Benchmarking of U.S. Shipyards

Industry Report

NSRP ASE

January 2001

National Shipbuilding Research Program
Executive Control Board

5300 International Boulevard
North Charleston, South Carolina 29418

DATE: January 30, 2001

TO: U.S Shipbuilding Industry

FROM: Chairman, Executive Control Board (ECB)
National Shipbuilding Research Program (NSRP)

SUBJECT: U.S. Shipbuilding Industry Benchmarking Report

During the development of the NSRP Strategic Investment Plan (SIP) in 1998, it was concluded by the NSRP Executive Control Board (ECB) that a baseline was needed to measure performance of the U.S. Shipbuilding industry during the period of the program. To establish the baseline First Marine International (FMI), an expert in performance measurements in the shipbuilding and repair industry was competitively selected to survey the industry. The FMI benchmarking system has been used in more than 150 shipyards worldwide and most recently it has formed the basis of industry studies in the U.S., mainland Europe, Japan, South Korea and the UK. The FMI system allows a shipyard's current competitive position to be established and provides an evaluation against international best practice of the applied technology and practices in key areas. By surveying nine of the ECB yards, an overall industry evaluation (baseline) was conducted. The benchmarking was started in May 1999 and completed in October 2000. The delay in completing the surveys resulted when special considerations were taken to satisfy ITAR restrictions. FMI personnel (UK Citizens) trained knowledgeable and experienced U.S. citizens to use the FMI system to conduct the in-yard surveys of the Naval shipbuilders. This letter forwards the U.S. shipbuilding industry benchmarking report with comments and recommendations.

During the same period when the U.S. shipyards were being surveyed, FMI conducted surveys of four competitive European shipyards. Japanese and Korean personnel, trained by FMI, conducted surveys of top performing shipyards in their countries. Although the U.S. industry report does not directly report on the results of the foreign benchmarking surveys, the averages of the combined European, Japanese and Korean benchmarking results are provided for comparison in the U.S. industry-wide report.

The surveyors recognized that there are certain best practices that may not be applicable to naval shipbuilding and they left it to the U.S. yards to make that judgment. The benchmarking effort identified Asian and European best practices and how the U.S. yards stack up against them. One of the objectives of the U.S. industry is to strive to become internationally competitive and the report provides the relevant information to assist in this objective.

In reviewing the U.S. shipbuilding industry report, the following conclusions are offered:

- The U.S. shipbuilding industry is getting better, but so is the competition, which has been improving at a faster rate.
- Improvements are needed in individual shipyards as well as in the industry as a whole.
- Some U.S. shipyards are best in the world in isolated factors surveyed. However the broad spread of Best Practice Ratings in the industry-wide report shows the need to improve the industry as a whole to bring the lower performing yards up closer to the higher rated yards. Collaboration is needed to narrow the band near the top performer.

- The U.S yard average and wide spread of Best Practice Ratings validate the needs identified in the Strategic Investment Plan for technology and process improvements and also validate the project portfolio funded in the first two years of the Plan.
- The need for fully funding the Plan is validated by the results of the benchmarking. Although improvement in U.S. shipbuilding performance was validated by the benchmarking, more improvement is needed and the Plan provides the roadmap for the improvement with the appropriate funding.

The following actions are planned or are needed to continue the improvement of the industry:

- The Strategic Investment Plan is being updated to take into account the new information made available by the benchmarking effort.
- Because Navy incentives are crucial to accelerate the improvement curve, the ECB urges the Navy to take action on the Navy Business Practices recommendations.
- The Navy is urged to fully fund the Strategic Investment Plan and continue the investment to restore the U.S. shipbuilding industry to prominence and better efficiency.
- A second round of benchmarking is planned in approximately 18 to 24 months using the same benchmarking system to measure the effectiveness of the projects funded and shared throughout the industry. Using the 2000 survey as a benchmark, this next round will also provide input for any needed revision to the Strategic Investment Plan.

In taking the action to develop and update the Strategic Investment Plan, measure the performance of the U.S. shipbuilding industry against the best in the world, and continue the strong collaborative nature of the NSRP, the ECB strongly reaffirms its position of industry leadership teaming with the Navy to carry out the mission and vision of the program.

Sincerely,

S/

Harvey Walpert
Chairman, ECB

Industry report

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NOTE:

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

0 KEY FINDINGS AND RECOMMENDATIONS

The shipyard benchmarking projects in the USA, Japan, South Korea and Europe have allowed important overall conclusions to be drawn regarding the strengths, weaknesses and overall positioning of the U.S. shipbuilding industry. These include:

Price competitiveness (in terms of $ added value per CGT): The leading commercial yards appear to be only a little less competitive in certain higher added-value ship types than the level set by the international market. However, they are a long way behind the level of performance required to compete in the volume ship types. There is strong evidence to suggest that market prices will increase in the short to medium term and the competitiveness gap is likely to get smaller.

Productivity: Based on the survey results, the U.S. shipbuilding industry is more productive than it was in the mid 1990s and there has been an acceleration in the rate of improvement in recent years. It is essential that the rate of improvement is maintained as productivity is still well below the European average and as low as 25% to 40% of that found in many Japanese yards. To establish a position in the higher value international markets, a typical U.S. medium or large yard should be looking to target a 75% improvement in productivity over the next five years (equivalent to 11.8% year on year).

Use of best practice: There has been an improvement in U.S. yards in "use of best practice" (measured on the FMI scale of reference) of 1.1 (some 55% in terms of improvement in average score) in about twenty years. This is significant but disappointing when compared to the rates of improvement achieved in many Far East shipyards. At 3.1, the average for the U.S. large yards is below the norms for industrialized countries. Having said that, there are examples of yards using best practice in certain areas as evidenced by scores of 4.0 and above. The best practice rating required needs to be calculated for each individual yard, however, it is estimated that small yards should be looking to achieve an average rating of at least 2.5 and larger yards at least 3.75.

Future characteristics: The medium cost base (principally labor related) in the U.S. means that yards do not have to have the highest technology in every respect to win high value orders in the international market. However, it does mean that they have to have an effective implementation of some established techniques that will provide the basis for future improvement. These include work station organization, accuracy control, better organization of on-board outfitting, reduction in non added value activities such as materials handing and scaffolding, reduction in inventory and the adoption of standards of all types, at all levels. The industry needs to have a more effective engineering and production engineering capability that can deliver reduced lead times, lower material content and cost, and the production information needed to support more advanced build strategies.

Closing the gap: A number of yards have an excellent infrastructure that has benefited from recent investment. Others are very basic and will require investment to significantly improve performance. However, in most yards, much can be achieved through improving procedures and working practices without significant investment in facilities. Particular emphasis should be placed on improving practices in the pre-production areas without which production is limited in the extent it can improve. Shipyards need to have a market-focussed long range performance improvement plan that addresses facilities and procedures and provides a logical forward-looking framework. Several major infrastructure improvement projects were noted during the surveys, however, only the facilities that were up and running were surveyed.

1 INTRODUCTION

This report summarizes the findings of the NSRP ASE project entitled Benchmarking of U.S. Shipyards. The overall objective of the project is to assist the U.S. shipbuilding industry to improve its performance by:

- identifying the strengths and weakness of individual shipyards;
- providing focus for the NSRP ASE strategic plan by identifying the strengths and weakness of the industry as a whole;
- making suggestions for improvement at company and industry level;
- quantifying the change brought about in the shipyards by the NSRP ASE project.

Industry consultants First Marine International (FMI) and KPMG LLP (KPMG) have undertaken the work under contract to NSRP ASE. The FMI benchmarking system has been used to carry out the benchmarking.

Nine companies comprising fifteen shipyards have been benchmarked. All were benchmarked in May and June 1999 by an FMI team except for Ingalls, Newport News, Bath Iron Works and Electric Boat which were postponed to 2000 to allow the approach to be modified in light of the ITAR regulations. In the case of these latter four yards, a U.S. team undertook the survey work in late summer 2000 and wrote the individual yard reports.

This industry report is based on the benchmarking of the following fifteen shipyards:

- Alabama Shipyard (one yard);
- Avondale Shipyards Division (one yard);
- Bath Iron Works (one yard);
- Electric Boat (two sites - scored as one yard);
- Halter Marine Group (seven yards);
- Ingalls Shipbuilding (one yard);
- National Steel and Shipbuilding Company (one yard);
- Newport News Shipbuilding (one yard);
- Todd Pacific Shipyards (one yard).

The benchmarking system and the methods used to undertake the study are explained in Appendix 1. Essentially, the system benchmarks fifty elements of shipbuilding technology on a scale of 1 to 5, where 5 represents state-of-the-art international best practice. The aim is to identify the strengths and weaknesses and to provide the information required to produce a prioritized performance improvement plan that is driven by market requirements.

