coded categories:

- High, 1.0 and above
- Medium, 0.5 to below 1.0
- Low, more than zero to less than 0.5
- No gap

The table provides the list of elements sorted in descending order of the all yards average technology gap.

Element description	All yards	Large yards	Mid-tier yards
Design for production (F7)	High	High	High
Inventory and logistics (I6)	High	High	High
Pre-erection outfitting (C3)	High	High	High
Module building (C1)	High	Medium	High
Status of purchasing and the supply chain (I1)	High	Medium	High
Dimensional and quality control (F8)	High	Medium	High
Supplier performance (I4)	High	Medium	High
Subcontract policy (I9)	High	High	High
Metrics and measures (K4)	High	Medium	High
Relationships with suppliers (I5)	High	Medium	High
Outfit steel (A11)	Medium	Medium	High
General storage and warehousing (B5)	Medium	High	Medium
Job and skills flexibility (H1)	Medium	High	Medium
Vendor furnished information (I7)	Medium	Medium	High
Process engineering (K3)	Medium	Medium	High
Production engineering (F6)	Medium	Medium	High
Ship design (F1)	Medium	Medium	High
Test and trials and setting to work (F10)	Medium	Medium	High
Painting (D7)	Medium	Medium	Medium
Manpower and organization of work (G1)	Medium	Medium	High
Pipe shop (B1)	Medium	Medium	High
Outfit parts marshalling (C2)	Medium	Medium	Medium
Materials handling (C6)	Medium	Medium	Medium
Outfit installation (D6)	Medium	Medium	High
Environmental control (E3)	Medium	Low	High
Attitude to change and new technology (K1)	Medium	Medium	High
Production control (G5)	Medium	Medium	High

Table 2.3 – Average technology gap (continued over page)

Element description	All yards	Large yards	Mid-tier yards
Stiffener stockyard and treatment (A2)			
Stores control (G6)			
Block assembly (C4)			
Minor assembly (A6)			
Erection and fairing (D2)			
Welding (D3)			
Staging and access (D5)			
Outfit scheduling (G4)			
Performance and efficiency calculations (G7)			
Curved and 3D unit assembly (A9)			
Layout and material flow (E1)			
Vendor recruitment (I3)			
Materials and equipment standards (I8)			
Organization for performance improvement (K2)			
Production management information systems (G9)			
Sub-assembly (A7)			
Master planning (G2)			
Flat unit assembly (A8)			
Coding system (F4)			
Steelwork scheduling (G3)			
Parts listing procedure (F5)			
Identification of sources of supply (I2)			
Steelwork production information (F2)			
Onboard services (D4)			
Outfit production information (F3)			
Training and education policy (H2)			
Stiffener cutting (A4)			
Plate stockyard and treatment (A1)			
Plate and stiffener forming (A5)			
Superstructure unit assembly (A10)			
Sheet metal working (B3)			
Electrical (B4)			
Storage of large/heavy items (B6)			
General environment (E2)			
Quality assurance (G8)			
Education and skill levels (H3)			
Purchasing procedures (I10)			
Unit and block storage (C5)			
Ship construction (D1)			
Lofting methods (F9)			
Machine shop (B2)			
Plate cutting (A3)			

Table 2.3 (continued) – Average technology gap

3 INDUSTRY PRODUCTIVITY

3.1 Productivity

Determination of the productivity being achieved by individual US shipyards or the industry as a whole is not part of this study. However, the increased use of industry best practice is likely to have improved productivity.

Past studies have established a correlation between the use of best practice and productivity. As the use of best practice increases, productivity increases. The correlation indicates that the overall improvement in the core productivity of the large yards should be about 10% since the GSIBBS and 20% for the mid-tier yards.

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 core productivity because there are disruptive influences that cause actual productivity to be lower. These include first-of-class effects, interference between contracts, facilities development, large variations in workload and others. 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, complex vessels, large variations in workforce size and high customer factors (see Section 3.2) tend to result in higher performance drop-offs. On occasion, the drop-off can be dramatic and unpredictable.

As was identified in FMI's findings for the GSIBBS, high customer factors and high levels of vessel complexity can contribute to a perception of low productivity. These are both areas where there appears to have been little change.

3.2 Customer factor

In the US and some other 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. This effect is referred to as the customer factor.

FMI's findings for the GSIBBS concluded that the customer factor resulted in an increase in overall work content of about 10% for US naval auxiliaries and 15% for surface combatants and that it was likely to be higher for submarines and aircraft carriers. There is no evidence from the current survey that the customer factor has reduced over the last ten years. There is potential to reduce this additional work content through a change in Government and DoD policies and procedures. This represents a substantial opportunity for performance improvement and is the subject of a separate study report.

3.3 Vessel complexity and specification

The trend toward increasingly complex vessels was also identified in FMI's findings for the GSIBBS and there is no indication that this is reducing. The principal driver of complexity and hence work content is the vessel's specification. The specification of the DDG 51 Class appears to have resulted in a design that has significantly more work content per unit of volume than a modern international destroyer. Part of the difference is related to capability but a substantial portion is due to the outfit density and general complexity of the vessel. Seawolf, DDG 1000, and increased automation on new vessels in general are also examples of the trend. Even LCS, the concept of which was for low-cost commercial vessels, have morphed into much more complex vessels than were originally intended.

Cost, risk, first-of-class performance drop-off, and the probability of cost and schedule over-runs all increase with vessel complexity. Therefore, if exposure to all of the above is to be minimized, overly complex vessels should be avoided. The continuing trend for complex vessels may not be giving the best balance between capability and value for money.

3.4 Shipyard incentives

One of the keys to encouraging performance improvement in the industry is to create an environment that encourages the shipyards to improve productivity. Traditionally, the mainstay of this has been competition between shipyards but also incentives built into contracts. However, competition is distorted by political influence, sole source situations and strategic considerations. FMI's findings for the GSIBBS included various suggestions for encouraging shipyards to improve and creating an environment that would encourage investment, such as a stable workload. In this study, these issues are discussed in the separate Government actions report.

Despite the reduced competitive environment, this study has confirmed that competition still exists in parts of the industry and that it certainly has a positive influence on productivity. It is also encouraging to see that there has been improvement in sole-sourced shipyards, even though this is sometimes in response to the reduced funding available to the Navy.

Finally, the results of this study indicate that an effective way to improve shipyard performance, reduce cost and provide a climate for investment is to stabilize the naval procurement program.

3.5 Support for performance improvement

A number of Government-sponsored schemes have been providing industry with information and financial assistance to support performance improvement efforts. At a national level, these include the National Shipbuilding Research Program (NSRP), the Navy Manufacturing Technology (ManTech) Program and its centers of excellence, particularly its shipbuilding center of excellence, and the Naval Shipbuilding and Advanced Manufacturing Center (formerly known as the Center for Naval Shipbuilding Technology). There are also several local schemes dealing with specialist areas. NSRP has been the cornerstone for industry performance improvement efforts for a number of years. The program has provided necessary research and a unique forum for discussion. Although it has been criticized in the past for developing technology that has not been implemented, there is no doubt that in recent years the support provided by NSRP has continued to play an important part in facilitating the improvements seen within the industry.

4 EDUCATION AND SKILLS SURVEY

4.1 Objectives

Benchmarking element H3, Education and skill levels, was extended by the study scope of work to include an education and skills survey with the following principal objectives:

1. Identify common workforce skills gaps and deficiencies across the industry
2. Identify potential skills shortages in the labor pool

The sections below describe the approach to the survey and present the findings and conclusions.

4.2 Methodology

The current workforce numbers and their education, training and experience were gathered from each shipyard using a questionnaire. The questionnaire, supplemented by shipyard interviews, was also used to gather information relating to the availability of personnel in the labor pool. 56 roles were included covering; commercial and administrative, technical/production management, engineering, production, and production support functions. A full listing is provided in Appendix 2.

To analyze and present the findings, the roles were consolidated into 27 skill groups, based on the type of work and the required skills and qualifications of each role. The groups are defined in Appendix 2. For the purpose of this study, the workforce is limited to shipyard personnel and subcontractors have not been included.

The levels of skills and experience have been assessed against benchmarks derived by FMI for the study. Skills shortages have been identified from information provided by the industry and supplemented by some additional analysis explained in the following sections.

4.3 Survey results

Consolidated data for the 27 skills groups is presented in Table 4.1. This shows that 59,133 personnel are employed in the US shipyards surveyed. Column D is a benchmark that shows the minimum number of years that an employee must have worked in the role to be considered experienced. It is not the number of years within the industry. Column E is a benchmark that shows the proportion of people that should have the required level of experience in Column D for efficient operations. Column F is the actual proportion of employees that have the years of experience shown in Column D. The benchmarks in Column D and E have been derived on the basis of consultant experience, from other benchmarking studies and through discussion with some leading European shipyards.

A	B	C	D	E	F
Skill group	**Number of people employed**	**Proportion of people with specific trade/ professional role-related qualifications (%)**	**Benchmark years of experience in role to be considered experienced (years)**	**Benchmark proportion with the minimum experience specified in Column D (%)**	**Actual proportion with the minimum experience specified in Column D (%)**
Commercial/administrative					
Facilities	624	90	3	25	84
Finance and accounting	547	98	2	25	87
General clerical	2,257	99	2	21	91
Human resources	901	99	2	50	88
Project, commercial & contract mgmt.	1,044	99	9	50	61
Purchasing and supply chain	1,014	98	5	50	72
Sales and marketing	63	100	5	50	78
Senior management	177	98	10	50	32
Technical/engineering					
Draftsmen	3,487	99	5	50	88
Engineering – electrical and weapons	1,255	100	10	50	47
Engineering – hull	1,413	100	10	59	46
Engineering – management	730	100	10	75	88
Engineering – mechanical	1,425	100	10	50	39
Engineering – support	1,503	98	4	25	83
Estimating, planning, and production and cost control	3,103	99	9	50	43
ILS and crew training	367	86	5	49	78
Production engineering and performance improvement	570	99	5	75	65
Production and production support					
Production – white collar	1,653	99	10	50	46
Production management & supervision	3,957	97	10	50	42
Electrician	4,934	94	5	28	56
Machinist	2,529	97	5	42	63
Painter	2,110	99	2	25	73
Pipe worker	3,184	97	5	50	52
Production support	5,858	99	2	29	85
Sheet metal, carpenter and insulation	3,683	96	4	25	59
Steelworker / Boilermaker	5,215	85	5	25	44
Welder	5,530	91	2	25	70
Industry totals:	**59,133**	**96**	**N/A**	**37**	**63**

Table 4.1 – Industry workforce size, skills and experience

4.4 Skills and qualifications

Ninety-six percent of the total workforce has specific role-related qualifications appropriate for their current positions. Employees either join the companies with the base skills required to perform their specific role or are provided with them prior to progressing onto the shop floor or place of work. Virtually all employees in the large shipyards have specific role-related qualifications. In the mid-tier shipyards, the overall average is 85% with a number of production disciplines being below this average. These include electricians, machinists, pipe workers, carpenters, and steelworkers.

Although a high proportion of the workforce has met shipyard standards, there is no industry-wide standard for role qualifications. Furthermore, the shipyard-defined qualifications, generally in the professional roles, may not align with nationally or internationally recognized standards.

In general, all engineers are expected to have a formal engineering degree. However, other professional roles are not as prescriptive regarding the qualifications required. For example, formal management training/qualifications are not generally required and supply chain managers are not always required to have relevant professional qualifications. That said, some senior and middle professional personnel have obtained the appropriate formal qualifications. The benefits of formal qualifications, in broadening an individual's outlook and introducing new ideas and up-to-date processes and practices, should not be overlooked. As proposed in Appendix 1 H3 – Education and skill levels, consideration should be given to establishing an industry-wide skills and qualifications requirements matrix.

4.5 Experience

In addition to having the necessary qualifications and training, a proportion of personnel in each role need to have previous role-specific experience relevant to the shipyard's product mix. The number of years of experience and the proportions vary by skill group. For example, engineers and production managers should have high levels of relevant experience while some supporting roles require very little vessel or role-specific experience. The experience benchmarks applied are defined in Section 4.3 and Appendix 2.

Table 4.1 columns E and F provide a comparison of current percentages versus benchmark-suggested percentages of employees having the benchmark-suggested years of experience. With 63% of the workforce having at least the benchmark experience levels required, overall the industry has good levels of experience. However, the survey identified a number of key disciplines where there is lower than the benchmark percentage of experienced personnel, as indicated by Column F of Table 4.1 being less than Column E. These include:

- Leadership, both senior and production management
- Engineering
- Estimating, planning, and production and cost control
- Production engineering and performance improvement

The trend is generally reflected equally across the large and mid-tier shipyards. However, the lower-than-benchmark percentage for the senior management skill group is specific to the large shipyards, where there have been recent changes. Although there are some appointments from outside of the industry, such positions are generally filled by promotion, which brings down the experience percentage. The lower percentage for production management relates to the test and trials management and the first line production supervision in both large and mid-tier shipyards. That said, the majority of these personnel are promoted internally and therefore have extensive shop floor experience. The lower percentages of experienced personnel could, in part, be due to a high retirement rate in recent years but it could also indicate skills shortages in the labor pool.

In general, there is a lower-than-benchmark percentage in the hull, mechanical and electrical disciplines of engineering across the industry. The detailed data behind the table shows combat systems and ship control engineering to have a high percentage of experienced shipyard personnel, although some shipyards subcontract this specialist area. Engineering management also has extensive experience, with nearly 90% industry-wide having at least 10 years' experience in their specific roles. However, with long intervals between design cycles, it is difficult to maintain the core design skills which are a key to constructing complex vessels and achieving high levels of productivity.

Within estimating, planning, and production and cost control, the detailed data shows that only 35% of the industry personnel in planning and scheduling have 10 years' experience. The mid-tier shipyards have a lower percentage than the large shipyards.

In production engineering and performance improvement there is a lower-than-benchmark percentage, predominantly within production engineering. However, with reference to Appendix 1, F6 – Production engineering, there has been an increased focus on this area over the last 10 years. If this trend continues, the knowledge and experience is likely to increase. Maintaining experience and knowledge is critical to having an effective production engineering function and achieving high levels of productivity.

Analysis at the shipyard sector level highlights some production trades where the percentage of experienced personnel is either above or marginally below the benchmark percentage. These include pipe workers in the large shipyards and steelworkers, electricians, machinists, sheet metal workers, and carpenters in the mid-tier shipyards. For the mid-tier shipyards, the proportion of experienced pipe workers is 15% below the benchmark percentage.

4.6 Skills shortages in US labor pool

There is a correlation between the experience of a workforce and the availability of suitable skilled and experienced personnel in the labor pool. A lesser experienced workforce would imply that experienced personnel are not readily available to be hired. This correlation is reflected in the findings of the survey, so skills groups with lower levels of experience are assumed to be generally in shorter supply.

The blue collar roles identified by the shipyards as requiring the recruitment of unskilled personnel to ultimately fill skilled positions or having major shortages of expertise are listed in Table 4.2.

Role	Apparent shortage	
	Large shipyards	Mid-tier shipyards
Steelworkers	✓	✓
Welders	✓	✓
Sheet metal workers	✓	
Mechanical fitters / outside machinists	✓	
Pipe workers	✓	✓
Electricians	✓	✓
Machine shop operators	✓	✓

Table 4.2 – Shortages in the production labor pool

The large and mid-tier shipyards reported difficulties in recruiting skilled and experienced personnel in all areas of production. In particular, a shortage of skilled steelworkers, pipe workers and welders was identified. In general, unskilled workers are recruited and trade-specific training is provided by the shipyards. For pipe workers, the current proportion of experienced personnel across the industry is also only marginally above the benchmark percentage. Although there is only a limited requirement for machine shop operators, they were also identified as being in short supply.

For white collar workers, there is currently no reported industry-wide major skills shortage. Compared to blue collar workers, there is a greater availability of skilled or partially skilled personnel. However, there are specific regional skills shortages. These include:

- planning and scheduling
- quality management and inspection
- electrical engineering
- welding engineering and metallurgy
- signatures and survivability
- information and communications technology

The correlation between experience levels and skills shortages means that there could also be some additional skills shortages in the labor pool. Although not highlighted by a number of shipyards as being in short supply, a review of Section 4.5 indicates that there could also be shortages in the following roles:

- structural engineering
- senior management
- production engineering
- production supervision
- mechanical and system engineering
- naval architecture
- estimating and cost control
- test and trials

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

When viewed as a whole, the industry has made some significant improvements since the GSIBBS and the gap with the 2004/2006 international shipyard averages has reduced or disappeared in many areas. However, the degree of improvement is variable and there remain opportunities to improve productivity. There are technology gaps in all element groups against the targets proposed in this study.