It is important to note that higher levels of technology are not intrinsically “better”. The highest technologies often imply a high capital cost and their application may not be appropriate in countries that do not have a high base cost. Most shipyards do not need to score 5 to be competitive. The important objective is to have a balance of technology across all of the elements at the level dictated by the shipyard’s cost base and target market.

There is a trade-off between investment in facilities and technology and labor cost that leads to the optimum use of best practice and the most price competitive position. Yards with a high cost base need to adopt high levels of best practice to achieve a performance level where they can be price competitive. The optimum level is also affected by the level of market price which varies with ship type and market sector.

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

Assessment of overall performance is an important factor in the benchmarking process. The use of best practice helps to explain why overall performance is what it is. Again, this is discussed in detail in Appendix 1. The measures used to assess performance vary from company to company. The two indicators used in this study are:

1. Man-hours spent per compensated gross ton (CGT) produced, which measures productivity.
2. Break-even cost per CGT produced, which measures cost competitiveness.

Break-even cost refers to all costs excluding purchases such as material and equipment.

This report is subdivided into the following sections:

- Section 2 summarizes the overall performance of the industry and its overall use of best practice;
- Section 3 provides a more detailed summary of the use of best practice in the industry and gives recommendations for performance improvement.

2 FINDINGS

2.1 General

At the time of the surveys, the yards were engaged in a variety of newbuilding work in the commercial and military sectors. The commercial output was substantially for the Jones Act sector while the military output was mainly for the U.S. Navy but with some exports. The overall product focus is relatively complex vessels. Some yards have a healthy orderbook and promising enquiries, others are less well positioned. The slump in oil prices was reported to be having a significant detrimental effect on the core market of some yards at the time of the visits. One yard had withdrawn from newbuilding for the time being and was concentrating on ship repair.

In general, the survey teams were impressed by the positive attitude of the personnel who took part and by the improvements in the use of best practice that have occurred in several yards over recent years. In terms of price competitiveness, some of the commercial yards appear to be only a little less competitive in some ship types than the level set by the international market. However, they are a long way behind the level of performance required to compete in the volume ship types where the price is currently set by South Korean yards. There is strong evidence to suggest that the prices offered in South Korea are not sustainable and they will increase in the short to medium term. Therefore, to some extent, the gap is likely to get smaller.

A general indication of the level of commercial yard price competitiveness has been gathered and compared to the international market requirement. The cost base in the U.S. varies from State to State and between yards. As a result, a relatively small performance improvement may allow those with a lower cost base to become truly internationally price competitive in some commercial ship types. Shipyards with a higher cost base have further to go.

A number of yards have an excellent infrastructure that has benefited from recent investment. Others are very basic and will require investment to significantly improve performance. However, in most yards, much could be achieved through improving procedures and working practices without significant investment in facilities. Particular emphasis should be placed on improving practices in the pre-production areas.

Most of the people interviewed were aware of the need for performance improvement. All yards are already engaged in a variety of improvement programs, some of which are independent of the NSRP ASE program. However, most yards lacked a coordinated overall performance improvement plan that is focused on market requirements. Managers are less aware of how to create a culture of continuous improvement and attention needs to be given to drawing the whole workforce into the improvement process and empowering them to make improvements for themselves.

The results of the individual yard surveys have given managers an overview of the current situation and allowed them to identify their strengths and weaknesses. Most shipyards have the knowledge and ability to help themselves in many areas but may require external assistance to implement some of the more advanced technologies.

2.2 International comparison

As part of this survey, industry personnel were asked to complete questionnaires relating to vessel design and work content, and shipbuilding performance and output over the last three years. Information of this nature was not provided by any of the combatant builders. Where it was forthcoming, the information has been used to determine overall performance in commercial shipbuilding in terms of man-hours and $ per CGT. The indication of overall price performance given in the previous section was derived from the assessment of break-even cost ($ per CGT) provided by this data. Similar analysis has allowed the overall productivity (man-hours per CGT) to be calculated. CGT and the calculation of CGT are explained in Appendix 1, Section 4.

Figure 2.1 below plots use of best practice (Overall best practice rating) against overall productivity (Man-hours per CGT) for both small and large yards. The original curves were drawn in 1992 at the time of the EC Study of the Competitiveness of European Yards carried out by KPMG and FMI. That study benchmarked forty international shipyards. The 1999/2000 benchmarking projects in the U.S., Japan, South Korea and Europe have allowed the chart to be updated. The origins and relationships expressed in this figure are explained in further detail in Appendix 2.

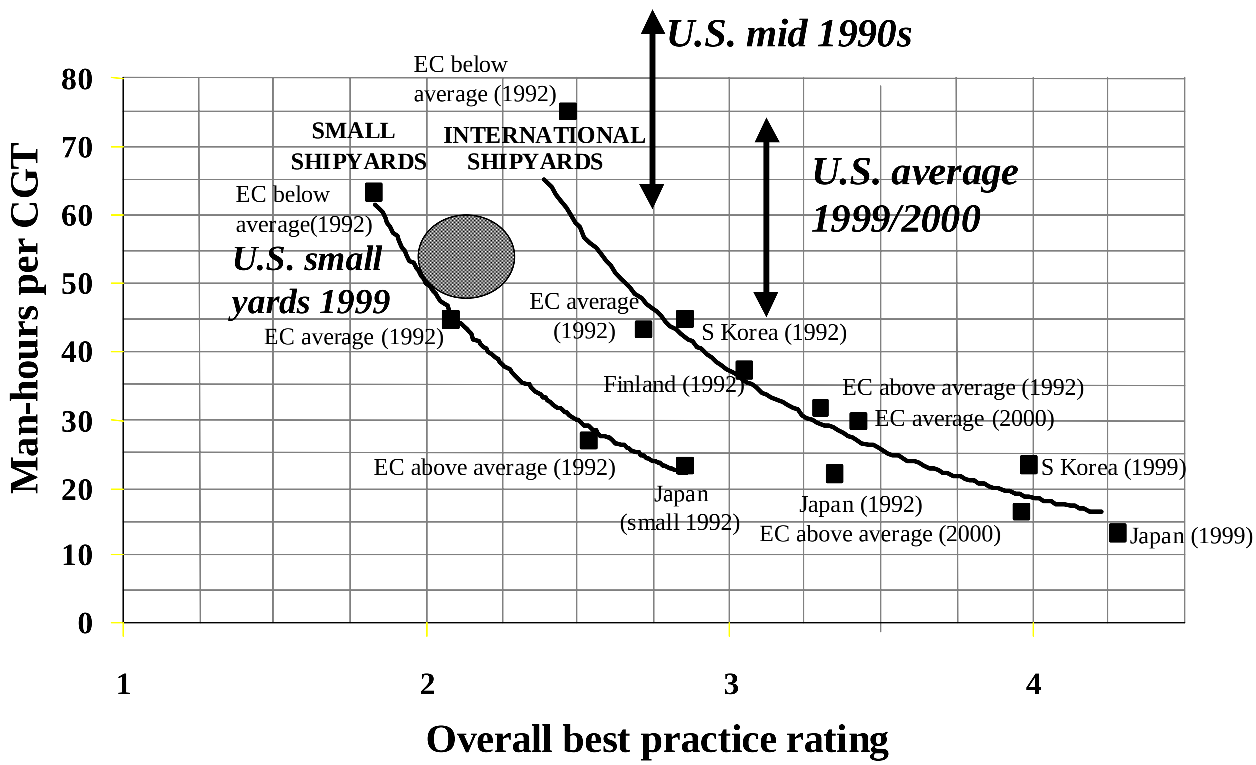

Figure 2.1 – Best practice and overall performance

The overall average best practice rating in Figure 2.1 includes the results from all the yards surveyed whether or not they provided performance data. The range of performance indicated by the vertical arrow covers only those yards that provided such data.

It is important to note the extent of the improvement in both performance and use of best practice in Japan, South Korea and Europe over the seven year period from 1992 to 1999. South Korean performance in particular shows a year-on-year improvement of some 10% and a total movement of about 1.15 in best practice rating. Starting from a higher performance base, the rates of improvement in Japan and Europe have been less dramatic but nevertheless impressive.

With regard to the U.S., prior to 1999, surveys were carried out in 1978 and 1994. Of the two, the 1978 NSRP survey can best be compared with the recent work. The 1978 survey covered thirteen U.S. and sixteen foreign shipyards. The team was well trained and the project was carried out to a high standard. However, both the number of elements surveyed and the definition of the levels were different and adjustments have to be made for these differences.

In the case of the 1994 study, a poorly defined Level 5 had been added in the late 1980s and, furthermore, the definition of the levels of technology for Levels 1 to 4 were not explicit in many areas. The survey team had no formal training and this led to inconsistencies in the scoring. In addition, there was no measure of effectiveness which is critical for the highest levels. Many of the scores cannot be justified and the impression that the U.S. industry has been moving in the wrong direction between 1994 and 2000 is false.

Between 1994 and 1999, FMI rationalized the number of elements surveyed and significantly improved the descriptions of the elements.

Looking now at the improvement between 1978 and 1999/2000, the results from 1978 and 2000 have been adjusted so that they can be analyzed on a like-for-like basis. It is found that the industry average of 2.5 in 1978 would have scored about 2.0 on the 1999/2000 scale of reference. Thus the movement in use of best practice has been 1.1 in about twenty years. This is significant but disappointing when compared to the rates of improvement achieved in many Far East shipyards.

Having said that, studies done by FMI in the mid 1990s indicated an average score of 2.75 in a small sample of non-combatant yards. This in shown on figure 2.1 by the double-headed arrow marked “U.S. mid 1990s”. Thus, the best practice rating has increased by about 0.35 in the five years from mid 1990s to 1999/2000 (shown on figure 2.1 by the double-headed arrow marked “U.S. average 1999/2000”) compared to 0.75 in the previous fifteen years. Thus it appears that there has been an acceleration in the rate of improvement in recent years. This is encouraging and it is essential that this impetus is maintained as productivity in U.S. commercial yards is well below the European average and as low as 25% to 40% of that found in many Japanese yards. What is clear however, is that the U.S. industry is performing better than it was in the 1990s. The answer to the question whether or not the gap is closing between the U.S. shipbuilders European/Asian yards is unfortunately yes and no. On the evidence available there is no overall picture but there is evidence that some yards are closing the gap and others are not. There are also examples of yards using best practices in certain areas. This is evidenced by scores of 4.0 and above.

Another point to note is the general positioning of the yards above the two trend lines which indicates that there is considerable scope to improve performance by working more effectively without the need to make fundamental changes to infrastructure or the basic technologies employed. However, in order to become internationally price competitive, companies will have to increase their use of best practice in all areas.

Targets for improvement should be set by calculating the performance required to be competitive in a particular market sector. A performance improvement plan can then be drawn up to close the gap between the current and the required performance. It should be noted, of course, that the market leaders and the industry's competitors are not standing still.

The value added by the shipyard is only one element of the ship cost/price. The quantity and cost of materials and equipment generally carry equal weight in the overall cost equation. Earlier studies have shown that U.S. shipbuilders often use more materials and equipment in their designs than is the case in the international sector. In many cases, they also pay more for their purchases. This is affected by the use of best practice. Yards that operate at higher levels of the best practice are generally more able to produce optimized designs. They also tend to adopt more advanced purchasing strategies.

2.3 Use of best practice

This section contains a summary of the best practice ratings assigned during the survey visits to each group of elements and shows the overall balance between them. A description of the overall strengths and weaknesses in each element, a short overview that justifies the scores and a general indication of the areas where improvements can be made is given in Section 3. These include suggestions for industry-wide action and areas of co-operation. More detailed yard specific suggestions have been included in the individual shipyard reports.

The improvement suggestions made in this report are an indication only because the actual degree of improvement required is different in each yard and must be market driven. Each yard should determine the level of productivity required to be successful in its target market. Then, using the graph in Figure 2.1 as guidance, translate this into the level of use of best practice required. The future characteristics of the yard can then be determined and a yard specific plan drawn up to close the gap between the use of best practice as identified by this survey and the optimum use of best practice for the yard. While the overall objective is to have a balance across all elements, there may be market driven reasons for having an imbalance and these need to be taken into account. It is estimated that small yards should be looking to achieve an average best practice rating of at least 2.5 and larger yards at least 3.75.

The lowest and highest average ratings for each group of elements for all the U.S. yards surveyed are shown in Table 2.1. To avoid distortion, the seven Halter yards have been averaged and counted as one. The scores assigned to the individual elements within each group are given in Section 3.

Group	Lowest average rating	Highest average rating
Steelwork production	1.8	3.4
Outfit manufacturing and storage	1.6	4.0
Pre-erection activities	1.8	4.6
Ship construction and outfitting	2.2	3.6
Yard layout and environment	2.0	3.7
Design, engineering and production engineering	2.5	4.0
Organization and operating systems	2.6	3.9

Table 2.1 – Best practice rating by group

The differences between each group can be seen more clearly in Figure 2.2 below. The bars extend over the range of average ratings assigned for all yards. Thus the left hand end of a bar gives the average score of the lowest yard for that group of elements and the right hand end the average score of the highest yard. The highest (or lowest) yard in any one case is not necessarily the highest (or lowest) in another.

The thick vertical lines show the overall averages for each group of elements for the industry excluding the small yards. The small yards are excluded so that the averages can be compared to the averages found in the Japanese, South Korean and European yards (which included large yards only).

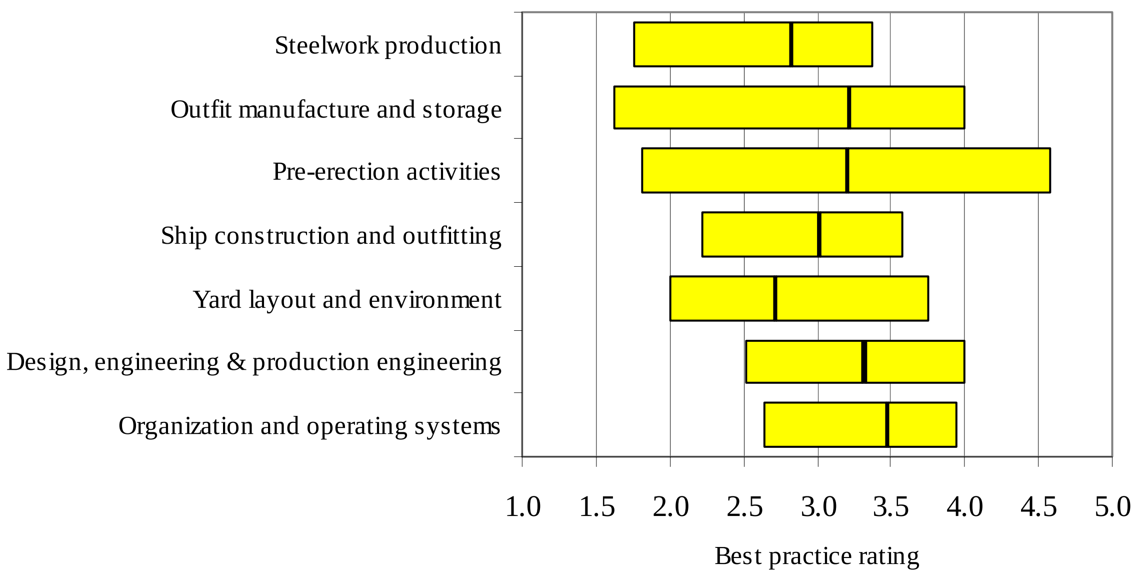

Figure 2.2 – Balance of use of best practice

As can be seen in the chart, the weakest scores are in steelwork and yard layout and environment and the highest scores are in the pre-production areas. It should be noted (not shown on the chart) that in some groups of elements, the best individual U.S. yard scores are higher than the foreign yard averages.

The overall industry average for the large U.S. yards for all fifty elements surveyed is 3.1. This is below industry norms for large yards in industrialized countries.

The scores assigned to the individual elements range from 1 to 5, with 0.5 assigned if the rating of the element is considered to be between whole numbers. The scores in Table 2.1 and Figure 2.2 do not fit this pattern because they are the average scores for each group of elements.

3 SURVEY NOTES

3.1 Steelwork production

Figure 3.1 below shows the range of ratings for all the yards benchmarked for each element in the steelwork production group. The vertical bar shown on each line in the figure is the average score of the large yards only. Subsequent paragraphs summarize the findings and give some ideas of developments that the shipyards might consider.

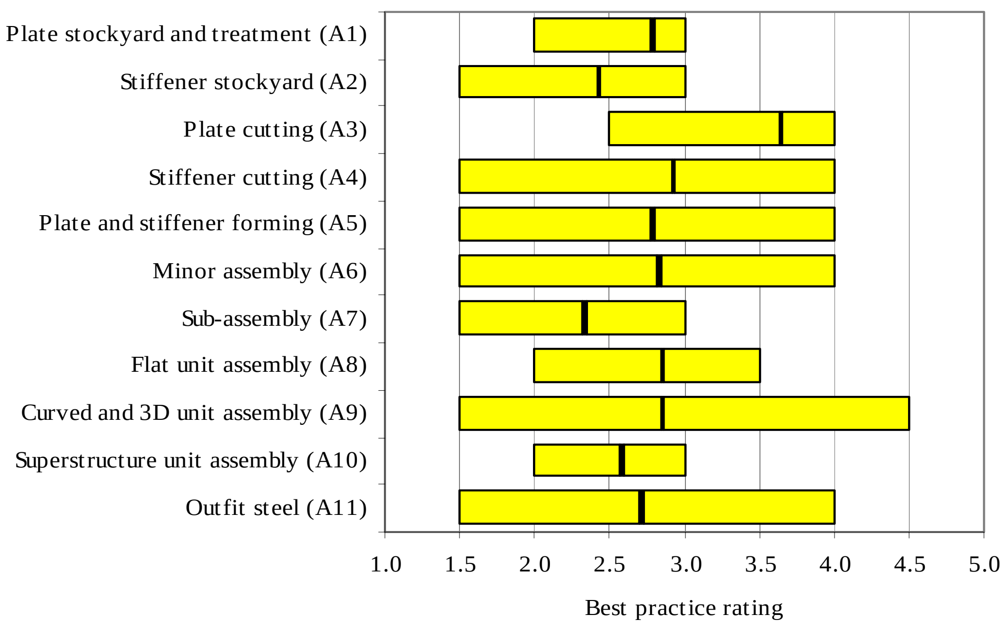

Figure 3.1 – Steelwork production

The steelwork production group scored poorly in comparison with the average scores for the other groups of elements industry-wide. The lowest yard averaged 1.8 for this group, the highest averaged 3.4. The average for the large yards for this group was 2.8.