The FMI report “Findings for the Global Shipbuilding Industrial Base Benchmarking Study, Part 1: Major Shipyards”, dated August 2005, stated that the industry was generally well equipped to achieve internationally comparable levels of productivity in naval construction. However, it stated that there were major opportunities for improvement in the ‘soft’ areas including design, production engineering, planning, estimating, inventory and logistics, accuracy control, and manpower and organization of work. Deficiencies in these areas result in low productivity even though shipyards may be well equipped. They also lead to high levels of inherent work content, high first-of-class performance drop-off, and poor cost and schedule adherence. There has been significant improvement in the soft areas but deficiencies that have become apparent in production, such as being unable to achieve the planned level of advanced outfit, particularly on a first-of-class, all have their roots in the soft areas and probably to some extent the Navy. Therefore, even though there has been improvement, further development would be beneficial.

There is still a need to invest in infrastructure in some shipyards, particularly in the high investment areas such as construction points and block assembly buildings but also in some lower cost areas. However, any reductions or uncertainties in the Navy’s future shipbuilding plans would make such investments more difficult to justify. The industry also needs to engage with the unions to encourage them to update their practices and achieve alignment with the common goal of having a productive, sustainable industry that can efficiently satisfy the country’s needs. There are also some skills shortages that need to be addressed and relatively low levels of experience in some important job functions.

The adverse influence that the Navy and Government can have on shipyard performance does not appear to have diminished and there are opportunities to make improvements. In addition to reducing the burden on shipyard operations, the Government needs to provide an environment that encourages shipyards to improve. Currently, competition between the yards is an important factor and, where work is single-sourced or allocated, it becomes much more difficult to encourage improvement and sustain continuous development. That said, some shipyards have gone a long way toward achieving this.

5.2 Priority areas for improvement

Suggested targets and technology gaps are explained in Section 1.6. The average technology gap and the additional criteria listed below have been used to produce a list which prioritizes the elements for industry-level action. The intent of this is to provide a guide; specific opportunities need to be tested by cost/benefit analysis. The criteria are:

1. The size of the gap between the average current score and average target (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 near term results).
4. The typical cost of raising the level of technology in the area concerned (high priority given to low cost items).

The approach to prioritization is similar to that used to produce the prioritizations for individual shipyards, except that it is based on average industry technology gaps and not the gaps in individual shipyards. Therefore, high priority elements in individual shipyards may not necessarily be ranked highly at industry level. Several prioritization approaches have been trialed and the results are similar. The resulting ranking of the top twenty elements at industry level is shown in Table 5.1. The color coding for the technology gaps is the same as that applied in Table 2.3. Appendix 3 contains the full list of priorities for each sector.

Rank	Element	Technology gap	Large rank	Mid-tier rank
1	Design for production (F7)		1	4
1	Dimensional and quality control (F8)		2	1
3	Process engineering (K3)		2	7
4	Pre-erection outfitting (C3)		7	2
5	Manpower and organization of work (G1)		2	11
6	Outfit installation (D6)		9	4
6	Inventory and logistics (I6)		5	11
8	Production engineering (F6)		7	16
8	Attitude to change and new technology (K1)		10	7
10	Subcontract policy (I9)		5	19
11	Vendor furnished information (I7)		12	11
11	Metrics and measures (K4)		15	4
13	Production control (G5)		17	7
14	Job and skills flexibility (H1)		10	24
14	Test and trials and setting to work (F10)		14	19
16	Ship design (F1)		15	19
17	Outfit parts marshalling (C2)		12	27
17	Master planning (G2)		18	16
19	Module building (C1)		29	2
20	Status of purchasing and the supply chain (I1)		26	7
20	Organization for performance improvement (K2)		18	19

Table 5.1 – Industry priorities

Suggestions for improving individual shipyards have been included in the individual shipyard reports and suggestions for industry-wide actions by element have been made in Appendix 1. The top five priority elements in Table 5.1 have been combined with other, closely related high-priority elements to form the five industry-wide priority action areas below.

- Ship design and design for production
- Dimensional and quality control
- Production and process engineering
- Pre-erection outfitting, outfit installation and module building
- Manpower, organization of work, and job and skills flexibility

These are discussed in the following sections with suggestions made for industry-wide, Government and collaborative initiatives. Although the industry has made progress, some of the priorities are similar to those identified in FMI's findings for the GSIBBS. Many of the suggested actions are also still valid but they have been updated to reflect current circumstances where applicable.

As was highlighted in FMI's findings for the GSIBBS, the responsibility to implement the majority of the suggested improvements principally lies with the industry. However, Congress, the Navy and other Government departments will need to facilitate changes in some areas and could take other actions to assist. These are discussed in a separate report.

The scope of the suggested initiatives is limited to the elements of the benchmarking system included in the study. There may be other areas that require attention that are not discussed here. The industry already has several improvement programs in place. It is recommended that the scope of the current initiatives and programs be reviewed in the context of the findings of this study.

5.3 Ship design and design for production

The shipyards have well-established design and engineering organizations. In general, a system-oriented design approach is adopted, although the development and implementation of product-oriented design is progressing. There have been improvements in developing and documenting design rules and guidelines and incorporating design for production practices for optimum producibility. However, design processes are often inconsistent and project based. Man-hour expenditure can be high and design lead times long. International shipyards have a standard approach to ship design for all vessel types with well-defined design stages and clearly specified outputs for each stage, including design for production elements. In addition, long intervals between design cycles in the US reduce the opportunities for applying design for production principles, introducing new methods and maintaining core design capability. Maintaining the technical workforce is of particular concern with regard to the future capability and performance of the industry, which was also mentioned in FMI's findings for the GSIBBS.

At the shipyard level, each yard should have a formalized and consistent design and engineering strategy from which design rules and guidelines are developed for each stage of the design process in order to optimize production performance. It is also important that for each design rule and guideline the impact of non-conformance is clearly defined in terms of production cycle time, man-hours and performance.

At an industry level, to improve ship design and design for production performance the following actions are proposed:

1. Develop a standard, rationalized and consistent design approach to be applied to all Navy vessel types.
2. Establish and execute a Navy-industry strategy to incrementally develop and introduce new design and engineering methods suitable for Navy vessels and maintaining core design capability. This would start with R&D projects building confidence to redesign selected portions of legacy designs, with the goal of frequent design upgrade cycles that reduce total design and production costs.
3. Establish with the Navy multi-yard design for production standards for vessel design, including the earliest design stages, which enable the individual building yards to continue the detail design for optimum producibility.
4. Apply the above improvements with increased Navy and industry cooperation to smooth demand and stabilize employment of the technical workforce.

5.4 Dimensional and quality control

The majority of the US shipyards have well-established accuracy control (AC) and quality control (QC) departments with well-defined procedures. There have been improvements in implementation of the procedures. Despite this, there appears to be a low level of confidence in the use of statistical evidence to modify production processes and improve performance. Accuracy and distortion issues cause substantial rework and increase the levels of work left undone until a later, more costly stage. Affected work includes outfitting, insulation and paint. The practices of added material and weld hold-back on stiffeners are common to compensate for possible inaccuracies. The removal of added material is rework as the edge of the plate has to be recut. This is particularly costly on vessels with minimized scantlings.

The schedule impacts and true costs of poor accuracy, quality and distortion control appear to be underestimated and they are not generally recognized as being key aspects of performance improvement. There is still a general acceptance of rework as being an inherent part of the US shipbuilding process. This is not the case in leading international shipyards which have adopted a total quality approach and many no longer have dedicated AC and QC departments. AC and QC requirements are fully integrated into pre-production and production activities with cross-functional teams meeting at regular intervals to resolve problem areas.

Based on the overall impact to the build strategy, the outfit and paint strategy, and the ship assembly time, the following industry-level actions are proposed to assist the shipyards to make the necessary improvements:

1. Promote awareness of the schedule impacts and true costs of non-value-added 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 35 years.
3. Promote the use of statistical analysis as an intrinsic part of the performance improvement process.
4. Conduct an integrated study to improve dimensional and distortion control processes through ship design, block breakdown, welding and other technologies.

5.5 Production and process engineering

In all the foreign yards surveyed in 2004, the production engineering function led the development of both the technical and production methodologies and processes. These include key performance improvement activities such as design for production, facilities development, and the development of shipbuilding and build strategies. Although many US yards have established and increased the production engineering function, it has not reached the levels needed to achieve an integrated design-production strategy and product-oriented operations. The use of legacy designs also limits the opportunities for shipyards to introduce and implement new production engineering methods. This leads to designs being improved for producibility rather than being optimized. The lack of strong production engineering remains one of the major contributors to poor performance in US yards. The issue needs to be addressed by the Navy, at an industry level and within the individual shipyards.

Process engineering is a companion function that leads development of yard-wide methods and processes. Progress has been made in this area too, especially for localized process improvement activities. However, the overall benefits are limited by the lack of strong production engineering.

The industry needs to further develop a strong production engineering function and it is recommended that this should be encouraged at industry level by:

1. Developing a shipbuilding industry production engineering charter defining the role and functional responsibilities of production engineering in US shipyards and the Navy.
2. Developing a production engineering training and certification program that can be recognized by the Navy and will provide a basis for incentives.
3. Introducing a production engineering requirement for future ship acquisitions and design projects with demonstration of the developing production methodology at each stage of design.
4. Conducting regular upgrades of legacy designs in selected ship areas to incorporate up-to-date production engineering principles.

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

5.6 Module building, pre-erection outfitting and onboard outfitting

There has been considerable improvement in the overall average score of these three interrelated activities but the range of use of best practice in US yards remains wide. These elements still have a high priority because there are some technology gaps and each of these has a very significant impact on the cost of outfit-intensive vessels. With regard to module building, although the shipyards are at different stages of development, in general the industry needs to:

1. Make more use of outfit modules (the assembly of functionally-related outfit components onto a frame).
2. Improve the design of outfit modules to include more cold outfitting and testing.
3. Make modules larger.
4. Redesign more areas of legacy designs to take advantage of outfit modules.
5. Develop the design process to inherently incorporate outfit modules.

Some shipyards have shown that they can achieve a very high level of advanced outfitting but not always in good environmental conditions or in the most appropriate orientation. In general, the amount of advanced outfit installed still needs to be maximized and the conditions and orientation optimized. However, the principal weakness is that the planned levels of outfit do not tend to be achieved on a first-of-class or vessels early in a series. This is generally due to weaknesses in design, planning or the timely supply of equipment and materials. Specification stability and systems development also have a major impact. One action that the industry could take to improve this is to define the optimum naval design and pre-production processes required to support advanced outfitting and outfit module construction. This should include the naval ship definition processes. Key design rules that facilitate high levels of pre-outfitting applied at each stage in the process could also be included.

A high level of module building and pre-outfitting reduces the amount of outfit that is installed at the more expensive onboard stage. The remaining onboard outfitting needs to be completed by zone-by-production-stage, then by system to facilitate testing and setting to work. Flexible multi-disciplinary teams can help facilitate this. The industry could research the optimum approach to the use of these teams and work to overcome any union barriers that may still exist. It could also research what the optimum manning densities are at each stage, as currently this is not routinely measured.

Clearly painting, hot work and outfitting are strongly related. Developing any of these areas will require corresponding changes in the others. One aspect that appears lacking is research and subsequent implementation of outfitting approaches that reduce the dependency on hot work. Also, it appears that some naval legacy outfitting-related rules would benefit from review.

The need for research in this area has been identified by the industry as a whole and research into some aspects is currently being undertaken or has recently been completed. This includes NSRP projects in flexible infrastructure, adhesive hangers, standardized warfare system interfaces, and electronic modular enclosures. Also, there have been ManTech projects in outfitting sequencing and scheduling, improved stud fixtures, and outfitting tools and processes. The timing of these projects means that there has been limited opportunity for them to have noticeable impact.

5.7 Manpower and the organization of work

Although a few yards have scored relatively well in this element, the average score has reduced since 2004, meaning that the industry now lags further behind the international yards. There is also now a significant gap between the rating for this element and all of the other elements in the Organization and operating systems group. To improve, the industry as a whole needs to:

1. Remove all trade demarcation.
2. Increase levels of flexible working.
3. Fully implement workstation organization and product-oriented operations.
4. Make more use of multi-disciplinary teams.
5. Fully implement area management through the whole organization.
6. Stabilize employment levels.
7. Make more proactive use of subcontractors.

As discussed in the FMI's findings for the GSIBBS, most US yards are aware of the benefits of making improvements. Some progress has been made toward product-oriented approaches in pre-production and production. However, flexible, multi-disciplinary teams will be required to realize the full benefits and this will need the full cooperation of the workforce, middle management and the unions. The Government could also assist by working in partnership with the industry to continue to smooth demand and provide more stable employment. This in turn would allow the yards to focus more on the well-being and long-term development of their employees.

5.8 Facilities and equipment investment priorities

For the industry as a whole, performance improvement and investment projects that address the priorities listed in Table 5.1 and Appendix 3 are likely to be worthwhile investments. Fully closing the technology gaps in some of these areas will require investment in hardware and facilities. Often though, the benefits that can be derived from developing the generally more cost-effective soft areas need to be maximized before investing in equipment and facilities. Also, in some instances, a change in the soft areas is required to fully realize the benefits from facilities development.

Specific FMI facility and equipment suggestions have been included in each shipyard's benchmarking report. To provide an industry overview, the key recommendations are summarized below. The recommendations are sorted by relevance, i.e., the commonality between shipyards and their priority rankings.

Material handling and storage: Material handling and storage improvements of various sorts have been recommended in all the yards surveyed. The suggested investments include:

- Purpose-designed stackable pallets and trestles
- Purpose-designed handling and manipulating equipment
- Conveyors
- Block movement systems
- Warehouse automation, NC picking and high volume storage

Unit and block assembly: Investments relating to flat unit, curved unit, superstructure and block assembly, and outfitting have been suggested in a high proportion of the yards. The suggested investments include:

- Additional covered area to reduce outdoor working
- Temporary covers to allow more sensitive outfit to be installed
- Product-specific assembly workstations
- Automation/mechanization of edge preparation, welding and grinding processes
- Panel line material handling improvements
- Access and supporting arrangements

Welding: Increased levels of mechanized and automated welding and robotic welding in workshops have been suggested in a high proportion of the yards. Welding R&D facilities are also required in some yards. Additional product standardization will be required to justify increased automation in some areas.

Module building: In about half of the yards, high priority facility investment suggestions have included establishing or expanding purpose-designed facilities to assemble outfit modules on current and future designs.

Support and services: Improvements in construction support and services in the grand blocking, construction and post-launch stages of construction have been recommended in a high proportion of the shipyards. The suggested investments include:

- Temporary covers
- Purpose-built, pre-erected, and permanent staging and modular solutions
- Personnel access to higher elevations which includes escalators
- Services support towers and gantries
- Ventilation and air conditioning

Workstation organization: Improvements in workstation operations in minor assembly, sub-assembly, and outfit steel and aluminum manufacturing have been suggested in a high proportion of the shipyards. This will require some investment in facilities and some equipment such as mechanized material handling, positioning fixtures, manipulators, and automated or robotic welding. In most of the shipyards, an enabler to the improved mechanization/automation is the further development of interim product families and design for production.

Pipe shop: Opportunities to improve pipe shop performance through investment in equipment and facilities has been identified in a high proportion of the yards. In most, an enabler to the increased automation is the introduction or expansion of pipe piece family manufacturing. The suggested investments include:

- Automated pipe storage and loading into the shop
- Automated pipe measuring and cutting
- Robotic straight pipe production line
- Purpose-designed assembly cells based on pipe piece families
- Automated pipe welding

Construction points: A few shipyards require investment in their construction points, particularly if difficulties in the efficient construction and launching of heavily outfitted ships are to be overcome. Other improvements include increased erection crane capacities, environmental protection, and access for people and materials.