Steelwork production methods in use ranged from basic at the left hand end of the bars to being equivalent to leading foreign industry norms at the right hand end. In some yards, the lack of mechanization and automation can be justified by low throughput but, even in these cases, much can be done in the way of low-cost tools and equipment improvements and, above all, by organizational changes – for example, the implementation of workstation organization.

The plate stockyard and treatment element scored about average within the group although some yards would benefit from improvements in both the layout and drainage of their stockyards. Plate and stiffener (shape) inventory levels are too high in many yards with the associated costs of double handling and degradation of material. Most yards have integrated treatment lines for plates and stiffeners but these were often found to be under-utilized, sometimes due to low workload but also through inferior methods of materials handling into, and out of the lines.

Stiffener storage, with few exceptions, did not score well. Some yards lack a dedicated stiffener storage area and are handling these materials in an ad-hoc fashion with forklifts and/or mobile cranes.

Plate cutting scored the highest of all the elements in the steelwork production group. Most yards now apply NC plasma cutting. However, direct link to a single product model ship design and engineering process is rare. Other areas for improvement include more efficient and less manpower-intensive materials handling, and better housekeeping.

Stiffener cutting scored less well with some yards continuing to mark and cut stiffeners by hand. Where automated lines are in place, some are either not used or were being set to work at the time of the survey. As a result, plate parts are often produced to a higher level of accuracy than stiffener parts.

Most plate and stiffener forming is done cold, sometimes in conjunction with heatline bending. Complex shapes are formed by pressing and/or line heating. The use of wooden templates is not uncommon. The inverse curve method is applied in some yards in frame bending but the curves may be manually drawn.

Low-cost improvements are possible in the preparation areas by further attention to reducing inventory and improving parts marshalling and general housekeeping.

Given the importance of accuracy and consistency in parts preparation and the low scores still found in these elements across the industry, many yards need to raise the level of technology applied in this area. The levels of throughput in many of the yards visited would justify further investment or, where this is not the case, clusters of yards may consider carrying out steel preparation collectively. This would provide the level of throughput required to justify investment in the most efficient equipment and techniques.

All yards manufacture minor and sub-assemblies during the course of building steel units. However, many do not consider these to be separate and distinct stages of assembly and examples were seen where minor and sub-assemblies were built alongside the units to which they were going. The application of mechanization and automation is more common in minor assembly than in sub-assembly. In the case of sub-assembly, no yard scored above 3.0 and methods generally remain basic. Much needs to be done in adopting workstation organization and the use of purpose-designed jigs and fixtures. Also, of equal importance, the identification and rationalization of interim products would allow variety to be reduced.

Most of the yards had mechanized process lines for the production of flat-based panels and units and it is in this high volume area of assembly that investment continues to be made. In spite of this, no yard scored over 3.5. The fairing aids used in panel build-up are still predominantly of the conventional welded type. Semi-automatic welding is becoming extensively used. Accuracy control can only be classified as “very good” in one yard.

Curved and 3d unit assembly on average scored similarly to flat unit assembly. This work tends to be done at fixed positions with generally what must be described as conventional methods and tooling. One-sided welding is applied to plate joints but little else has changed for some time.

With one exception, yards do not consider superstructure assembly to be distinct from the assembly of other structural blocks. Many yards would benefit from the implementation of dedicated areas for superstructure assembly, along with the appropriate use of dedicated workstations and specialized access equipment. In summary, assembly methods were found to be relatively basic and manpower intensive.

A few yards have made arrangements to produce outfit steel in dedicated areas and have made a conscious effort to reduce work content. Others produce outfit steel in a variety of locations and, in these, the process tends to be relatively inefficient. Only a small amount of outfit steel is sub-contracted although this is an increasing trend. Improvements can readily be made through increased standardization of outfit steel parts with the use of specialized jigs and fixtures for their manufacture.

3.2 Outfit manufacturing and storage

Figure 3.2 below shows the range of ratings for each of the elements in the outfit manufacturing and storage group. The vertical bar shown on each line in the figure is the average score of the large yards only. Subsequent paragraphs summarize the findings and give an indication of the developments that shipyards might consider in the future.

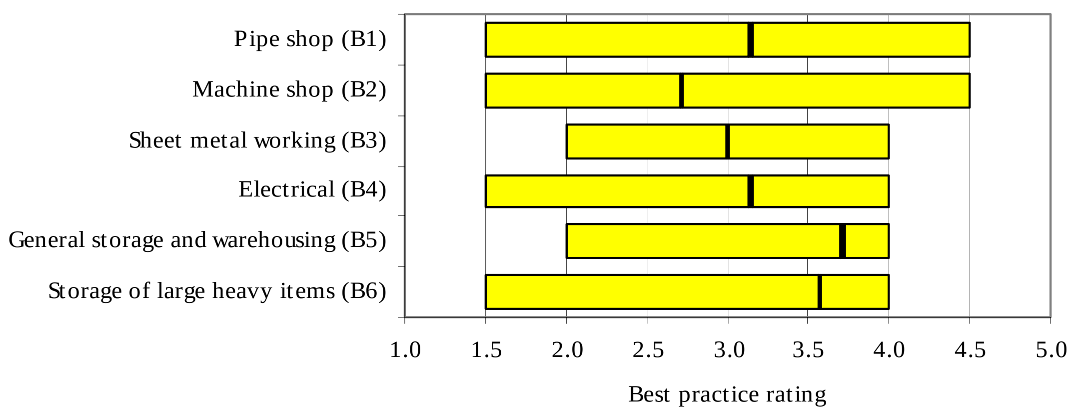

Figure 3.2 – Outfit manufacturing and storage

The outfit manufacturing and storage group scored relatively well in comparison with the average scores for the other groups of elements industry-wide. The lowest yard averaged 1.6 for this group, the highest averaged 4.0.

At 3.2, the average score for the large yards for this group is close to the overall industry average for all groups. However, there is a wide range of scores with examples of almost world-class practices at one end of the scale and very basic practices at the other. To some extent, the range is a reflection of the fact that both large and small yards are included but there are also some examples of wide variations in individual yards.

For the outfit manufacturing shops, the choice is often between making an investment in high technology manufacturing to improve performance or subcontracting the work. Throughput is not generally high enough in smaller yards to warrant high technology shops so these yards tend to take the subcontract option, often maintaining a low technology back-up facility. This is not the case in all small yards and some that continue to manufacture outfit items with a low level of technology suffer from low productivity in these areas. There appears to be an opportunity for some yards to raise throughput in outfit manufacturing areas, and hence justify higher use of best practice, by co-operating with other shipbuilders.

There is a full spectrum of approaches to pipe manufacture and a consequent variety of performance levels. Some yards have almost state-of-the-art, largely automated facilities while others template a large proportion of pipes or manufacture them at the point of installation. In terms of the average number of man-hours required to manufacture a pipe spool, one Japanese yard surveyed was spending about half as many man-hours as the best performing yard included in the U.S. survey. This is partly due to differences in the approach to the organization of work but is mainly due to the emphasis that Japanese shipbuilders place on making the work simple. All the yards included in the survey would benefit from identifying and rationalizing the variety of their pipe interim products. The yards with the least automated facilities should give consideration to adopting a cellular manufacturing approach and all yards would benefit, to a greater or lesser extent, from the application of lean manufacturing methods in this area.

Machine shops scored worst in this group and, with some exceptions, were found to be equipped with aged machinery set out in a traditional manner by machine type. With one exception, the most capable machine shops were found in those yards that also undertook repair work. The bulk of machining work in shipbuilding tends to be sub-contracted and in many cases there is no real need to have sophisticated machine shops. However, a few yards still do a substantial proportion of this work in-house and in these cases the comments made in the previous paragraph relating to rationalization of output and layouts are equally applicable here.

By and large, the yards subcontract the work traditionally carried out in sheet metal shops. Some work is still done in-house, often in shops that are best described as “jobbing shops”. There are, however, examples of excellent sheet metal shops that are embracing the doctrines of cellular production and lean manufacturing and these have scored highly.