APPENDIX 1 – USE OF BEST PRACTICE IN US SHIPYARDS

A STEELWORK PRODUCTION

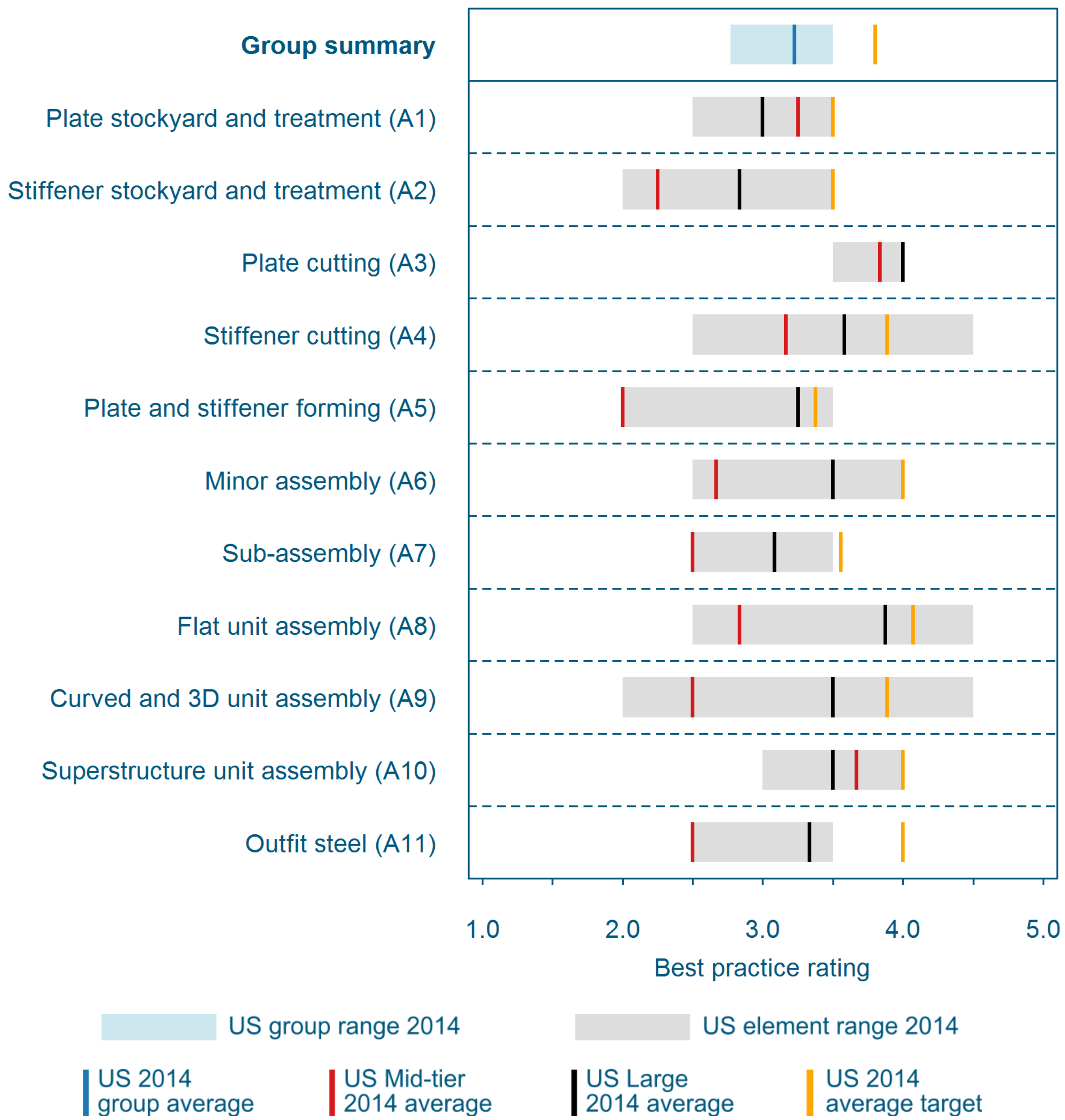

Figure A1.1 – Steelwork production

A1 Plate stockyard and treatment

The technology applied to the plate stockyard and treatment process by the large US yards has increased a small amount since the last survey as equipment has been modernized in some yards and there has been some progress in the use of weldable primer. Inventories still tend to be high with a large variety of plate sizes, thicknesses and grades requiring a large, outdoor storage area and excessive handling. As previously recommended, this major weakness needs to be addressed through rationalization of scantlings on new vessel designs and increased use of standard plate sizes. It is also important for the yards to look at opportunities to purchase treated plate, to increase coordination of acquisition with other yards, and to consider establishing regional supply centers. The mid-tier yard average has increased with instances of increased outsourcing and undercover storage. However, both sectors are below the 2004/2006 international averages and 2014 average targets.

Proposed actions

- Study increased standardization of scantlings for future designs
- Examine increased coordination of purchasing across shipyards
- Promote the development of regional treated plate supply centers ideally serving multiple yards with increased plate standardization

A2 Profile stockyard and treatment

In 2004/2006, the stiffener stockyard and treatment technology in both US sectors was below that applied to plate and well below the international and target averages. It has increased since that time, with this element having the largest increase in the structural production group for the large yards. There are instances of reduced stiffener variety through redesign, increased outsourcing of the storage and treatment process, and improved treatment equipment and process controls. However, this element still has the lowest average score in the group for large yards and is well below the 2004/2006 international and 2014 target averages in both sectors. Inventory and variety are high in most yards and storage arrangements and handling equipment tend to be only marginally acceptable from the standpoints of efficiency, quality and distortion avoidance. As with plates, reduction of inventory and variety are key enablers to improving this process. It is also important for the yards to consider the purchase of treated stiffeners, to increase coordination of acquisition with other yards, and to assess establishing regional supply centers.

Proposed actions

- Study increased standardization of scantlings for future designs
- Examine increased coordination of purchasing across shipyards
- Promote the development of regional treated stiffener supply centers ideally serving multiple yards with increased stiffener standardization

A3 Plate cutting

The level of applied technology in plate cutting is high across the industry as it was in 2004/2006. The large US yard average is at the 2014 target level and just below the 2004 average for large international yards, while the mid-tier yard average has increased and is approaching its corresponding 2006 international and 2014 target averages. The yards tend to have modern equipment, good dimensional controls and low work in process in the cutting areas. However, excessive edge grinding appears to be a common issue that would benefit from requirements clarification and basic automation.

Proposed actions

- Study methods to reduce edge grinding costs

A4 Profile cutting

There is a very wide variety of stiffener cutting technology used by the large US yards, from labor-intensive manual marking and cutting to state-of-the-art robotics. Although individual yard scores may have increased or decreased, the average is unchanged and is below the 2004 large international yard average and 2014 target. There has been a large improvement in the mid-tier yards with higher levels of automation commonly being applied. This sector now exceeds the 2006 mid-tier international yard average and is making good progress toward the 2014 average target. It appears the need to split or de-flange rolled members has been reduced by design and it is often outsourced. As with plate, excessive edge grinding appears to be a common issue that would benefit from requirements clarification and basic automation.

Proposed actions

- Study methods to reduce edge grinding costs

A5 Plate and profile forming

Plate and stiffener forming equipment varies greatly across US yards but is often old and forming methods tend to be traditional, i.e., cold forming with computer-generated production information. Some yards have line heating capabilities but their application is limited on thin steels and some special grades. It appears that the need to form stiffeners has been reduced by design as well as the need for complex curvature in plate. The large yard average has increased a small amount, enough to exceed the 2004 large international yard average. It is now approaching the 2014 target. The mid-tier average has not increased and is well below the 2006 mid-tier international and 2014 target averages. While the approach in most yards is adequate for their current product mix, it appears to be not especially efficient. It could be improved if increased volumes were produced in region centers. The issues are principally yard-specific process development and facilities investment issues.

Proposed actions

- Promote the development of regional specialist forming centers

A6 Minor assembly

The yards use various methods to accomplish minor assembly including in some cases mechanized lines, automated welding, well-organized work centers, and traditional worktables. There is little change from the previous scores and the US average is well below the 2004/2006 international and 2014 target averages in most cases. Recurring features are that minor assembly is not commonly recognized as a distinct stage and the wide variety of interim products has not been rationalized through a production engineering process. Accordingly, there is only limited use of purpose-designed fixtures, mechanized fairing aids and machine welding.

Proposed actions

- See proposed actions in F6 – Production engineering

A7 Sub-assembly

The large US yard average for sub-assembly has seen little change and is below the 2004 large international yard and 2014 target averages. The mid-tier average has increased and now exceeds the 2006 mid-tier international average but is still below the 2014 average target. The level of sub-assembly technology is mixed across the US industry and often within individual yards, where there may be instances of automation within a majority of traditional methods. There are good examples of mechanized lines, automated welding and well-designed work centers. However, sub-assembly tends to be treated as a single class of work rather than rationalized into interim product families with purposed-designed solutions for each. It appears that the lack of design standardization results in a lower expectation for automation than would actually be justified. Accordingly, there is only limited use of purpose-designed fixtures, automated welding, and mechanized fairing aids and manipulators.

Proposed actions

- See proposed actions in F6 – Production engineering

A8 Flat unit assembly

The flat unit assembly element is not assessed for submarine builders. For surface ships, there has been a small increase in the large yard average and it is now higher than the 2004 large international yard average and approaching the 2014 average target. The mid-tier yards have had a large increase in average score due to improved facilities and fixtures. They are now nearly equal to the 2006 mid-tier international average but remain well below the 2014 target. Most large US yards have moderate to high levels of mechanization in their panel lines but unit assembly methods are more conventional in both sectors with low levels of mechanization. Shop areas and moving lines dedicated to the assembly of unit families are uncommon. In many cases, units are assembled and outfitted outdoors due to a lack of, or sub-optimal utilization of, shop areas.

A notable positive is that both sectors appear to have increased the amount of early integration of outfit and structure. Dimensional and distortion control are also getting more attention in most of the yards. However, there should be an increased focus on the reduction and elimination of allowances made for interim product inaccuracies. Based on the overall impact to the build strategy, the outfit and paint strategy, and the ship assembly time, the industry would benefit from additional studies to improve dimensional and distortion control through ship design, block breakdown, welding and other technologies.

Proposed actions

- Study integration of ship design, block breakdown, welding, and other technologies to improve dimensional and distortion control

A9 Curved and 3D unit assembly

The common characteristic of curved and 3D unit assembly is the use of fixed position workstations with telescopic jigs or solid plate jigs for surface ships and purpose-designed mechanized fixtures for submarines. Submarine builders use higher technology and there is, therefore, a higher average and range of scores among the large US yards than there would otherwise be. However, the gap between the large yard average and their 2014 average target is among the largest in the structural production group, indicating opportunities for improvement exist. The mid-tier yards have had a large increase with improved facilities and fixtures but are below the 2006 mid-tier international and 2014 target averages.

The application of mechanized assembly lines may be hard to justify with the relatively low level of output from most US shipyards. However, creating indoor shop areas dedicated to the assembly of unit families is likely to be beneficial. Further, some yards are sensibly focusing on low cost improvements such as dimensional and distortion control and increasing the use of non-welded fairing aids in assembly. As discussed in A8 – Flat unit assembly, the industry would likely benefit from additional studies to improve dimensional and distortion control through ship design, block breakdown, welding and other technologies. Further development and use of stud and non-welded aids is also recommended in their applications to all structure and outfit assembly, outfit installation, and erection processes.

Proposed actions

- Study integration of ship design, block breakdown, welding, and other technologies to improve dimensional and distortion control
- Conduct industry-wide investigations of available stud- and non-welded aids, jigs and systems

A10 Superstructure unit assembly

This element is not assessed for submarine builders. For surface ships, the approach to superstructure unit assembly and outfitting in most of the US yards is generally consistent with their approach to other units. However, considering the superstructure's position in the erection sequence and its impact on ship testing, higher levels of pre-erection completion are likely to be beneficial. This can be facilitated by a dedicated indoor shop area, purpose designed for pre-erection superstructure completion. Although there has been a small increase in the large yard average and it is now approaching the 2004 large international yard average, it is below the 2014 target. For the mid-tier yards, there has been a large improvement with higher levels of undercover superstructure assembly and pre-erection outfitting. This sector now exceeds the 2006 mid-tier international yard average and is making good progress toward the 2014 target. The remaining issues are principally yard-specific process development and facilities investment issues.

Proposed actions

- No industry-wide collaborative initiatives proposed

A11 Outfit steel

There has been little change in the technology applied to manufacturing outfit steel/aluminum components in US yards. The averages in both sectors equal or exceed the 2004/2006 international averages, although they are well below the 2014 target with this element having the largest technology gaps in the structural production group. Almost all the international shipyards surveyed in 2004/2006 subcontracted the fabrication of outfit steel/aluminum components. This includes such items as minor foundations, small hatches, doors, ladders, walkways, companionways, railings, etc. Many US shipyards still do this work in-house using a wide range of technology. There is some automation but majority is manufactured using more traditional methods. There would be benefits in simplifying and standardizing the items produced and, where improved manufacturing technology cannot be justified, developing additional outsourcing alternatives, perhaps to a regional center.

Proposed actions

- Study opportunities to simplify and standardize outfit steel/aluminum components
- Promote the development of high-tech regional centers for the production of a rationalized range of outfit steel/aluminum items

B OUTFIT MANUFACTURING AND STORAGE

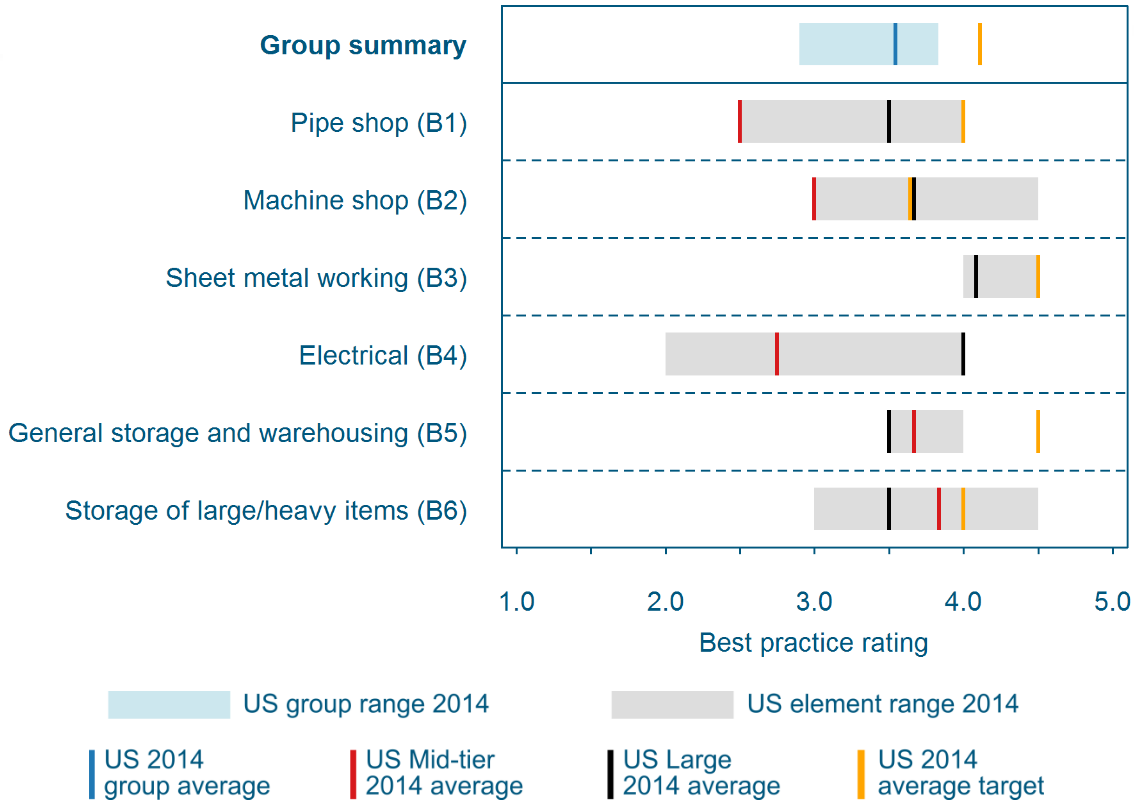

Figure A1.2 – Outfit manufacturing and storage

B1 Pipe shop

There has been an increase in the large US yard pipe shop average and no change in the mid-tier average. Both sectors are still above the 2004/2006 international averages and are below the 2014 target. There are improvements to be made in the pipe shops but a pre-requisite to major advances is reducing the variety and complexity of the spools through improved design practices. The pipe shops currently use relatively low levels of automation and few yards are using manufacturing cells focused on pipe families. Lean initiatives have been undertaken in several yards. Work in process varies across the industry from low to very high. Necessary actions are principally yard-specific product rationalization, variety reduction, process development and facilities investment issues.

Proposed actions

- Re-visit NSRP reports on pipe piece family manufacturing and design for production

B2 Machine shop

While most international new construction shipyards do not have a major machine shop, submarine builders and ship repair yards generally do. If a machine shop is operated, it would ideally be arranged in a cellular layout for producing a predetermined range of products and include specialized material handling equipment. To be highly efficient, it would require a high throughput of similar work. Most US yards' requirements can be characterized as job shop type work of low throughput and high variety with outsourcing alternatives existing for a majority of the work types. The large yard average has increased a small amount; it is still above the 2004 large international yard average and near the 2014 average target. Mid-tier yards outsource a substantial portion of new construction machine shop work. The issues are principally yard-specific questions of outsourcing versus facilities investments.

Proposed actions

- No industry-wide collaborative initiatives proposed

B3 Sheet metal working

Nearly all leading international shipyards outsource the manufacture of sheet metal products. Subcontracting of onboard installation work, including HVAC, is not uncommon. All of the large US yards maintain a substantial sheet metal shop although some have successfully outsourced duct and other sheet metal manufacturing. While individual yard scores may have increased or decreased, the average is unchanged and is above the 2004 large international yard average. However, it is below the 2014 target, which was increased from the 2004 target due to the increased affordability of automated equipment in recent years. The yards tend to have moderate to high levels of technology for cutting and forming but low levels for the downstream assembly and welding processes. As with pipe work, an enabler of major advances is to reduce the variety and complexity of duct and other sheet metal work through improved design practices. This would benefit both in-house and outsourced work. This element is not assessed for the mid-tier yards, as they outsource the majority of sheet metal work and have little or no sheet metal shop facilities.

Proposed actions

- Consider studying methods to simplify and standardize sheet metal work

B4 Electrical

There has been little change in the average electrical score for either US sector although individual yard scores may have increased or decreased. The large yard average is at the 2014 target level and above the 2004 large international yard average. The mid-tier average is well below both the 2006 mid-tier international yard average and the 2014 target. With the exception of wire ways, almost all electrical manufacturing in leading international yards is outsourced. The US yards vary greatly in the degree to which they outsource this work and the level of in-house technology applied. A contributing factor is the variable degree to which cable lengths and small item installation details are defined by the design and production feedback processes.

Proposed actions

- No industry-wide collaborative initiatives proposed

B5 General storage and warehousing

There has been little change in the large US yard average for general storage and warehousing. It is below the 2004 large international yard average and well below the 2014 target with the largest gap within the outfit manufacturing and storage group. Within this group, the large yard averages are above the 2004 international averages in all four of the shop elements but below them in both of the storage elements. This indicates an opportunity to focus on material-related issues. The mid-tier yard average is unchanged, just below the 2006 mid-tier international average and below the 2014 target.

Most US shipyards run proficient but conventional warehouse operations. Inventory levels tend to be very high, staffing levels tend to be high and additional off-site warehouse space is often used. There is limited use of just-in-time deliveries. Material is often handled a large number of times between the supplier and the point of use. There is some use of line-side stores and limited instances of supplier replenishment or direct delivery to the point of use. The use of barcoding and parts kitting both appear to have increased.

Proposed actions

- Study contractual and other factors that encourage delivery of materials earlier than required, including GFE, and develop alternative solutions

B6 Storage of large/heavy items

Although the advantages of just-in-time delivery of large and heavy items are recognized in most large and mid-tier US yards, some appear to store these items for considerable periods prior to installation. One of the reasons for this is poor schedule stability and adherence but the desire to guarantee material availability is also a factor. Another may be contractual arrangements that encourage early delivery or require extended storage of GFE. There is an increase in the large yard average for this element, which is approaching the 2004 large international yard average and is below the 2014 target. The mid-tier yard average is unchanged, just below the 2006 mid-tier international average and below the 2014 target. Some shipyards have purpose-built facilities to store large and heavy items and some use makeshift arrangements. Quality assurance and preventive maintenance processes appear to be well established in most yards.

Proposed actions

- Study contractual and other factors that encourage delivery of large and heavy items earlier than required, including GFE, and develop alternative solutions

C PRE-ERECTION ACTIVITIES

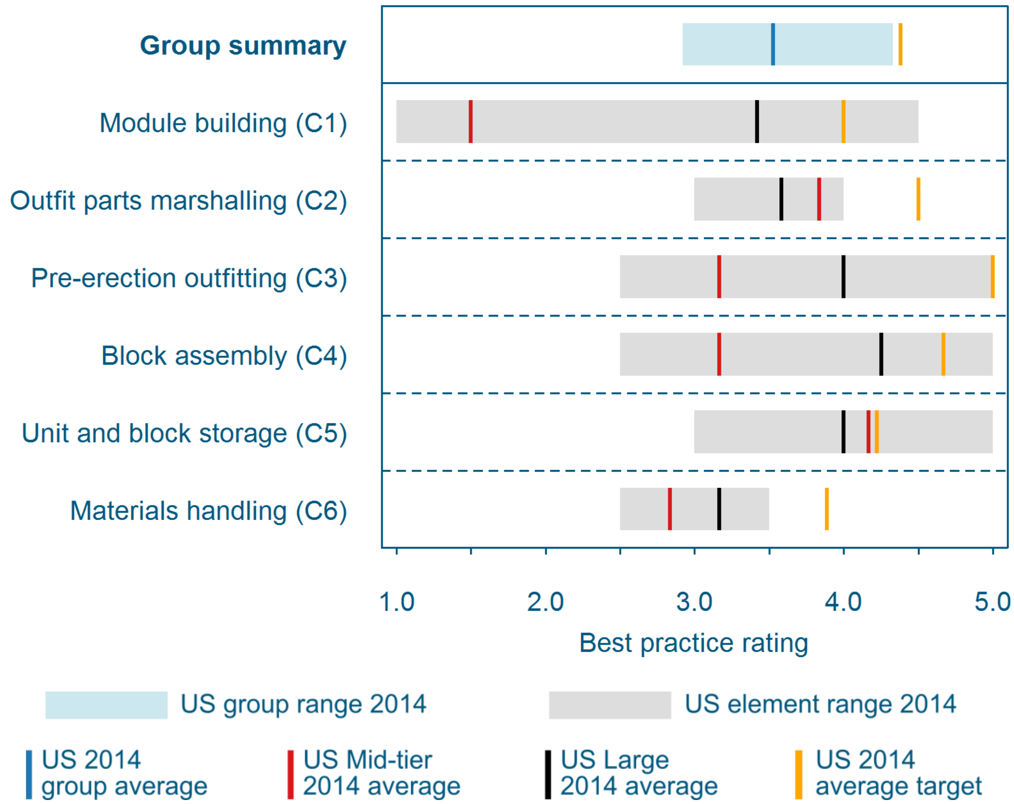

Figure A1.3 – Pre-erection activities

C1 Module building

In some large yards there has been an increased level of attention given to the use of outfit modules which has led to an increased overall average score. The average for the large yards is now close to the 2004 international yard average but the mid-tier average has not changed. Both averages still fall short of the proposed targets.

The number of outfit modules used on new designs has increased and there are now some dedicated module assembly facilities. Attention is also being given to retro-fitting outfit modules on some legacy designs. The design of some modules needs to be improved to reduce weight and move more work to earlier stages of construction. In general, the use of this technique needs to be extended and the benefits need to be realized in the mid-tier.

As was the situation at the time of the last survey, although most of the yards are aware of the benefits of module building, it is felt that few are familiar with the design techniques that make module building highly efficient and effective. One of these techniques is spatial design which allocates volumetric space to functions, such as an outfit module, from an early stage in the design. Whichever design approach is used, the key is to identify outfit modules from an early stage.

Proposed actions

- Undertake a short study to define module building benefits by ship type
- Develop design guidance for outfit module definition
- Investigate the feasibility of regional module assembly facilities
- Also refer to comments in F6 – Production engineering
- The Navy should consider the cost benefits of funding redesign of legacy vessels to produce modules

C2 Outfit parts marshalling

There has been a small reduction in the large yard average as some of the outfit parts marshalling systems now contain higher levels of inventory (buffer storage), longer lead times and higher levels of material handling. However, there has been significant improvement in the mid-tier yards with far more emphasis now being placed on supporting production through outfit parts marshalling, although some aspects of data processing are still relatively manual. The mid-tier average is now higher than the international mid-tier average in 2006. Although most of the large yards surveyed operate an effective outfit parts marshalling system, the benchmarking score still lags behind the 2004 international large yard average. There is still a technology gap in both sectors between the average score and the proposed target.

Proposed actions

- Expand on the guidance provided as part of this study to produce a short manual that explains the optimum characteristics of an outfit parts marshalling system that can be implemented in individual shipyards

C3 Pre-erection outfitting

The benefits of pre-erection outfitting are well understood in the US shipyards and the levels being achieved have progressively increased since the last survey. However, the degree to which this is successfully achieved and the workshop conditions vary across the shipyards. The US average score now exceeds the 2004/2006 international score in both sectors. However, the US averages still lag behind the proposed target. In general, the design process needs to be improved to facilitate achieving the planned levels of advanced outfitting on a first of class. Also, some facilities require further improvement to support higher levels of advanced outfitting and this will require a review of the shipbuilding strategy and overall process flow in some yards.

Proposed actions

- Develop an ideal naval ship design process that will facilitate high levels of advance outfitting on a first of class and can be implemented in individual shipyards

C4 Block assembly

There has been a small improvement in the approach to block construction in both sectors. The majority of the US yards adopt a natural block breakdown and average block size has increased. However, block sizes are still sub-optimal in some yards due to erection cranage limitations. Most of the yards have purpose-designed block assembly facilities. The average ratings for both sectors are now slightly ahead of the 2004/2006 international shipyard averages. Increasing block size, improving accuracy control, removing excess material prior to assembly, and applying an advanced outfitting methodology are required to achieve the proposed target.

Proposed actions

- No industry-wide collaborative initiatives proposed

C5 Unit and block storage

The need for unit and block storage is reducing in some yards due to better production planning and improvements in facilities. Therefore there have been small improvements in the scores in both sectors. Most of the US yards have block storage areas and transport arrangements comparable with international yards and the US averages are now ahead of the 2004/2006 international averages. Most yards have well laid out and serviced block storage areas. Typically blocks are moved using self-loading transporters. In most yards, the level of block storage prior to erection is relatively low although in a few it is excessively high, with too much reliance being placed on the need for production buffers.

Proposed actions

- No industry-wide collaborative initiatives proposed

C6 Materials handling

Overall, there has been a small improvement in the approach to materials handling but the mid-tier yards have made large gains. This is mainly because there are now more purpose-designed pallets, better defined storage areas and some more modern equipment. However, the overall methodology remains basically the same as it was at the time of the last survey. The US average scores are below 2004/2006 international averages and the proposed targets in both sectors. The majority of movement is in “unit loads” by road on trailers or forklifts. There is little use in US yards of integrated conveyor systems and NC controlled transport systems as is found in some leading international yards.

In all US shipyards, there remains a lack of purpose-designed pallets and trestles for the transport of parts and assemblies. There is very little use of high density, multi-level pallet stacking. The extent of inefficient material handling is still significantly higher in US shipyards and results in high levels of non-value-added effort.

Proposed actions

- Support an industry-wide study of material handling and storage requirements, costs and solutions, including the design of specialized equipment. Potentially include modeling to recognize the full labor costs associated with multiple handling of materials

First Marine International

D SHIP CONSTRUCTION AND OUTFITTING

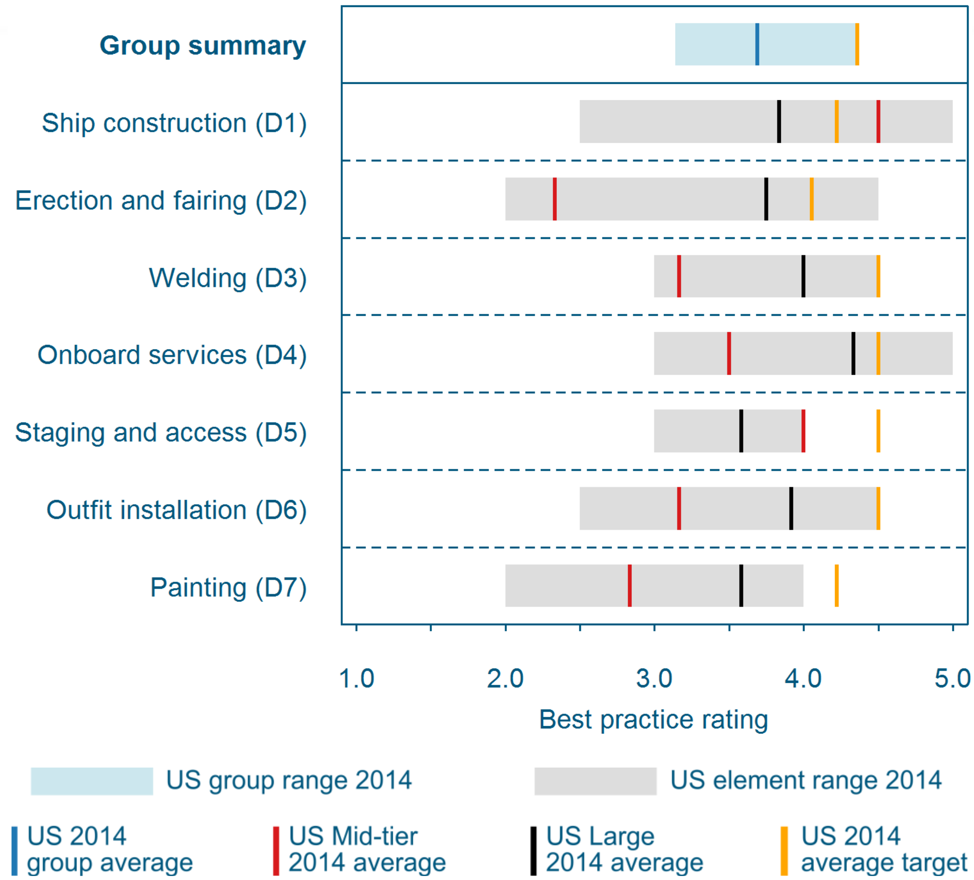

Figure A1.4 – Ship construction and outfitting

D1 Ship construction

Although the US large yard average is now slightly above the corresponding 2004 international average, sub-optimal construction facilities are a feature of a number of the larger US yards. This is often combined with construction cranage that is below capacity for the adoption of a natural block breakdown for all vessels in the product mix. There has been significant investment in the mid-tier yards surveyed with current production largely under cover in well-equipped facilities. Thus the average score for the mid-tier yards is much higher and exceeds both the 2006 international average and the proposed target.

As a rule of thumb, crane capacity should ideally be not less than 1/50th of the erected steel and outfit weight of the largest vessel. The other general issue is protecting the workforce at the construction point from the worst effects of climate. Although there have been improvements which have been facilitated by better block construction, a number of yards still need to look at ways of providing better protection. This may be through the use of temporary or permanent covers or by adopting build strategies which facilitate earlier closure of internal spaces.

Proposed actions

- No industry-wide collaborative initiatives proposed

D2 Erection and fairing

Although there have been improvements in one or two yards, very little attention has been paid to improving accuracy control to speed up and reduce the cost of the block erection processes. In several yards there has been some regression in this area. A number of yards still have some way to go in achieving better accuracy control in order to improve the efficiency and speed of the block erection process. It is surprising to still see units and blocks being scribed in at erection. The achievement of consistent block accuracy is principally a shipyard-specific process development issue. See F8 - Dimensional and quality control.

Accuracy control also has a major impact on work content in block alignment and fairing. Fairing methods that use traditional welded attachments remain widespread although some yards have made progress with stud welded systems and with alignment and fairing methods which do not require welded attachments. It is felt that an industry-wide study would still be of value in this respect to ensure the transfer and implementation of best practice.