Some electrical shops were found to be “jobbing” type installation support facilities that may occasionally manufacture a switchboard or fit a console. This type of manufacturing work is often sub-contracted. Some yards which did not subcontract had efficient and well-organized workshops. Most yards have gained a performance advantage from pre-cutting cables. The next step is to consider cable looming. There is an opportunity to gain further advantage from the development and further rationalization of electrical interim products such as cableways.

General storage and warehousing and storage of large heavy items scored well, averaging 3.7 and 3.6 respectively. Most are typical well run traditional storage areas with appropriate use of specialized racking, storage and handling equipment. No high-density mechanized storage systems and no automated picking or transport systems were seen. Some yards had made good use of line-side stores but others could not see the advantage and remained convinced that the losses due to pilferage would be greater than the savings their adoption would yield.

Some yards have made efforts to reduce inventory levels. In general there is good opportunity to make savings by reducing inventory levels and adopting less time-consuming approaches to the receipt, storage and handling of equipment and materials. Consideration should be given to minimizing the size of central warehouses with larger items arriving just-in-time to the point of use and more consumables being kept line-side. JIT is not yet a feature of U.S. yards.

3.3 Pre-erection activities

Figure 3.3 below shows the range of ratings for all the yards benchmarked for each element in the pre-erection activities group. The vertical bar shown on each line in the figure is the average score of the large yards only. Subsequent paragraphs summarize the findings and give some ideas of developments that the shipyards might consider.

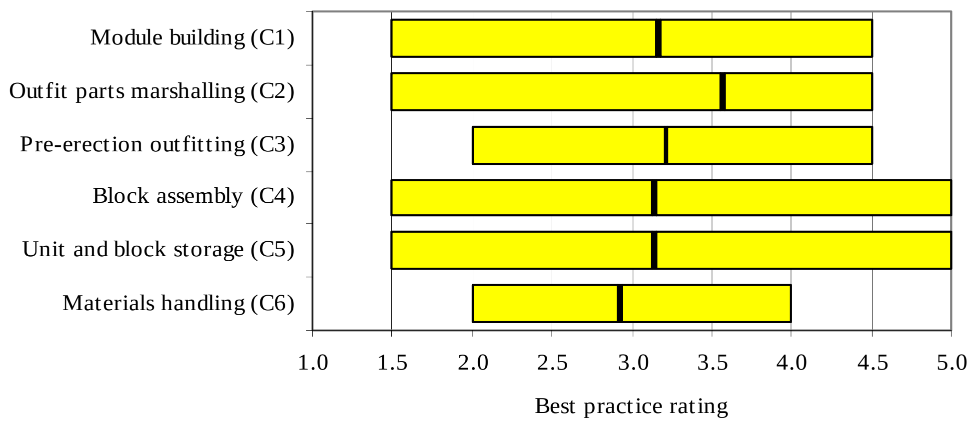

Figure 3.3 – Pre-erection activities

The pre-erection activities group scored relatively well in comparison with the average scores for the other groups of elements industry-wide. The lowest yard averaged 1.8 for this group, the highest averaged 4.6. The average for the large yards for this group was 3.2.

Although there is a general understanding throughout the yards of the cost benefits of adopting higher technology in these pre-erection activities, there is a very wide variation in the practices applied in both the small and the large yards. This confirms the opportunity here for low scoring yards to make significant progress, often without the need for major capital expenditure in new facilities. With the exception of block assembly, progress is possible in all elements without major capital expenditure as success tends to depend on engineering and planning and organizational issues.

The most important aspect in achieving best practice in module building is to develop the view that steelwork and outfit activities are not separate production processes and should be integrated as far as practicable throughout the whole shipbuilding process. This view is not yet generally accepted and module building was sometimes seen to be limited to the pre-assembly of minor outfit components off the ship. The objective being pursued by some yards is to produce integrated modules of steel and outfit, which are painted and tested off the ship. There are examples where this has been achieved and this has reduced expensive on-berth outfitting and shortened build cycle times. Families of module types may be developed which, with workstation organization and outfit manufacture optimized for each family type, will reduce costs further.

Outfit parts marshalling scored most highly compared with other elements in the group. In most yards, outfit parts are marshalled by zone and workpackage with information driven from centralized planning systems. Further gains can be made, however, through the extension of the use of line-side stores and through more rationalization and standardization of consumables and commonly used parts to reduce the number of items that need to be listed and controlled.

While pre-erection outfitting scored relatively well, there were some instances where the observed level of pre-erection outfitting was below the reported yard norm. This was put down to late client design decisions, first-of-class construction, or lack of detailed technical information. International best practice implies the development of interim product types, materials standards and module family types to be used in all designs. Use of these would offset the influence of the factors mentioned above and enable an increased level of pre-erection outfitting to be achieved for all contracts including first of class and one-offs.

Block assembly and unit and block storage scored to the average of the other elements in the group. Most yards had dedicated block assembly areas with suitable transport systems to the erection point, although block assembly was often found to be done in the open in poor environmental conditions. A “natural” block breakdown was not always possible due to insufficient erection cranage. Developments towards best practice include improved facilities for block assembly areas such as higher capacity cranage, better services arrangements and the use of non-welded fairing aids. Dimensional accuracy, with few exceptions, was found to be poor and much still needs to be done to achieve the elimination of surplus material at joints.

Methods of materials handling varied less across the yards surveyed and achieved a mid-range average score of 2.9. Extensive use is made of flat-bed trailers and fork lift trucks with material and equipment usually, but not always, palletized. Parts are marshalled in designated areas and there is generally some focus on reducing inventory. Greater use of just-in-time deliveries would bring about further savings. Materials handling does not add value to the product and its cost is very significant. More thought needs to be given to rationalizing and reducing handling which, amongst other things, requires the application special purpose handling, manipulating and transport equipment.

3.4 Ship construction and outfitting

Figure 3.4 below shows the range of ratings for all the yards benchmarked for each element in the ship construction and outfitting group. The vertical bar shown on each line in the figure is the average score of the large yards only. Subsequent paragraphs summarize the findings and give some ideas of developments that the shipyards might consider.

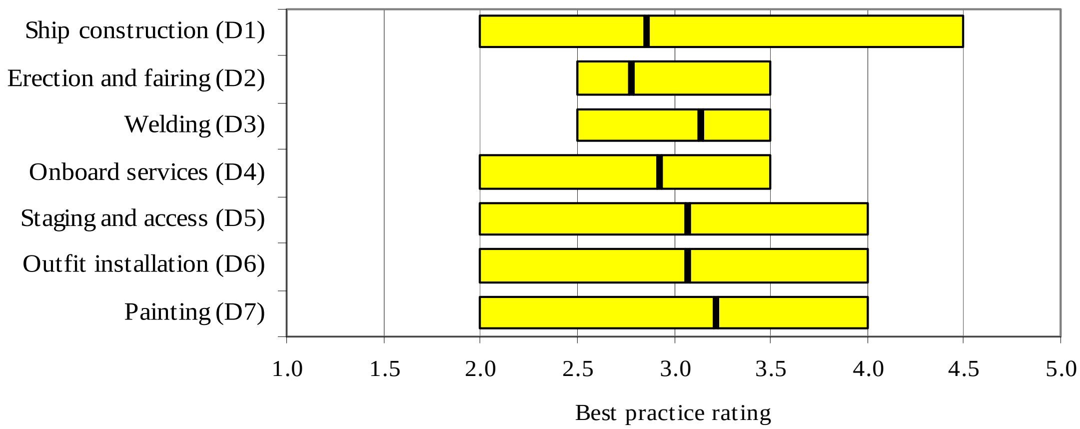

Figure 3.4 – Ship construction and outfitting

The ship construction and outfitting group scored close to the overall industry average for all groups of elements. The lowest yard averaged 2.2 for this group, the highest averaged 3.6. The average for the large yards for this group was 3.0.

Although the highest score for the specific ship construction element was 4.5, the average for this element was less than three. Most building positions have little or no environmental protection and many are serviced by cranes which are undersized for the sizes and types of ship under construction. Consequently, berth cycle times are high and "natural" block breakdowns are not possible in many cases.

Erection and fairing also scored poorly and often features relatively long hanging times and fairing with conventional welded attachments. The efficiency of this activity depends heavily on the level of accuracy both designed-in and achieved in practice through the manufacturing and assembly processes. The use of excess material on erection joints acknowledges the failure to achieve the required tolerances that are necessary to ensure the "lego block" assembly achieved by the leading shipbuilders. Poor accuracy control is a significant weakness in U.S. shipbuilding.

The result of accepting this re-work as a normal part of the construction process limits the shipyards' ability to reduce cycle times and man-hours at this expensive stage of assembly. A logical route is to determine what accuracy is actually required to virtually eliminate the need for excess material and the requirement for fairing. This requires that all the proceeding processes are within specified tolerances and that the accuracy requirements for each stage of the process is known.