Proposed actions

- Carry out and circulate the results of a literature search into non-welded fairing aids

D3 Welding

At the time of the last survey, good progress had been made in the application of more efficient and productive welding processes. Since then, progress has been slow but steady with a small increase in the benchmarking average score in the large yards. Some advanced welding techniques such as friction stir welding are now routinely being used to good effect, although this is often by subcontractors. The proposed targets have been set a little higher than the 2004/2006 international averages. More attention to the application of robotics and further mechanization in some yards, especially the mid-tier sector, will help to close the gaps. There is still a good degree of sharing of industry-wide welding information, which is probably sufficient to keep the yards informed of the behavior and benefits of new materials and processes. Laser welding is yet to find an application in US shipbuilding. Processes and procedures applicable to the thin and special materials inherent in warships would still benefit from additional research and development.

Proposed actions

- Increase the level of research and development into the fabrication of thin and specialist materials

D4 Onboard services

The range and extent of services that have to be placed on board a vessel after block erection does, of course, depend on the amount of work remaining to be done. Yards that achieve least in pre-erection outfitting, by definition have the greatest amount of work remaining to be done on board, all of which requires electrical and mechanical services. With a few notable exceptions, there has been some progress toward making more use of ships' services to support production, reducing the post-erection workload and organizing services more effectively on board. The highest scoring US yards now plan the provision of services at the build strategy stage and, in the best, this will influence ship design. There are only a small number of yards where services are still provided on demand in an unplanned fashion. Housekeeping has improved and there remain only one or two examples of really poor service distribution. In these yards, hoses and cables can often be seen spread around internal spaces and draped over the vessel and block sides in an apparently unplanned and uncoordinated manner.

Proposed actions

- No industry-wide collaborative initiatives proposed

D5 Staging and access

At the time of the last survey it was clear that most shipyards spend excessive hours and cost on non-value-added staging activities. Although staging is still used, there has been a distinct industry-wide reduction in the amount of staging and the methodologies associated with its installation have improved. There are also more permanent mezzanine floors in use. There is still potential to make further improvements, particularly inside vessels. There can be further reductions and eventual virtual elimination of staging through the application of a natural block breakdown and the planning of pre-erection and post-erection outfitting and painting. The elimination of the need for staging is preferable to simply replacing staging with man lifts of one type or another. A number of innovative mobile platforms and other systems have recently been brought to the market and are often seen in international yards. None of these modern systems were seen in the US yards. Although the use of staging and the provision of access is generally now more planned than at the time of the last survey, staging in some US yards is still provided on an ad hoc, as required basis.

Proposed actions

- Investigate available staging systems and industry best practice

D6 Outfit installation

As is appropriate for shipyards constructing predominantly high outfit ratio, complicated vessels, most of the yards have given attention to improving the overall approach to outfitting and the organization of onboard outfitting. There has been a good level of facility investment aimed at improving outfitting and increasing block size. In general, the planned outfitting strategy in US shipyards is good but it often takes a number of vessels in a series to achieve the intended strategy. The reasons for this relate to the design process, change order control and the phasing of the design and construction process. The net result is an unplanned and unbudgeted shift of work to more expensive stages of construction on early vessels in the series.

Although not prevalent, there now tends to be a more structured zone-by-stage outfitting methodology being applied. Zone management tends to be the norm but managers usually manage the work in their zone through trade foremen and there is only limited use of multi-disciplinary teams. Although done intuitively, no shipyard formally measures outfit manning density, which is a key measure that controls productivity and duration. The average industry benchmarking scores for both sectors are now slightly above the 2004/2006 international averages but fall short of the proposed targets.

Proposed actions

- No industry-wide collaborative initiatives proposed

D7 Painting

Almost all US yards surveyed have already made or are about to make a substantial investment in painting facilities. Some paint cells and associated facilities are state-of-the-art but others are quite basic. The investment has been partly driven by Navy paint system requirements but also by environmental legislation and the need to improve productivity. The approach to painting still varies widely across the industry with some good applications of the process. In general, the amount of painting achieved at an early stage is closely linked to the overall outfitting strategy employed. There is a high degree of focus on completing hot work prior to painting on block. However, finished coats are rarely applied at this stage and there is often considerable post-painting rework.

The application of paint and the naval requirement for increasingly sophisticated paint systems is currently having a major influence on the productivity that can be achieved in outfit. It is therefore recommended that painting and its influence on outfitting and through-life costs should be the subject of review and one of the principal focuses for research and development. The average score for the large yards is currently ahead of the 2004 international average but the mid-tier score lags further behind. There is still a gap between the proposed target and the current score in some yards. This is largely because paint systems tend not to be progressively maintained throughout construction, there is a large amount of rework, and block painting durations can be lengthy.

Proposed actions

- Undertake a study into the approach to painting, Navy requirements, and the influence on outfitting and through-life costs with a view to determining an optimum painting strategy

E YARD LAYOUT AND ENVIRONMENT

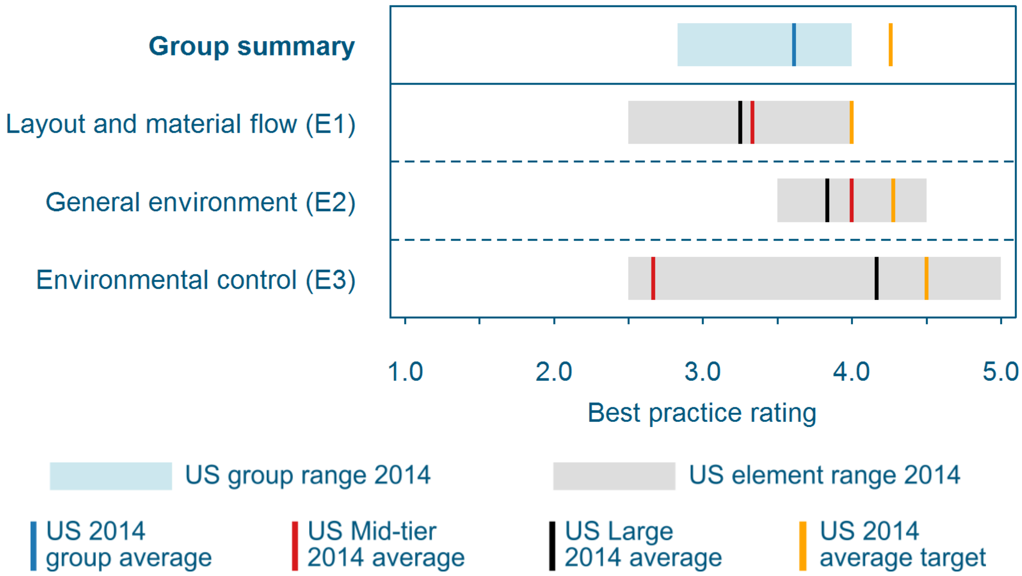

Figure A1.5 – Yard layout and environment

E1 Layout and material flow

Recent investment in several US shipyards, predominantly the mid-tier yards, has improved the overall layout and material flow. The large yard average has increased very slightly but it still lags the 2004 international large yard average and the proposed target. The mid-tier yard average has increased significantly but still lags the 2006 international mid-tier average. Some yards have reached the proposed target score. Generally, the flow within individual workshops tends to be better developed than the overall flow within the shipyards, as this suffers from the fact that the yards have been developed over several decades and are on constrained sites. In almost all shipyards, better interim product definition would make it easier to set the layout of the shipyard in a rational manner. During the 2004/2006 survey, it was noted that many yards had high work-in-process levels. This appears to have reduced to some extent. For yards not already at the proposed target, the target should be considered as a long-term goal that guides the shipyard's long-range facilities plans.

Proposed actions

- No industry-wide collaborative initiatives proposed

E2 General environment

The US large yard average for General environment has increased and is still above the 2004 large international yard average. The mid-tier average has also increased and is now above its 2006 international counterparts. Both sectors are approaching their 2014 average targets. Almost all the US shipyards have a mixture of old and new buildings. Conditions have improved and are generally satisfactory as buildings tend to be well maintained and housekeeping is often good in most areas. Factory-like conditions have been achieved in the newest buildings. Although there have been improvements, work-in-process is high in many areas and detracts from the working environment. A large amount of work is done outdoors in some yards and most yards would benefit from increased use of purpose-designed service towers in ship construction areas and overboard. The issues are principally yard-specific questions of process developments and facilities investments.

Proposed actions

- No industry-wide collaborative initiatives proposed

E3 Environmental control

This element was not assessed in 2004/2006. Although the approach to environmental issues varies regionally, the Environmental control element achieved consistent scores across the large shipyards. Nearly all of these have ISO14001 accreditation and are within a half-point of the large yard target score or better. Fines or penalties relating to environmental infringements are rare in this group and use of the Health and Safety OHSAS 18001 accreditation is growing. Practices are markedly poorer for the mid-tier yards, as policies are principally guided by doing the minimum necessary to comply with legislation. The average rating here is over 1.5 points lower than for the large yards. There remain opportunities across the whole industry to improve the public relations benefits that can be leveraged from a proactive environmental approach. This is particularly true for the labor market, as there are opportunities being missed to improve public perception of the industry.

Proposed actions

- Collaborative campaign to improve public perceptions of the environmental impact of the industry

F DESIGN, ENGINEERING AND PRODUCTION ENGINEERING

Figure A1.6 – Design, engineering and production engineering

F1 Ship design

There has been a marginal increase in the average score for the large yards but there has been no overall change in the mid-tier yards. However, for both the large and mid-tier shipyards, the average scores either meet or exceed the 2004/2006 international averages. All the shipyards have established design and engineering departments with a range of skills covering all the normal design processes. Specialist skills and concept designs are often subcontracted. However, there is in general a lack of production knowledge and experience within the design teams. This is often compensated by establishing project design-and-build teams, although this approach can often lack coordination and direction. For the majority of the shipyards, a design and engineering strategy with specific objectives and clear inputs and outputs for each stage of design needs to be defined.

Many of the shipyards still use a system-oriented design approach. The concept of product-oriented design is understood and is being developed, particularly in steelwork. However, due to continued use of legacy designs and long vessel build series there is often a long time period between new designs. This provides limited opportunities for shipyards to introduce and implement new design and engineering methods. It also creates difficulties in retaining appropriately skilled personnel. Consequently, designs are adapted for improved producibility rather than being optimized for production performance, leading to increased construction costs and, possibly, schedule. One of the barriers to changing the design is the design cost, so there would be benefit in reviewing the approach to the naval design process with a view to minimizing cost.

There is good use of the latest 3D computer technology although, with the continued use of legacy designs, some shipyards are required to maintain multiple software systems. There are even some legacy designs that remain in 2D paper format.

Proposed actions

- Develop an ideal naval ship design process that achieves build strategy goals and can be implemented in individual shipyards
- Establish a Navy-industry strategy to maintain core design capability

F2 Steelwork production information

There have been some changes in the content and format of the steelwork production information, although these have not led to a significant change in the averages scores. However, the average scores for large and mid-tier shipyards still exceed the 2004/2006 international averages. The majority of the shipyards have made the transition to workstation-oriented drawing packages. The information is extracted directly from the 3D modelling software and, through good use of the modelling software, there is generally minimal production information added manually. Some of the shipyards continue to rely on production information in paper format, although this is partly due to the use of legacy designs or customer requirements. For the majority of the shipyards, there is an opportunity to streamline the steelwork production information development with the introduction of a product-oriented design and construction philosophy.

Proposed actions

- Define a product-oriented approach to developing steelwork production information
- Integrate shipyard and customer design systems to support increased use of electronic production information

F3 Outfit production information

There have been significant increases in the US average scores for the large and mid-tier shipyards, with both scores considerably higher than the 2004/2006 international averages. The form and content of outfit production information have been developed in line with steelwork production information. Although system-based information packages are still produced in some of the shipyards, the majority work with workstation drawings. The information is generally extracted directly from the 3D modelling software. There is good use of the modelling software, with minimal ship-lifted information required. For most shipyards the outfit interim product structure is relatively immature and therefore outfit modularization is limited. There is an opportunity to streamline the steelwork production information development with the implementation of a product-oriented design and construction philosophy.

Proposed actions

- Define a product-oriented approach to developing outfit production information

F4 Coding system

There have been significant improvements to the parts coding systems across the mid-tier shipyards, aligning them with the large shipyards where there has been limited change. Effective and rationalized parts coding goes beyond the use of ESWBS; it is the embodiment of the shipbuilding strategy and is of major assistance in organizing design and construction. The US average scores for both the large and mid-tier shipyards are significantly above the 2004/2006 international averages but most coding systems still need some development to reach the proposed target. The coding systems are fairly comprehensive, linking the part to the ship, system, location, and stage of construction. However, in the absence of a mature product-oriented design approach the coding systems do not generally identify the individual product families. This inhibits full implementation of workstation organization including automated scheduling, information generation and performance feedback.

Proposed actions

- Develop a consistent common parts coding structure that can be independently developed into yard-specific coding systems while maintaining sufficient common structure to facilitate industry-wide cooperative manufacturing initiatives

F5 Parts listing procedure

There has been no significant change to the parts listing procedures across the shipyards. However, there have been improvements in the implementation of the process in terms of greater use of the CAD system capabilities and the maintaining of common/master parts catalogues. The US average score for the large shipyards still exceeds the 2004 international average. Despite an improvement in score, the mid-tier yards continue to marginally lag the 2006 international average. Developing system integration between the CAD system and the planning and material control systems would see an improvement in this area. Currently, a number of the shipyards rely on the manual transfer of information. This is man-hour intensive, prone to error and delays the transfer of data.

Proposed actions

- Continue to develop and promote NSRP's Common Parts Catalogue (CPC) initiative

F6 Production engineering

Across the industry there has been an increased emphasis on production engineering activities. However, the US average for the large shipyards still lags the 2004 international average. For the mid-tier shipyards, the US average score is significantly higher than the 2006 international average. Internationally, the production engineering function is regarded as the principal lead in all performance improvement and facility development activities. However, there are still a number of the US shipyards that do not have an established production engineering function. For these yards, production engineering tends to be a secondary problem-solving activity, lacking direction and objectivity, rather than an innovation leading activity.

The majority of the shipyards understand the concept of product-oriented design. This is designing to build the vessel from a rationalized, predetermined set of producible interim products that are the embodiment of the shipbuilding strategy and reflected in the parts coding system. A principal objective of a production engineering function is to develop and implement a product-oriented design and production operation philosophy throughout the shipyard. For the shipyards with an established production engineering function, the concept is being implemented, although further development of interim products is required. The interim product structure needs to be applicable for all vessels within the shipyard's product mix and be the cornerstone for the shipyard's shipbuilding strategy. As discussed at F1 – Ship design, in general there is a lack of production knowledge and experience in the design teams. A strong production engineering function covers all aspects of ship construction and establishes an effective link between the technical and production departments.

Proposed actions

- Establish a Navy-industry strategy to promote the development and incorporation of production engineering principles
- Develop an industry production engineering charter defining the role and functional responsibilities of production engineering in US yards

F7 Design for production

As a principal part of the production engineering function, there have also been significant improvements in design for production since the last benchmarking study, in particular across the mid-tier shipyards. The US average scores for the large and mid-tier shipyards follow a similar trend to production engineering. The large shipyards lag the 2004 international average, whereas the mid-tier shipyards exceed the 2006 international average. All the shipyards have established design for production programs and there has been a strong emphasis on capturing production knowledge and formally defining facility constraints and attributes. However, continued use of legacy/mature designs has reduced the opportunities for applying design for production principles and methods.

Proposed actions

- Establish a Navy-industry strategy to incrementally develop and introduce new design and engineering methods, including design for production elements, suitable for Navy vessels

F8 Dimensional and quality control

There has been no significant change to the dimensional accuracy and quality control organizations and procedures across the industry. There have been increases in the average scores for both the large and mid-tier shipyards due to improved implementation of the procedures. That said, the mid-tier shipyards continue to lag the 2006 international average, whereas the large shipyards now marginally exceed the 2004 international average. The majority of the shipyards have established AC & QC departments and well-defined processes and procedures, including a statistical accuracy control program. However, in general, there remains a low level of confidence in using the results of statistical analysis to facilitate process improvement, such as the neat cutting of steel. The practices of added material and weld hold-back on stiffeners are common to compensate for possible inaccuracies. These practices create considerable rework.

By comparison, leading international yards adopt a total quality approach and no longer have dedicated AC and QC departments. AC and QC requirements are fully integrated into all pre-production and production activities with cross-functional teams meeting at regular intervals to resolve problem areas.

Proposed actions

- Promote awareness of the schedule impacts and true costs of non-value-added work
- Promote the use of statistical analysis as an intrinsic part of the performance improvement process

F9 Lofting methods

This is the highest average scoring element in the group. In general, there is a consistent approach to lofting across the industry, with the shipyards having almost totally integrated the function with the CAD systems. There has been an increase in the US average scores for large and mid-tier shipyards principally due to the greater use of CAD system capabilities. The mid-tier average now exceeds the 2006 international average, whereas the large shipyards average still marginally lags the 2004 international average. The use of legacy designs can inhibit full lofting function integration.

Proposed actions

- No industry-wide collaborative initiatives proposed

F10 Test and trials and setting to work

The Test and trials and setting to work element was not surveyed in 2004/06. For this study, it scores moderately well within Group F for both the large and mid-tier shipyards. In general, the shipyards have established test and trials organizations and well-defined procedures. Although some progressive acceptance is achieved during construction, there is a tendency for the shipyards to carry out the majority of tests post-launch. Leading international yards will conduct testing at the earliest, most cost-effective stage in the build schedule, with testing starting in the workshops. Paper-based data management is common practice in US yards, whereas better use of electronic media would save time and cost.

Build and acceptance sea trials are often carried out separately and on every vessel. Commercial best practice of a single sea trial could be adopted on selected vessels in the series for certain classes.

Proposed actions

- Support and promote commercial best practices with regard to the conduct of sea trials, where practicable
- Promote the importance of better use of electronic data management

G ORGANIZATION AND OPERATING SYSTEMS

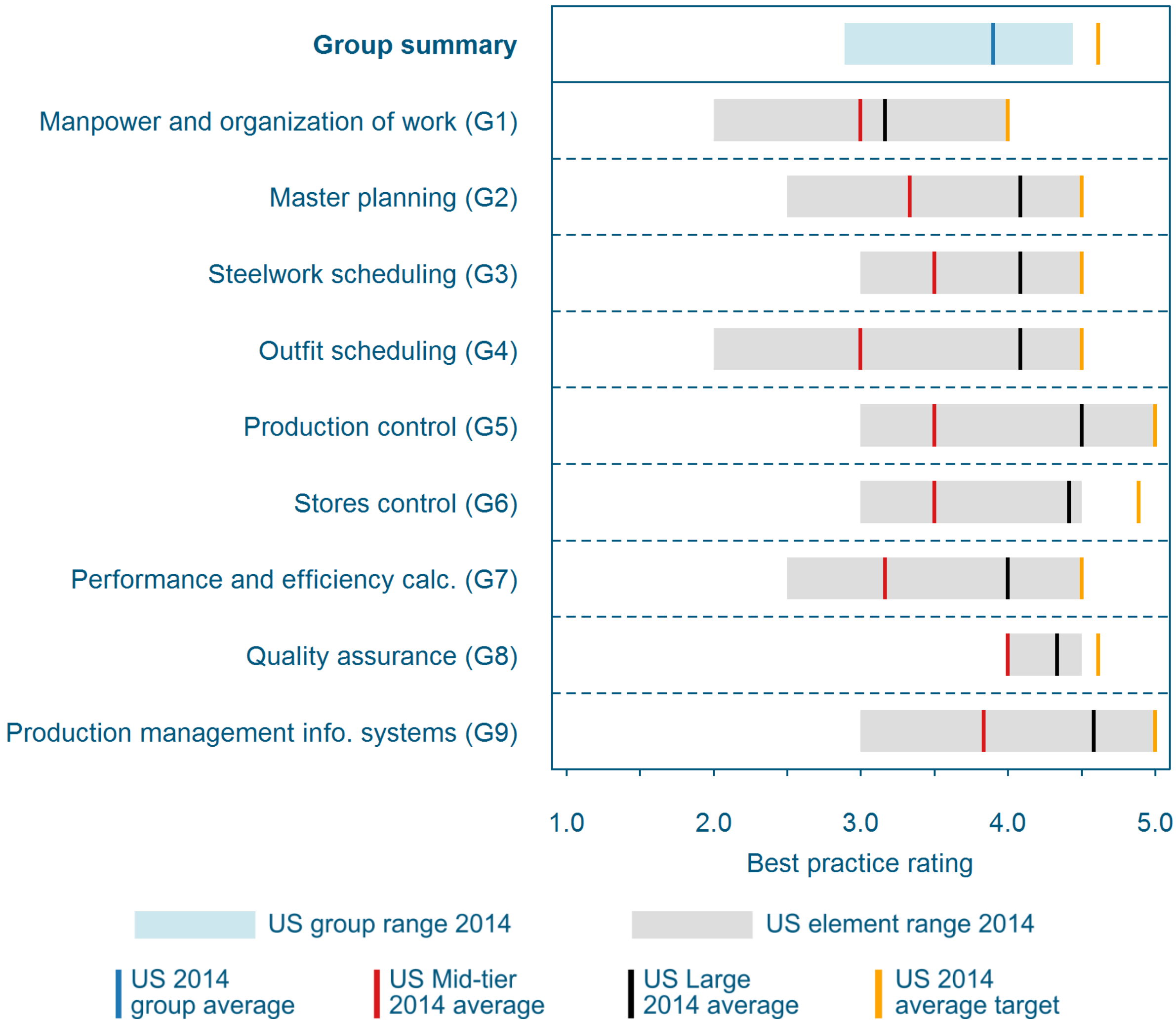

Figure A1.7 – Organization and operating systems

G1 Manpower and organization of work

In every one of the large shipyards, the Manpower and organization of work element scored the lowest within its element group. This demonstrates that while improvements have been made in many other areas, reorganization of the workforces into more effective operating structures remains a stumbling block for the industry. None of the large yards has improved its score since 2004 and some scores have been reduced. There is still some trade union resistance to fully flexible working, multidisciplinary teams and other actions that would improve productivity. Some members of the management teams are also resistant to change. In some yards, the situation appears worse that it was in 2004 with some companies becoming further entrenched into trade-oriented structures. Navy requirements for system-oriented work breakdown structures can also hinder the implementation of area management and workstation organization. The mid-tier yards exhibit considerably more flexibility in organization and have, on average, improved their scores since 2006.

Proposed actions

- Initiatives with principal unions to demonstrate the commercial and employee benefits of multi-skilling and area management
- Navy-industry investigation of the approach to work breakdown structures to support area management

G2 Master planning

For nearly all the large shipyards, the master planning processes were either at or around the target rating in 2004 or have become so since that time through significant improvements made in individual yards. As a consequence, the average rating for this group has improved and is now just above the average rating for the international yards from 2004. However, the approach to planning labor resources remains variable and there are widespread indications of poor schedule adherence across the industry. Department staff numbers remain medium to high and less use is made of planning standards and templates than would be expected given the generally good systems in place. Much of this is driven by a tendency to develop detailed planning unnecessarily early as this increases planning rework and potentially reduces schedule adherence. In many instances, it is influenced by Navy requirements for the early development of detailed plans. For the mid-tier yards, the planning processes have remained largely static over the last decade or have regressed slightly. High costs for upgrading and implementing new systems is a barrier to improvements in this sector.

Proposed actions

- Review and modify Navy influence on shipyard planning processes to ensure close alignment with shipbuilding planning best practice

G3 Steelwork scheduling

In line with the master planning processes, the steelwork scheduling and outfit scheduling procedures have improved such that the average rating for the large yards is now very close to the international yard average from 2004. The natural next stage for the industry is a more widespread use of product families to plan by workstation and zone. This would reduce planning workload as detail planning attributes can reside in the engineering data for products, categorized by 'families' of like production processes. Zones can be planned on standard templates. This would require simultaneous initiatives in design and the organization of the workforce. For the mid-tier yards, the processes have remained mostly static through the period.

Proposed actions

- No industry-wide collaborative initiatives proposed

G4 Outfit scheduling

See comments and proposed actions in G3 – Steelwork scheduling

G5 Production control

The average rating for production control in the large shipyards has increased since 2004 and remains above the international average from that time. Nearly all of the large yards are now at, or near, the target rating. Core production control processes are managed within integrated computer systems and there is good and increasing use being made of modern, wireless technologies on the shop floor. However, there remain a number of peripheral, manual and stand-alone processes in use, such as detailed production scheduling and the entering of time-card data. There is also a degree of manual, subjective progressing of work packages.

Improvement in the mid-tier yards has been more marked, albeit from a lower starting point. However, it is still well below the target rating. Considerably more effort can be made to reduce the workload in identifying and picking the materials needed in production and the work associated with calculating progress. There would also be benefits from improving the timeliness of the reporting information. The issues are principally yard-specific questions of process developments.

Proposed actions

- No industry-wide collaborative initiatives proposed

G6 Stores control

In 2004, the large yards rated slightly more highly than the international yards. Since then, improvements have been made and the average has increased. However, system-driven, automated materials picking is still unusual and bar codes are not yet used throughout. Stores inventory levels vary from medium to very high, making stores control more difficult. This can be exacerbated by production encouraging the early delivery of materials. More use could be made of supplier-replenished, unmanned line-side stores.

The mid-tier yards were a mixture of improvements and regressions for this element, resulting in no change to the average score over the last decade. The reductions in scores were generally due to the high levels of inventory being carried. There was also a surprising lack of integrated material control systems.

Proposed actions

- No industry-wide collaborative actions proposed

G7 Performance and efficiency calculations

Across the large and mid-tier yards, the process for performance and efficiency calculations has improved slightly. This has brought the large yards reasonably close to the 2004 international average, although they remain below the target score. It remains commonplace for shipyards to measure performance against the project budgets on a ship-by-ship basis. The use of process-oriented metrics, which is the more effective approach, has been growing but more can be done in many of the shipyards. For the mid-tier yards, the approach is often more basic due to the lack of integrated systems in use. For both groups, performance information could be published more widely than the departmental management distribution that it currently tends to be limited to.

Proposed actions

- Industry study to develop and expand the use of process-oriented metrics for performance improvement purposes

G8 Quality assurance

There has been a marginal improvement in quality assurance in both shipyard sectors. That said, the US average for the mid-tier yards continues to lag the 2006 international average, whereas the average score for large shipyards still exceeds the 2004 international average. Both sectors lag the proposed average target scores. The shipyards all operate an accredited quality assurance system and have established procedures. Most yards are using the system to assist performance improvement. However, not all yards include in-process non-value-added work that is an inherent part of the shipbuilding process in their definition of rework. For example, the removal of excess material added to compensate for possible inaccuracies during construction.

Proposed actions

- No industry-wide collaborative initiatives proposed

G9 Production management information systems

For the large yards, the production management information systems are all integrated systems with much of the information content tailored to the needs of the users. Most shipyards have developed or are developing wireless networks but the degree to which the information is available online varies. There is a corresponding growth in the use of wireless-enabled laptops, tablets and smart phones on the shop floors. The currency of the reporting information could be improved but this will need to be combined with improvements in the systems, as data transfer processes between dated systems are often unwieldy. There has been slightly less improvement for the mid-tier yards. For this group, there are higher levels of manual intervention required to develop the information needed.

Proposed actions

- No industry-wide collaborative initiatives proposed

H HUMAN RESOURCES

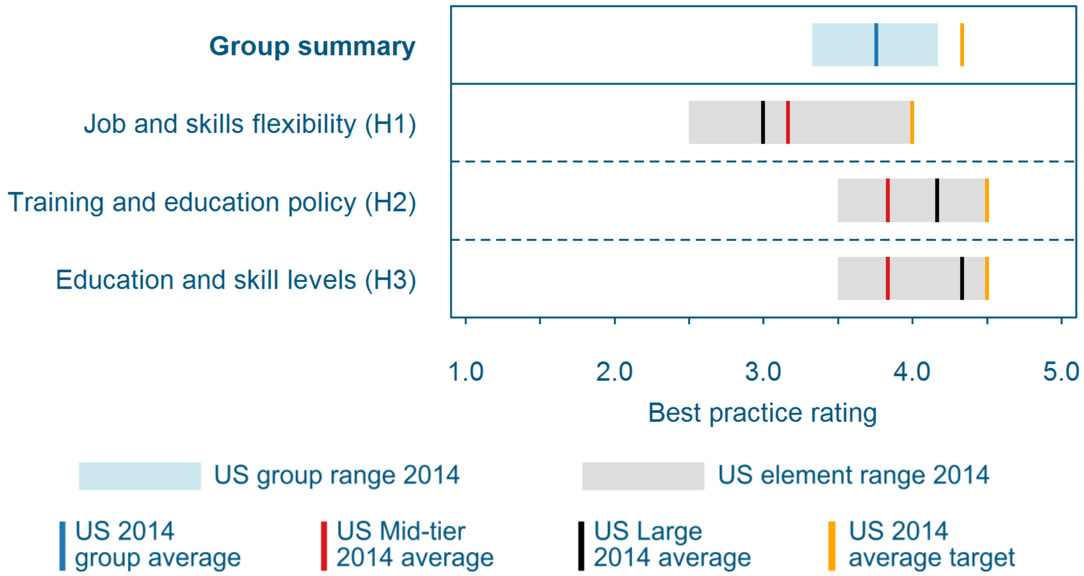

Figure A1.8 – Human resources

H1 Job and skills flexibility

Of the three Human resources elements surveyed, this element has the lowest average score. The large shipyards are generally unionized, with high proportions of the trade workforces being union members. Trade union collective bargaining agreements often allow for flexibility, with no demarcation between trades. The majority of the mid-tier shipyards are non-unionized. However, the shipyards are generally trade-oriented operations. In practice demarcation and restrictive working practices vary across the industry and in some shipyards they are restrictive. Some area-managed multi-disciplinary teams have been established. In general, the mid-tier shipyards have greater workforce flexibility.

Some initiatives have been implemented to introduce trade flexibility. However, multi-skill trade-training is limited and often at a basic competency level. For the industry to advance a more flexible multi-skilled production operation philosophy needs to be adopted. This requires a large proportion of the trade workforce to be trained to a high competence level in a secondary skill. For some shipyards this will require renegotiation of the union agreements.

Proposed actions

- See comments and proposed actions in G1 – Manpower and organization of work

H2 Training and education policy

In general, there is a consistent approach to education and training across both the large and mid-tier shipyards with well-established recruitment and training procedures in place. Particular attention has been placed on the recruitment of trade personnel. This is due in part to either addressing a recent or forthcoming recruitment drive or reducing 'new starts' attrition rates. Introductory and basic trade/skill-specific training and trade-recertification training are routinely carried out. Performance appraisals are regularly performed, although some shipyards need to establish reviews for all trade workers. Most shipyards operate an apprenticeship program.

Multi-skill training of employees is not a priority for most of the shipyards, although often union agreements, procedures and facilities are available for such training. Employees are not generally engaged in continuous personal development (CPD). Where CPD is undertaken, it is predominantly for salaried personnel. Some initiatives have been established but, for a number of shipyards, development programs are poorly structured or not yet mature. Greater emphasis on CPD, in particular for trade workers, is required by the shipyards. This will assist with employee engagement and the maintaining of core skills and experience, which are essential to the future sustainability of the industry.

Proposed actions

- A collaborative project to develop training materials for multi-skilling.

H3 Education and skill levels

There is a good skills base across the industry workforce. Trade workers are usually required to meet a minimum entry level and complete basic trade training or trade recertification training. Employee multi-skill training is limited and generally of a basic competency level, often achieved through on-the-job mentoring. Supervisors and production management are often recruited through internal promotion and therefore have extensive shop floor experience. Engineers are usually degree qualified and some middle and senior managers have formal management qualifications. Overall, 96% of the workers have the required trade or professional role-related qualifications. However, formal management training/qualifications are not generally a requirement. Ideally, this would involve a structured educational training program, influenced by industry-wide best practices and processes and managed by professional educators personnel. Undertaking of the course would be administered through the employees' development plan process.