Welding, with an average score of 3.1, demonstrated a higher use of best practice than most other elements in the group. There has been a general trend towards modern welding equipment and techniques with significant investments being made in most yards. There is extensive use of semi-automatic welding and in many yards "stick" welding is confined to tacking and servicing outfit installation.

The provision and layout of onboard services didn't score particularly well, although some yards are improving their practices through the use of palletized groups of welding plant, specially designed piped-services modules, cables and hoses lifted off decks and walkways, and pre-planning of services routes. Further gains could be made from pre-planning all services and the more effective use of services designed into the ship. Housekeeping varied widely within yards and from yard to yard and all would benefit from improvement.

There was a wide variation in the use of best practice for staging and access. Good staging and access procedures go hand-in-hand with a logical, controlled progression of final outfit installation. Unless outfitting is organized on this basis, staging and access requirements cannot be minimized or accurately planned, and costs will remain high. Best practice in staging and access implies minimal staging and the wide use of specialist access equipment, hydraulic arm vehicles, elevators and escalators as appropriate.

In the case of outfitting onboard, there is less scope for large scale improvement since these activities depend heavily on the amount of outfitting achieved during earlier production stages. However, onboard outfit should be organized into controllable work packages with a zone by stage approach. The benefit of this is that work can follow a logical and controllable series of repeatable steps in the form of a "rolling wave" of installation and painting, area completion and system testing. This is particularly important on complicated vessels such as cruise ships and surface combatants. This can only be achieved if supported by appropriate technical information.

This approach applies to all ancillary services such as the supply of staging and mechanical and electrical services mentioned above. In order to minimize costs, all need to be planned and organized to a consistent schedule. However, it also requires an attitude on behalf of workforce and management to ensure a clean and safe working environment as part of normal practice. As a result, it becomes possible to use more portable tools and equipment such as simple frames for keeping services off the decks and scissor lift units for overhead access. This type of technology application generally does not involve large capital expenditure but rather an improvement in the management of the process.

Painting scored quite well within the group. The use of paint cells was widespread and many yards were improving painting performance through the use of new products and production engineering solutions to minimize painting rework.

3.5 Yard layout and environment

Figure 3.5 below shows the range of ratings for all the yards benchmarked for each element in the yard layout and environment group. The vertical bar shown on each line in the figure is the average score of the large yards only. Subsequent paragraphs summarize the findings and give some ideas of developments that the shipyards might consider.

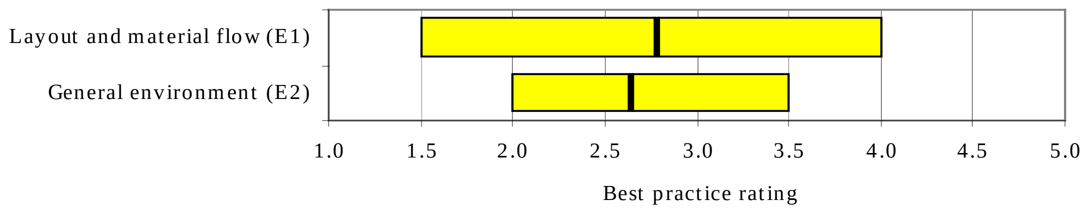

Figure 3.5 – Yard layout and environment

Yard layout and environment did not score well compared with the other groups of elements. The lowest yard averaged 2.0 for this group, the highest averaged 3.7. The average for the large yards for this group was 2.7.

Most yards have been developed progressively over a long period and although some of the changes have been well planned, others have led to a less than ideal layout. Many yards have inherent site constraints because of public roads and adjacent properties which make it difficult to achieve optimum layouts and material flows.

As far as possible, material flows should be linear. However, some yards have convoluted flows that have led to materials handling difficulties and additional cost. In many cases, low cost immediate improvements are possible but fundamental improvements will usually require significant investment.

A considerable amount of assembly work is undertaken in the open in many yards. While local climates may suit this approach to some extent, the working conditions it dictates are not conducive to high performance. The mixture of new and old, and, in some cases, temporary buildings reflect development over many years and these give varying working conditions. In some yards, the diverse location of associated activities gives difficulties in communications and management.

Housekeeping varies from good to extremely poor in most yards visited. Levels of fumes and noise were usually found to be low.

Best practice dictates that all shipyards should maintain a long-range facilities plan that is based on the requirements of their target market. This ensures that localized developments are carried out in the context of the overall plan.

3.6 Design, engineering and production engineering

Figure 3.6 below shows the range of ratings for all the yards benchmarked for each of the elements in the design, engineering and production engineering group. The vertical bar shown on each line in the figure is the average score of the large yards only. Subsequent paragraphs summarize the findings and give an indication of the developments that shipyards might consider in the future.

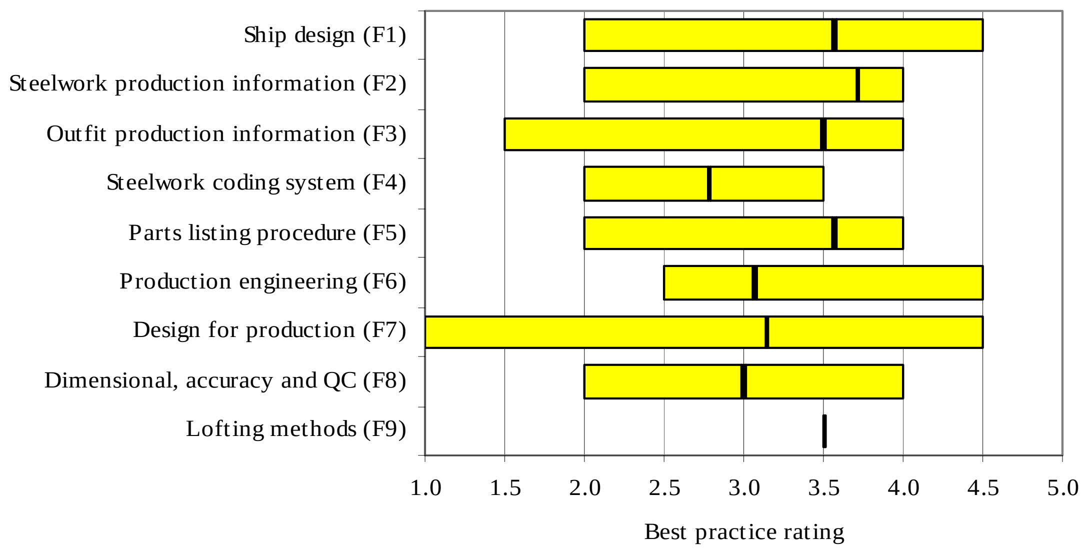

Figure 3.6 – Design, engineering and production engineering

The design, engineering and production engineering group scored well in comparison with the average scores for the other groups of elements industry-wide. The lowest yard averaged 2.5 for this group, the highest averaged 4.0. The average for the large yards for this group was 3.3.

Some companies sub-contract significant amounts of the design, drawing and lofting work while others have a full in-house capability that include CADCAM systems for the creation of product models. The low scoring companies should work towards adopting a product model based design process as this offers considerable downstream benefits. Some of the higher scoring companies still use two dimensional design tools for pre-contract design and convert to a product model for detailed design. They should consider using a product model earlier in the design process as this can reduce design lead-time and man-hours. All yards need to develop the design process to be able to provide the information required to support integrated outfitting within the compressed lead-times that are now being imposed by the market.

Ideally, production information should contain only the information required for the activity in hand and this should be extracted from a single integrated steel and outfit product model. Although the information is not always complete, the approach is generally that taken by the yards that scored highest. In others, however, shop-floor workers are expected to extract the information they require from less-detailed 2D drawings and in some cases they need to complete the detailed design work themselves. This leads to interferences, disruption of the workflow and rework.

Material and product coding systems achieved a low average score because many yards only use codes to identify individual parts. They do not have a standard and consistent coding system that enables clear definition of parts, interim products, systems and zones. Many yards also continue to work with coding systems which reflect system and production constraints that are no longer applicable. The coding system should embody the shipyard's breakdown of standard interim products around which its manufacturing capability is organized.

The more sophisticated yards list parts to be manufactured and purchased directly from a product model. There is usually a link between the parts lists and a schedule and the parts are managed within a computer-based material control system. Less sophisticated yards list parts on drawings and rely on production to produce requisitions for procurement or to arrange for their manufacture. It is important to strike the correct balance but, ideally, all parts should be listed automatically and standards should be used wherever possible.

The yards are relatively weak in production engineering, design for production and accuracy control. Leading shipyards put a great deal of effort into ensuring designs are easy to manufacture. Good design for production is the consequence of effective production engineering. Most yards include some level of production engineering effort but all would benefit from enhancing and expanding the capability. In addition to developing the producibility aspects of designs, the production engineering function should be responsible for developing shipyard production methods, processes and standards. The results of this can then be embodied in a formal shipbuilding strategy database. This is a statement of how the yard builds ships, the standard interim products that are manufactured, the standard products that are purchased and the design rules that the designers should follow if the ship is to be built in the most cost effective way. Formalizing the company's shipbuilding strategy is particularly relevant for yards that subcontract design work.