Proposed actions

- Consider centrally coordinated, industry-wide collaborative training initiatives to enhance production experience across engineers and designers
- Consider establishing an industry-wide skills and qualifications requirements matrix

I PURCHASING AND SUPPLY CHAIN

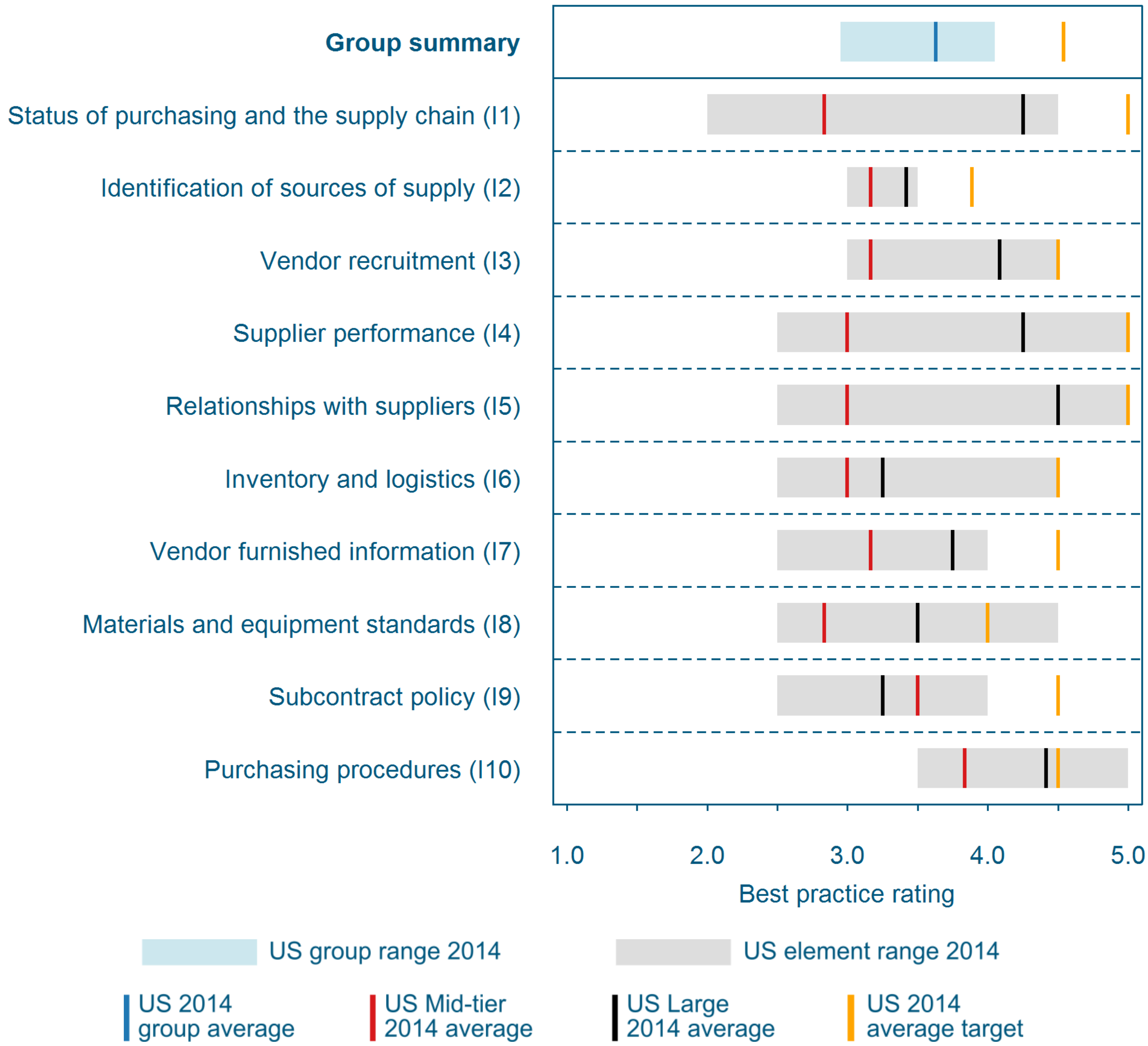

Figure A1.9 – Purchasing and supply chain

I1 Status of purchasing and the supply chain

The large yards scored well but remain some way short of the target rating. In dollar terms, the annual spend flowing through each supply chain department is very significant. While some of the industry recognizes the importance of this, it remains surprising that supply chain activities are not always represented by a dedicated vice president or equivalent.

Individually, there are a number of good initiatives that are driving cost out of the materials and equipment required. The procurement approach is generally guided by the 'Cost, Quality, Delivery' philosophy. However, it remains largely transactional with a great deal of emphasis on hard negotiation to minimize cost. There are few formal, well-communicated supply chain mission statements that are informed and guided by the strategic business plan. Most procurement departments do not have strategic guidance for issues such as ideal inventory levels; the target size, location and sector-focus of the supply base; the types of contracts to use; and the logistics of getting the equipment and materials to the point of use.

The mid-tier yards scored less well for this element as the supply base relationships tend to be more transactional for this group. Organizationally, the status given to the procurement departments is also generally lower than in the large yards.

Proposed actions

- Inform the supply-base development plans through an industry study into the factors affecting the ideal supply base in shipyards

I2 Identification of sources of supply

The processes associated with searching for new potential suppliers scored poorly for both the large and mid-tier yards, although the target is also lower for this element than for others in the group. The large shipyards are characterized by naval procurement, meaning that searches for new sources of supply are mostly limited to domestic suppliers. For commercial procurement, the Buy American Act and, to a lesser degree, the FARs also serve to minimize the international supply base. Where intelligence is available on international suppliers, ITAR often limits the opportunities to make like-for-like value comparisons.

The domestic supply base is reasonably static, particularly for high-value, low-throughput items. Thus searches for new suppliers are not routinely undertaken unless there is a requirement for a new technology or a failure of existing suppliers. For defense items, the domestic supply base is also shrinking. For a proportion of the high-value defense items, this means there is little competitive environment and any premium over internationally competitive prices is passed on to the Navy.

Proposed actions

- Benchmark the supply base value-chain by investigating internationally competitive market costs for equipment and materials
- Collaborating between Navy and industry professionals, identify key elements of defense procurement practices and requirements that contribute to the shrinking supply base and develop cost-benefit assessments to judge their efficacy

I3 Vendor recruitment

For the large shipyards, the vendor recruitment processes scored well. In practically all cases there are formal procedures for assessing all suppliers before they are appointed. In some cases the assessment criteria are varied by commodity type and have been extended to reflect the shipyard's target market and strategic business needs. However, as discussed in I1, Status of purchasing and the supply chain above, without a strategic mission statement for the procurement activities, the development of these supplier assessment criteria has to be done without visibility of either the strategic aims of the business or of other departments' requirements.

The mid-tier yards achieved a lower average score. Assessment criteria for new suppliers are more basic and rarely extend beyond the standard financial due diligence and debarment checks.

Proposed actions

- No industry-wide collaborative initiatives proposed

I4 Supplier performance

All of the larger shipyards assess supplier performance in some way and there is a range of processes being used to do so. However, only a minority share the assessment criteria or findings with suppliers themselves unless there is some corrective action to be taken. In some instances, the assessment process requires the buyers to manually analyze data. Supplier scorecards that cover the full range of performance issues are rare, as they would include cost, quality, delivery of vendor-furnished information, supplier organizational changes, and supplier R&D.

Processes for the mid-tier shipyards are less well developed. Performance assessment varies but can be as basic as infrequent reviews of QA failure rates. Again, a common theme is the lack of sharing the information with the suppliers unless action of some kind is required.

Proposed actions

- Develop an industry standard for supplier performance assessment criteria and communication of the findings with suppliers

I5 Relationships with suppliers

There is a significant difference between the large and mid-tier yards in this element. For the large yards, supplier relationships are recognized as important and many initiatives are undertaken to develop the relationships further, including arranging supplier visits and hosting supplier conferences. Suppliers are categorized into tier groups in a number of different ways. However, few yards account for an extensive range of criteria when categorizing suppliers, such as:

- the suppliers' competitive environment
- the value and volume of the supply
- the criticality of the supply

It is positive to see the growing use of long-term, partner and framework agreements. However, these tend to be driven only by the need to tie suppliers in for a series of vessels.

As discussed in I1 – Status of purchasing and the supply chain, the actual relationships often remain transactional and there are surprisingly few partnered R&D programs.

In the main, the mid-tier yards use a more ad hoc approach by leaving the assessment and management of supplier relationships to the commodity-based individual buyers. This is reflected in the score.

Proposed actions

- Collaborating between Navy and industry professionals, identify key elements of defense procurement practices and requirements that hinder the use of long-term, partner, and framework agreements and assess their efficacy
- Industry and Navy should consider working more closely to establish Navy-led, industry-wide relationships with key common shipyard suppliers

I6 Inventory and logistics

There is a wide range of practices across the large and mid-tier yards with regards to inventory and logistics but, for both groups, this element was among the lowest scoring of the purchasing elements. Inventory levels vary from medium to very high comprising a mixture of work-in-process, contractor-furnished equipment and government-furnished equipment. In many cases, this is incentivized by the contractual arrangements with the Navy. Materials buffer times generally exceed leading international standards and costly multiple handling is considered normal by many of the shipyards, particularly for in-house manufactured items.

The carrying of high inventory is common in shipyards where production has low confidence in the performance of the internal and external supply chains. This is the case in many of the US yards. Some good work is ongoing in individual yards to understand how and why the materials supply failure rates are unacceptably high. However, this is hard to achieve where the internal supply chain responsibility crosses departments. It is also routinely given a low priority because, in most cases, the cost of carrying inventory is under-estimated meaning that material supply issues are commonly resolved by simply increasing buffer storage times.

Proposed actions

- Navy review contract terms to ensure they do not incentivize the carrying of excess inventory
- Industry-wide, conduct a transparent review of the full cost of carrying excess inventory

I7 Vendor furnished information

This element achieved a reasonable score within the large yards but scored less well in the mid-tier group. Most yards provide good definitions of vendor furnished information (VFI) requirements including the timing and format of the content. There is also good use of online portals for VFI deliveries that perform workflow functions for the approval, control and storage of VFI items. However, the engineering, planning and materials control systems are often less integrated than would be ideal for VFI purposes. This means that opportunities to create seamless VFI procedures are limited, so it is common to see them managed through independent systems. The monitoring, expediting and performance assessment of VFI deliveries is then done off-line and, as a consequence, is often overlooked. Some yards also under-estimate the cost of poor VFI performance.

The planning approach to timing VFI requirements varies but is, in many cases, not optimal as the VFI lead times and phasing are neither rigorous in planning nor disciplined in execution. This is a common difficulty because there is a high workload involved unless yards have developed planning templates for VFI that are varied by product family only.

Proposed actions

- Industry-wide study into the true cost of late or incorrect VFI

I8 Materials and equipment standards

This element achieved a medium score for the large shipyards. Many have done good work in reducing the numbers of discrete parts used for each project. However, variety reduction is restricted by naval requirements to maintain configuration within vessel classes and this makes standardization a low priority for many shipbuilders.

For the mid-tier shipyards, this element was among the lowest scoring of the purchasing elements. Although there is some recognition of the advantages of reducing variety, full rationalization of parts used and the parts lists maintained has not generally been a priority for this group.

Proposed actions

- Review the full impact of naval requirements for commonality of parts on the ability of shipyards to reduce parts variety in new construction

I9 Subcontract policy

This element scored less well than any other purchasing element and is the only one where, on average, the mid-tier shipyards scored higher than the large yards. Many subcontracting[4] decisions are considered on a case-by-case basis and can vary from project to project. The degree of subcontracting is also low by international standards and there is some evidence of an embedded cultural resistance to outsourcing. This is commonly supported by the unions. However, it is not surprising as historically many US yards did as much work as possible in-house. Some shipyards have a good strategic understanding of their core competencies and the throughput levels required to cost-effectively do work in-house. However, due to the difficulties described, this is rarely translated into an informed, company-wide subcontracting strategy.

[4] Subcontracting includes the decision to buy rather than make products and the use of 3rd party subcontractors to complete specific scopes of work, such as painting.

There is more flexibility for the mid-tier shipyards regarding subcontracting, particularly where union influences are low. This is reflected in the scores.

Proposed actions

- Collaborative project to develop a core competence template, a subcontract rationale and assessment methodology

I10 Purchasing procedures

This element was the highest scoring of all the purchasing elements, for both the large and mid-tier yards. The purchasing systems are all computer-based and are integrated with the planning and production control systems. The level of integration with engineering varies. The logical next step for many shipyards is to put more information into the Engineering Bill of Materials (EBoM) that can be used directly by the purchasing systems. Use of e-commerce is limited and has not grown as much as for the commercial sectors. This is generally due to security constraints but it should be maximized wherever possible. As mentioned in I5 - Relationships with suppliers, it is encouraging to see a growing use of long-term, partner and framework agreements. However, there is some evidence that naval contracts can serve to limit the use of these. If this is the case, it should be reviewed.

Proposed actions

- Review naval contractual arrangements to ensure these do not limit the use of long-term agreements with suppliers

K PERFORMANCE IMPROVEMENT

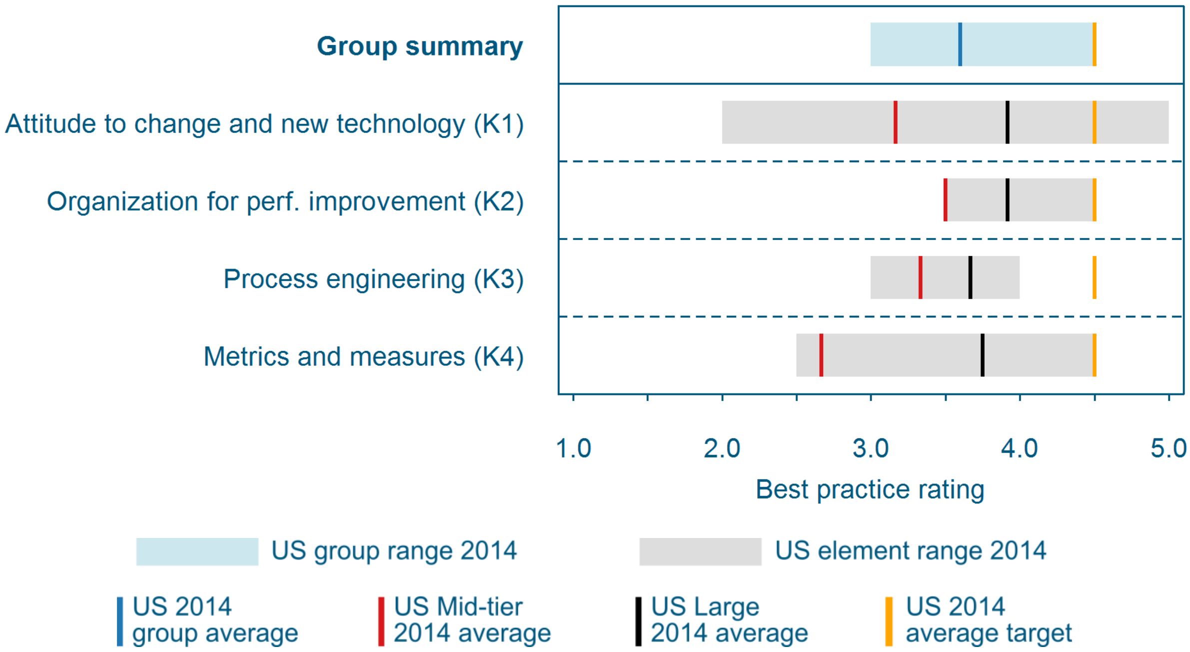

Figure A1.10 – Performance improvement

K1 Attitude to change and new technology

The attitude to change varies widely across both sectors but in general the large yards have achieved higher scores in this element. The leading yards are well on the way to achieving a solid culture of continuous performance improvement but the lowest scoring yards are still extremely conservative when it comes to adopting new techniques and technologies. Some yards have strong links with international shipyards. However, others do not often seek to acquire new technology from other sources. In some shipyards, the unions appear to be resistant to change and adopt behaviors, such as applying demarcation rules, which do not lead to high levels of productivity. In these yards, although management may be progressive and keen to develop, some members of the unionized workforce are not.

Proposed actions

- No industry-wide collaborative initiatives proposed

K2 Organization for performance improvement

All the shipyards surveyed have some type of organization to drive or assist with performance improvement and several yards have achieved the proposed target score. Several have dedicated teams of people focused on performance improvement but in others personnel have a split role and the responsibility for change rests with the line managers. The industry undertakes research collaboratively through NSRP and other such schemes but not much is carried out independently. Although it may exist informally, most yards do not have a documented vision of their future shipbuilding strategy associated with performance targets to guide development plans. Clearly such a vision would be helpful.

Proposed actions

- No industry-wide collaborative initiatives proposed

K3 Process engineering

A majority of the large yards now have a process engineering function that has the responsibility to work with departmental managers to develop processes. In the mid-tier and some large yards, process engineering is carried out but it is usually led by departmental managers and supported by ad hoc teams. About half of the yards benchmarked have well-trained process development personnel. Although a number of the shipyards have defined an interim product structure and have standard procedures for constructing them, the definitions tend not to be particularly granular. Rather than just accounting for the requirements of an individual project, most yards consider process engineering in the context of their whole product mix, which is positive.

Proposed actions

- No industry-wide collaborative initiatives proposed

K4 Metrics and measures

In general, performance targets tend to be expressed in terms of the budget required to carry out a specific task. A few yards complement this with the routine reporting of a range of output measures such as man-hours per pipe. A limited number also calculate some process measures but these tend to be produced on an as-required basis to support performance improvement initiatives. Ideally, overall performance targets should be expressed in a series of metrics that relate specifically to each department or workstation and are effectively communicated to all involved. Due to competitive pressures and other factors, there is reluctance within the industry to disclose the levels of productivity being achieved.

Proposed actions

- Industry collaboration to produce an ideal set of common performance measures which can be used to measure and drive performance. This would also allow benefits and achievements to be reported on a common basis

First Marine International

APPENDIX 2 – WORKFORCE SURVEY ROLES AND SKILL GROUPS

Category	Role	Benchmark years of experience to be considered experienced	Benchmark percentage of experienced personnel	Consolidated skill group
Commercial / Administrative	CEO and senior management	10	50%	CEO and senior management
	Legal / contract management	5	50%	Project management, commercial and contract management
	Finance and accounting	2	25%	Finance and accounting
	Sales and marketing / customer relations	5	50%	Sales and marketing
	Estimating and cost control	10	50%	Estimating, planning, and production and cost control
	Supply chain management	5	50%	Purchasing and supply chain
	Human resources	2	50%	Human resources
	Communications	2	25%	General clerical
	General clerical	2	0%	General clerical
	Information technologies	2	50%	General clerical
Technical / Production management	Planning and scheduling	10	50%	Estimating, planning, and production and cost control
	Production control	5	50%	Estimating, planning, and production and cost control
	Production engineering	5	75%	Production engineering and performance improvement
	Testing and trials management	10	50%	Production management and supervision
	Project / program management	10	50%	Project management, commercial and contract management
	Production management	10	50%	Production management and supervision
	Production supervision	10	50%	Production management and supervision
	Performance improvement	5	50%	Production engineering and performance improvement

Table A2.1 – Workforce roles and skill groups (continued over page)

Category	Role	Benchmark years of experience to be considered experienced	Benchmark percentage of experienced personnel	Consolidated skill group
Technical / Production management (continued)	Quality management and inspection	10	50%	Production - white collar
	Welding engineering and metallurgy	10	50%	Production - white collar
	Integrated logistic support	5	50%	Integrated logistics support and crew training
	Health / safety / environmental	5	25%	Facilities
	Facilities	2	25%	Facilities
Engineering	Engineering management	10	75%	Engineering - management
	Signature, survivability and other specialists	10	50%	Engineering - hull
	Combat systems and ship control	10	50%	Engineering - electrical and weapons
	Electrical	10	50%	Engineering - electrical and weapons
	Pipe systems	10	50%	Engineering - mechanical
	Mechanical	10	50%	Engineering - mechanical
	Naval architecture / arrangements	10	50%	Engineering - hull
	Structural	10	50%	Engineering - hull
	Testing & trials	10	75%	Engineering - hull
	Engineering support	2	25%	Engineering - support
	Other engineering	5	25%	Engineering - support
	Draftsmen - Electrical	5	50%	Draftsmen
	Draftsmen - Mechanical	5	50%	Draftsmen
	Draftsmen - Piping / HVAC	5	50%	Draftsmen
	Draftsmen - Structural / arrangements	5	50%	Draftsmen

Table A2.1 (continued) – Workforce roles and skill groups (continued over page)

First Marine International

Category	Role	Benchmark years of experience to be considered experienced	Benchmark percentage of experienced personnel	Consolidated skill group
Production	Steelworkers	5	25%	Steelworker / boilermaker
	Welder	2	25%	Welder
	Sheet metal worker	5	25%	Sheet metal worker, carpenter and insulation
	Pipe worker	5	50%	Pipe worker
	Mechanical fitter / outside machinist	5	50%	Machinist
	Machine shop operators	5	25%	Machinist
	Electrician	5	25%	Electrician
	Painter	2	25%	Painter
	Joiner / carpenter / insulator	2	25%	Sheet metal worker, carpenter and insulation
	Testing and trials	5	50%	Electrician
Production support	Warehousing and transport	2	25%	Production support
	Staging and access	2	25%	Production support
	Temporary services	2	25%	Production support
	Riggers / crane operators	2	25%	Production support
	Jigs and fixtures	5	25%	Steelworker / boilermaker
	Cleaning and protection	2	0%	Production support
	Maintenance	2	50%	Production support
	Security	2	25%	Production support

Table A2.1 (continued) – Workforce roles and skill groups

APPENDIX 3 – PRIORITIZATION TABLES

Element description (large yards)	Rank	Element description (large yards)	Rank
Design for production (F7)	1	Materials and equipment standards (I8)	36
Dimensional and quality control (F8)	2	Onboard services (D4)	37
Manpower and organization of work (G1)	2	Curved and 3D unit assembly (A9)	38
Process engineering (K3)	2	Outfit steel (A11)	38
Inventory and logistics (I6)	5	Ship construction (D1)	40
Subcontract policy (I9)	5	Stores control (G6)	40
Pre-erection outfitting (C3)	7	Superstructure unit assembly (A10)	42
Production engineering (F6)	7	Welding (D3)	42
Outfit installation (D6)	9	Stiffener cutting (A4)	44
Job and skills flexibility (H1)	10	Block assembly (C4)	45
Attitude to change and new technology (K1)	10	Production management info. systems (G9)	45
Outfit parts marshalling (C2)	12	Purchasing procedures (I10)	45
Vendor furnished information (I7)	12	Storage of large/heavy items (B6)	48
Test and trials and setting to work (F10)	14	General environment (E2)	48
Ship design (F1)	15	Training and education policy (H2)	48
Metrics and measures (K4)	15	Plate and stiffener forming (A5)	51
Production control (G5)	17	Flat unit assembly (A8)	51
Master planning (G2)	18	Erection and fairing (D2)	51
Organization for perf. improvement (K2)	18	Layout and material flow (E1)	51
General storage and warehousing (B5)	20	Lofting methods (F9)	51
Materials handling (C6)	20	Identification of sources of supply (I2)	56
Education and skill levels (H3)	20	Minor assembly (A6)	57
Outfit production information (F3)	23	Sub-assembly (A7)	57
Coding system (F4)	23	Pipe shop (B1)	57
Quality assurance (G8)	25	Sheet metal working (B3)	60
Painting (D7)	26	Vendor recruitment (I3)	60
Status of purchasing and the supply chain (I1)	26	Parts listing procedure (F5)	62
Supplier performance (I4)	26	Stiffener stockyard and treatment (A2)	63
Module building (C1)	29	Unit and block storage (C5)	64
Steelwork production information (F2)	29	Plate stockyard and treatment (A1)	65
Staging and access (D5)	31	Environmental control (E3)	66
Steelwork scheduling (G3)	31	Machine shop (B2)	67
Outfit scheduling (G4)	31	Plate cutting (A3)	N/A
Performance and efficiency calc. (G7)	34	Electrical (B4)	N/A
Relationships with suppliers (I5)	34		

Table A3.1 – Large yards prioritization of elements requiring action

Element description (mid-tier yards)	Rank	Element description (mid-tier yards)	Rank
Dimensional and quality control (F8)	1	Quality assurance (G8)	30
Module building (C1)	2	Materials and equipment standards (I8)	30
Pre-erection outfitting (C3)	2	Flat unit assembly (A8)	38
Outfit installation (D6)	4	General storage and warehousing (B5)	38
Design for production (F7)	4	Stores control (G6)	38
Metrics and measures (K4)	4	Production management info. systems (G9)	38
Production control (G5)	7	Plate and stiffener forming (A5)	42
Status of purchasing and the supply chain (I1)	7	Pipe shop (B1)	42
Attitude to change and new technology (K1)	7	Painting (D7)	42
Process engineering (K3)	7	Minor assembly (A6)	45
Manpower and organization of work (G1)	11	Curved and 3D unit assembly (A9)	45
Supplier performance (I4)	11	Environmental control (E3)	45
Relationships with suppliers (I5)	11	Vendor recruitment (I3)	45
Inventory and logistics (I6)	11	Purchasing procedures (I10)	45
Vendor furnished information (I7)	11	Stiffener cutting (A4)	50
Production engineering (F6)	16	Steelwork production information (F2)	50
Master planning (G2)	16	Training and education policy (H2)	50
Outfit scheduling (G4)	18	Sub-assembly (A7)	53
Ship design (F1)	19	Block assembly (C4)	53
Test and trials and setting to work (F10)	19	Staging and access (D5)	53
Education and skill levels (H3)	19	General environment (E2)	53
Subcontract policy (I9)	19	Parts listing procedure (F5)	53
Organization for perf. improvement (K2)	19	Identification of sources of supply (I2)	53
Performance and efficiency calc. (G7)	24	Superstructure unit assembly (A10)	59
Job and skills flexibility (H1)	24	Stiffener stockyard and treatment (A2)	60
Electrical (B4)	26	Plate cutting (A3)	61
Outfit steel (A11)	27	Storage of large/heavy items (B6)	61
Outfit parts marshalling (C2)	27	Layout and material flow (E1)	61
Steelwork scheduling (G3)	27	Unit and block storage (C5)	64
Materials handling (C6)	30	Machine shop (B2)	65
Erection and fairing (D2)	30	Plate stockyard and treatment (A1)	66
Welding (D3)	30	Sheet metal working (B3)	N/A
Onboard services (D4)	30	Ship construction (D1)	N/A
Outfit production information (F3)	30	Lofting methods (F9)	N/A
Coding system (F4)	30		

Table A3.2 – Mid-tier yards prioritization of elements requiring action

APPENDIX 4 – 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. This glossary is designed to help in this situation.

ACCURACY CONTROL (A/C)

The application of methods of auditing and controlling accuracy and dimensions during production. A/C emphasizes worker checks as well as improved fitting and welding techniques at stages of production to minimize problems at subsequent stages.

ADVANCED OUTFITTING – see PRE-OUTFITTING

ASSEMBLY

The process of joining pieces (steel or outfit) together 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, MINOR

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

ASSEMBLY, SUB

The process, or end result, of joining pieces and minor assemblies into a product which will then be joined to other assemblies to form units and blocks.

ASSEMBLY, PANEL

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

ASSEMBLY, UNIT

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

ASSEMBLY, BLOCK

The process of joining units to form blocks.

ASSEMBLY, GRAND BLOCK

The process of joining two or more steel 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 units.

BLOCK
An assembly formed by joining together two or more steel units.

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

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 to delivery for a particular vessel.

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

CELLULAR MANUFACTURING
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.

COMPUTER-AIDED DESIGN/COMPUTER-AIDED MANUFACTURING (CAD/CAM)
The application of computers to facilitate the design, engineering, lofting and manufacturing processes.

COMPONENT
Any single item which 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.

CONSTRUCTION (also ERECTION)
The process of installing steel 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 building site (e.g., inclined way, land-level facility or building dock) up to a point where the vessel is structurally complete and ready for launch.

CONSTRUCTION SITE (also CONSTRUCTION POINT, ERECTION SITE)
The land level or inclined building way, or building dock, from where the vessel will be launched.

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

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 mission requirements.

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

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

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

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 meet scheduled requirements.

ENGINEERING (also TECHNICAL)
Part of the design organization that develops the detail 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 in those parts at the preliminary design stage.

ERECTION – see CONSTRUCTION

ERECTION CYCLE – see CONSTRUCTION CYCLE

ERECTION SITE – see CONSTRUCTION SITE

FABRICATION (also PREPARATION)
The initial production process consisting of layout, cutting and forming to create outfit or structural piece parts.

FACILITIES
The buildings, cranes, plant and equipment available to the shipbuilder.

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

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

GROUP TECHNOLOGY
A basis for production organization which allows small batch and at one of the kind production to gain the benefits normally obtained from flow production of large numbers of products.

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

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

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

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

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

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

MINOR ASSEMBLY – see ASSEMBLY

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

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

NETWORK
The representation of a set of logically connected events or activities which shows the sequence and inter-dependence of those events or activities.

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

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

OUTFIT STEEL
Non-structural steel parts and assemblies usually related to outfitting, often outsourced.

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

OUTFIT MODULE – see MODULE

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 plates, together with associated stiffening.

PARTS LIST

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

PIECE PART

Product of the preparation or fabrication stage of production.

PIPE BANK

An outfit assembly comprising pipes from one or more ship systems mounted on supports and completed prior to installation.

PLANNING

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

PLANNING, STRATEGIC

Long term planning, beyond the current order book and generally over a timescale of at least ten years.

PLANNING, TACTICAL

Medium term planning with a time horizon of about three months. The preparation of an overall program for each contract and a corresponding program for each department.

PLANNING, DETAIL

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

PLANNING UNIT

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

PRELIMINARY DESIGN – see DESIGN

PRE-OUTFITTING (also ADVANCED OUTFITTING)

The process of installing outfit items during assembly of the structural units rather than during construction of the vessel or after launch.

PREPARATION – see 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 allows it to be manufactured effectively with the available facilities.

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, or of the crafts and facilities directly associated with that process.

PRODUCTION ENGINEERING (also INDUSTRIAL ENGINEERING)
The application of systematic methods to analyze and determine the requirements of production and to develop production methods to meet those requirements. In general, to reduce inherent work content, to improve the efficiency of production, to lower cost and reduce cycle time. This includes the integration of design and production.

PRODUCTION INFORMATION
Any information which informs production how and when to carry out their function.

PRODUCTION STAGE
A particular phase of the ship production process.

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

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

STAGING or SCAFFOLDING
Upright supports and working platforms giving access to a vessel during assembly and construction.

STRATEGIC PLANNING – see PLANNING

SUB ASSEMBLY – see ASSEMBLY

SUBCONTRACTING – see OUTSOURCING, SUBCONTRACTOR
An individual or company outside the shipyard which supplies services to the shipyard.

SUB NETWORK – see NETWORK

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

TACTICAL PLANNING – see PLANNING

TECHNICAL – see ENGINEERING

TRANSITION DESIGN – see DESIGN

UNIT
An assembly (steel and/or outfit) forming part of the vessel which will be joined to others to form blocks or taken to the construction site to be joined to the hull.

UNIT ASSEMBLY – see ASSEMBLY

UNIT BREAKDOWN – see BLOCK BREAKDOWN

VENDOR FURNISHED INFORMATION
Information supplied to the shipyard by an external supplier or sub-contractor.

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

WORK BREAKDOWN STRUCTURE
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.

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 material.

WORKSTATION DRAWING
A drawing which relates to a work package to be carried out at a specific workstation. Includes production information.

ZONE
A defined geographical sub-division of a ship.

HASKONINGDHV UK LTD
MARITIME & WATERWAYS

2 Abbey Gardens
Great College Street
Westminster
London SW1P 3NL
United Kingdom

+44 (0)20 7222 2115	Telephone
	Fax
info.fmi@rhdhv.com	Email
www.maritime-rh.com/fmi-home-page.html	Internet

Document title:	Part 1: Shipbuilding
Status:	Final, revision 3
Date:	18 March 2016
Project name:	2014 US Naval Shipbuilding and Repair Industry Benchmarking
Project number:	9Y1755
Client:	ASN(RDA)
Revision:	Draft issued 19 December 2014 Draft revision 1 issued 15 April 2015 Final issued 22 May 2015 Final revision 1 issued 02 July 2015 Final revision 2 issued 18 September 2015 Final revision 3 issued 18 March 2016
Drafted by:	Damien Bloor, Steve Maguire, Gilly Fox, Adam Broughton and Adam Hawkins
Checked by:	Adam Broughton
Date/initials check:	18 March 2016
Approved by:	Damien Bloor
Date/initials approval:	18 March 2016