The production engineering function should also be responsible for coordinating the development of type plans for each ship type in the target product mix. These include the initial functional and production definitions and high level planning information and can be used to significantly shorten pre-production lead-time.

Most shipyards are using modern equipment to carry out traditional methods of dimensional control. There are more sophisticated methods now available, especially if the yard is using a product model for design, that can lead to higher levels of accuracy. Self-checking and statistical accuracy control are only used to a moderate level in a few yards. This means that most units and blocks go to the building ways or dock with excess material on at least one edge. They are then fitted at the building position which is costly both in terms of direct man-hours and crane hanging times. The lack of accuracy in steelwork also has cost implications for the installation and connection of outfit systems.

The lofting methods scores show a remarkable level of consistency across all the yards surveyed. All yards are now using computer-based lofting systems that are generally an integral part of the drawing process. Many of the procedures would be world-class if there were direct links to NC cutting and forming machinery and if a structured method of determining shrinkage allowances was in place using data that had been produced from statistical process control.

3.7 Organization and operating systems

Figure 3.7 below shows the range of ratings for all the yards benchmarked for each of the elements in the organization and operating systems group. The vertical bar shown on each line in the figure is the average score of the large yards only. Subsequent paragraphs summarize the findings and give an indication of the developments that shipyards might consider in the future.

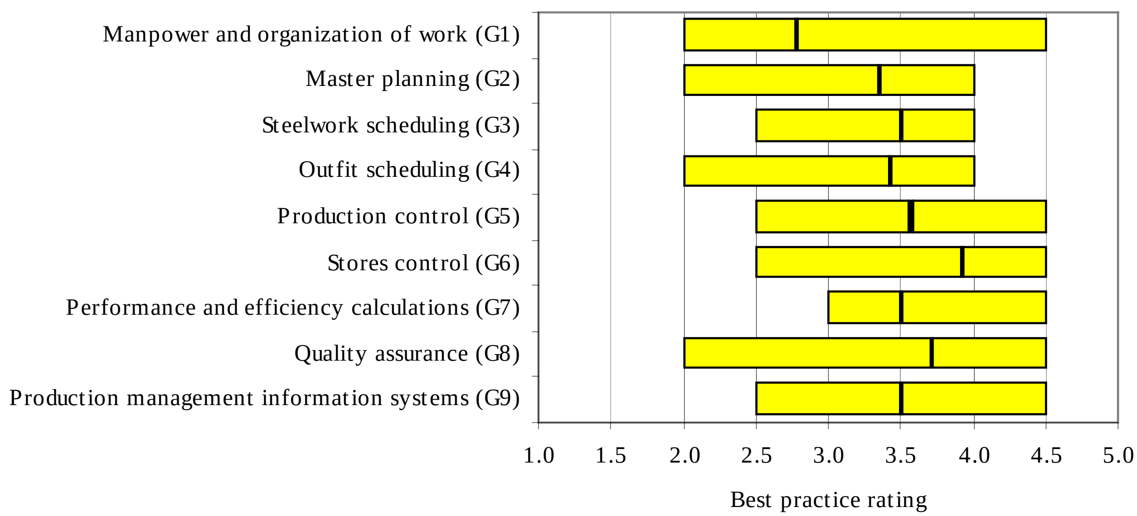

Figure 3.7 – Organization and operating systems

The lowest yard averaged 2.6 for this group, the highest averaged 3.9. The average for the large yards for this group was 3.5.

The organization and operating systems group of elements scored highest when compared with the average scores for other groups of elements industry-wide. This suggests a trend within the industry to pursue technology developments in the "soft" areas such as planning, scheduling, management information and quality control. It is true that successful development of these areas can be a precursor to effectively managing change in production. However, the fact that change management is often easiest for these functions can also make them overly attractive targets for improvement.

It is not surprising that manpower and organization of work, the only "hard" or shop-floor oriented element in the group, scored significantly lower than any other element. In the low scoring yards, labor is predominantly organized by trade. The higher scoring yards employ a high level of area management and at least part of the workforce is organized into multi-skilled work teams. However, they still need to develop the organization to fully embrace workstation operations. Shipyards often have difficulty in managing the interaction between project managers and the trade or area management in this respect. Successful yards are those that have developed strong project management and made it work well within the organization.

All yards surveyed used integrated networked master planning systems, although these were not always fully interactive with the strategic or tactical planning levels. Planning and scheduling systems should be simple and effective and control all work in the shipbuilding process. However, the planning process must not be onerous or require large numbers of personnel to operate. Initial planning and scheduling should be based on the standards set down in the shipbuilding strategy. The plan should be progressively refined as more detailed information is generated by the design process and the work content at each production stage is finalized. Data on actual progress and performance against ship systems and workpackages should be collected and used to update schedules and develop future estimates. A well structured coding system is one of the keys to doing this. Production control systems should be integrated with higher levels of planning and provide shop-floor supervision with all the information they need to carry out the work and monitor progress and performance.

All yards achieved a minimum of 3.0 in performance and efficiency calculations. While a number of yards use product related performance measures, most still operate a system that issues man-hour budgets to the shop-floor and consequently the shop-floor focus is on completing the work within the budget. In the yards that scored higher, progress against these budgets and the resulting efficiency is reflected in the overall plans and future estimates. However, only a few people in each yard were aware of the performance measures applicable to their area. In an organization that has performance improvement as one of its priorities, it is essential that those who have a direct effect on performance can see how performance is changing. Shipyards should therefore determine and/or make use of an appropriate set of performance measures and the levels being achieved should be visibly reported regularly, preferably at the production workstation. These measures can also be used to set targets for performance improvement.

While most of the yards were ISO9000 accredited, few were making the best use of the system. Quality assurance systems are often seen as being a market driven necessity that costs money and does not add value to the process. However, handled correctly, a QA system can be used to stabilize and rationalize the shipbuilding processes and this is an important aspect of employing modern shipbuilding techniques. The QA procedures and the shipbuilding strategy are very closely related and there is a strong argument for integration.

Some form of management information is available in all yards and generally the various systems used for producing the information were either integrated or at least compatible. In those that scored highest, management reports tended to be concise and tailored to the needs of the recipient. Some yards are moving towards more computerized systems where management information is available on-line as required.

APPENDIX 1 – THE FMI SHIPYARD BENCHMARKING SYSTEM

1 Introduction

Benchmarking is a tool by which a company can compare its practices with those of others to determine its strengths and weaknesses with a view to improving performance.

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

The FMI benchmarking system is shipyard specific. It allows a shipyard's current competitive position to be established and provides an evaluation against international best practice of the applied technology and practices in key areas. Assessment of the use of best practice helps to explain why performance is at the level it is, and identifies the areas that require attention if overall performance is to be improved.

The output of an FMI benchmarking study clearly shows any gaps and imbalances in the applied technology. This can be combined with the results of a market analysis to set future performance targets and define the overall shipyard characteristics that will allow the yard to compete in chosen markets. The overall objective is to produce a prioritized performance improvement plan that is driven by market requirements. Hence the term "Market-Led Benchmarking".

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

The system has been used in more than 150 shipyards world-wide and most recently it has formed the basis of industry studies in the USA, mainland Europe, Japan, South Korea and the UK. This provides a significant database for comparative purposes.

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

2 The system elements

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

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

Table 1 – Groups of elements

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

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

Table 2 - H2: Training and education policy

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

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

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

Many shipyards do not need to score 5 to be competitive. The important thing is to have a balance of technology across all of the elements at the level dictated by the shipyard's cost base and target market. Generally, yards with a high cost base require higher levels of use of best practice to be competitive.

In general, having isolated areas at a significantly higher level than others is not good. The adjacent areas may not adequately support the higher technology areas and thus the investment in the high technology areas alone may not yield the intended benefit.

3 Levels of technology

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

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

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

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

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

Level 5: represents state-of-the-art shipbuilding technology in the 1990s. It is developed from level 4 by means of automation and robotics in areas where they can be used effectively, and by integration of the operating systems, for example, by the effective use of CAD/CAM/CIM. There would be a modular production philosophy in design and production. The level is also characterized by efficient, computer-aided material control and by fully effective quality assurance. In summary, state-of-the-art use of technology and industry-leading business processes, facilities, systems, management and workforce.

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

4 Overall performance

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

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

CGT is a normalized measure of work content that is calculated by multiplying the gross tonnage by a factor that is representative of the complexity of the vessel. Ships that have a low level of complexity, such as bulk carriers, have lower factors than more complex vessels such as cruise ships and navy combatants. The system has been developed and refined over more than thirty years by leading shipbuilding organizations under the umbrella of the OECD. Factors have been developed for the main ship types but when a yard has been building unusual vessels, new factors may need to be calculated to support the benchmarking process.

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

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

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

5 The benchmarking survey

An FMI team visits the shipyard to gather data and assign the benchmarking scores. Individual members of the team visit the relevant offices and facilities and interview department or area managers and/or their nominated representative. Some of the interviews are done while walking around the yard, others are office based. Interviews may last up to 30 minutes, depending on the subject.

The yard is sent a proposed timetable prior to the visit together with a description of the scope of each survey element and a suggestion of the person in the shipyard the team would like to discuss each element with. The survey normally begins with a short presentation on the project (about 40 minutes including discussion) to senior managers and others with an interest in the project. This is followed by a quick guided tour of the facility that allows the team to orient itself, before splitting up to carry out the individual interviews.

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

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

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

6 The survey report

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

- best practice rating by individual technology element, organizational area, and overall,
- overall performance in terms of man-hours per CGT and $ per CGT,
- a short written interpretation of the results,
- comparison between the yard's best practice / performance rating against international standards,
- suggestions for improvements that will yield benefit in the short term.

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

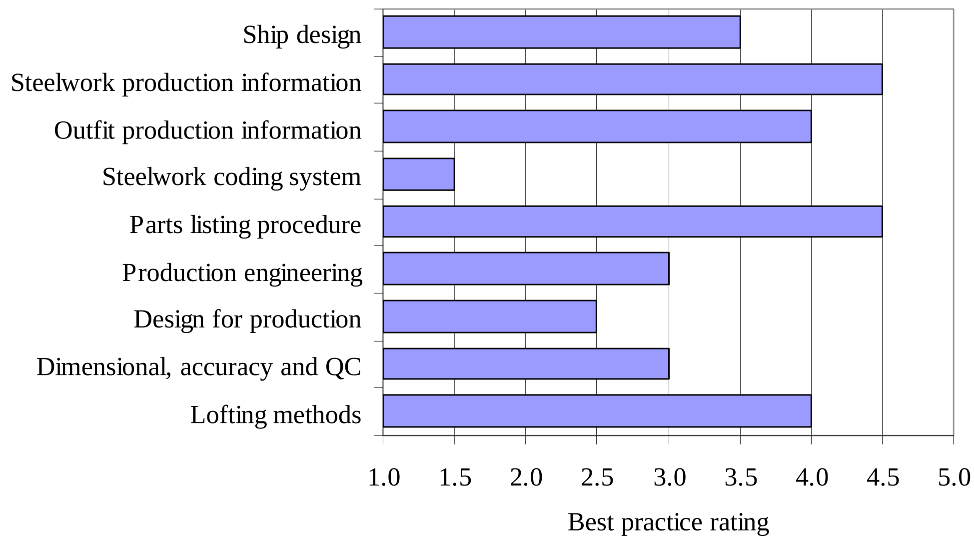

Figure 1 – Presentation of the results for one group of elements

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

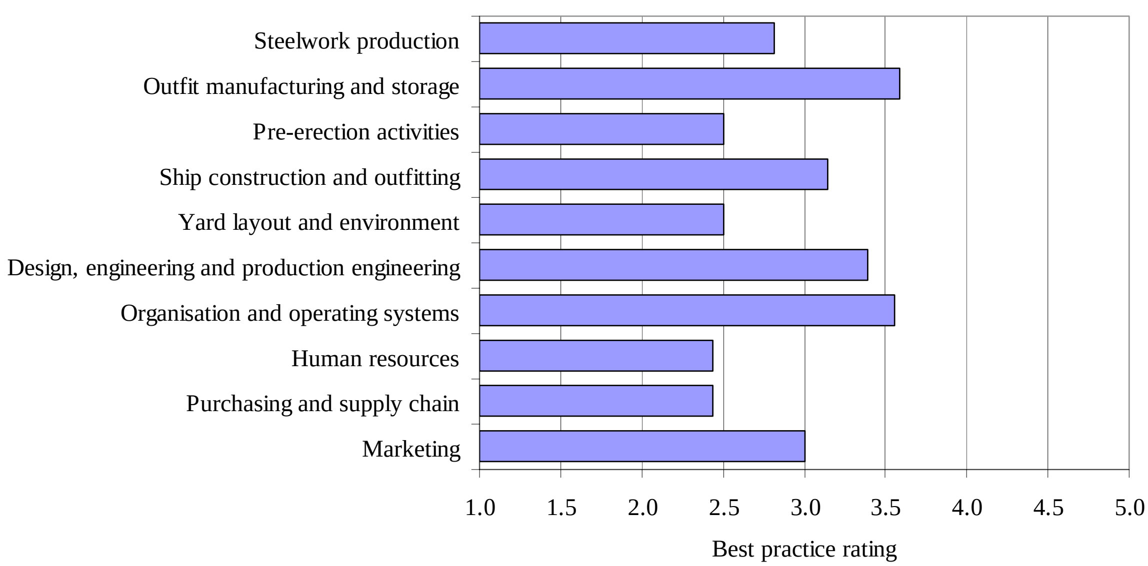

Figure 2 – Presentation of the results for all groups

7 Best practice and profitability

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

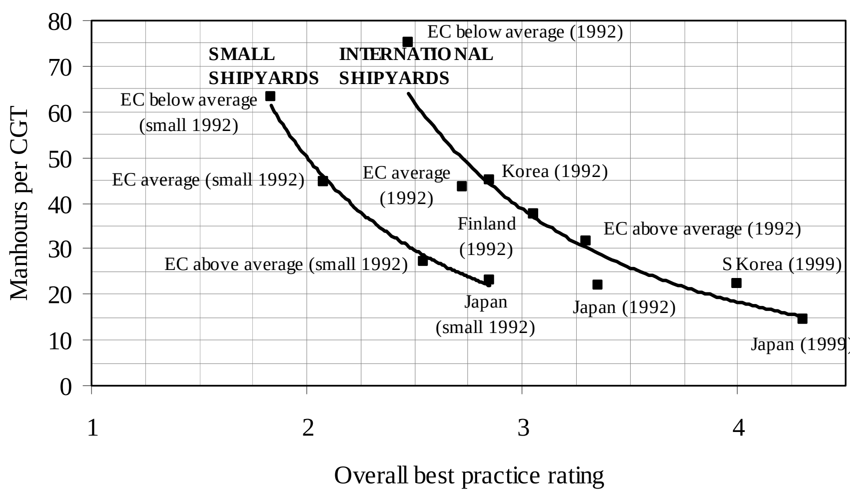

Figure 3 - International competitive performance

The figure shows that there is different relationship between the use of best practice and overall performance for large and small yards. In general terms, for a large yard to be internationally competitive it must be operating close to the right hand line. There may be another line that is appropriate to the builders of naval vessels. This should become clear later in 2000 after the current round of benchmarking has been completed.

The 1992 study also showed a clear relationship between use of best practice, performance and profitability. Summarized as:

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

Table 3 – Relationship between best practice, performance and profitability

Although the above relates solely to newbuilding, the principle applies also to ship repair and conversion. However, to-date no work has been done on the correlation between use of best practice and overall performance in these sectors.

8 Setting future targets

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

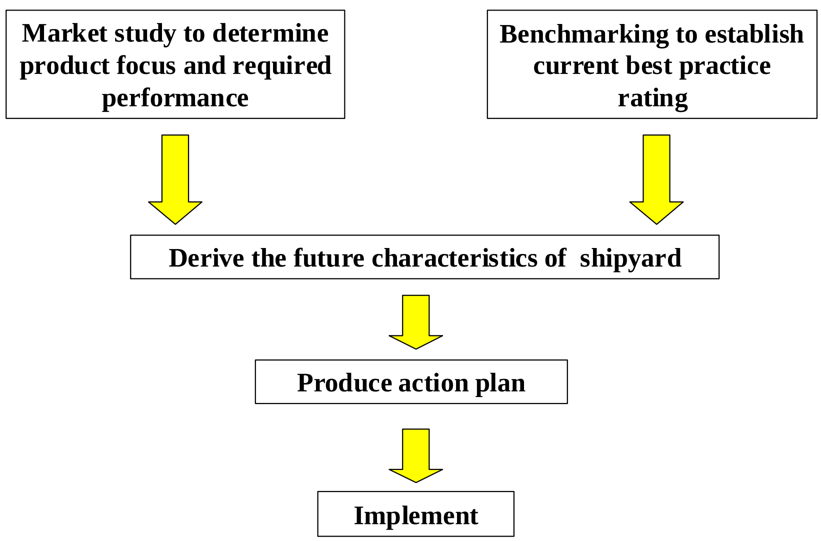

Figure 4 – Overall methodology

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

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

In the commercial market, performance targets are specified in the form of added value per unit of work ($/CGT); where added value is defined as price less material and sub-contract costs and the unit of work used is compensated gross ton. In effect, this unit specifies the available income per unit of work to cover shipyard labor, overhead and profit.

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

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

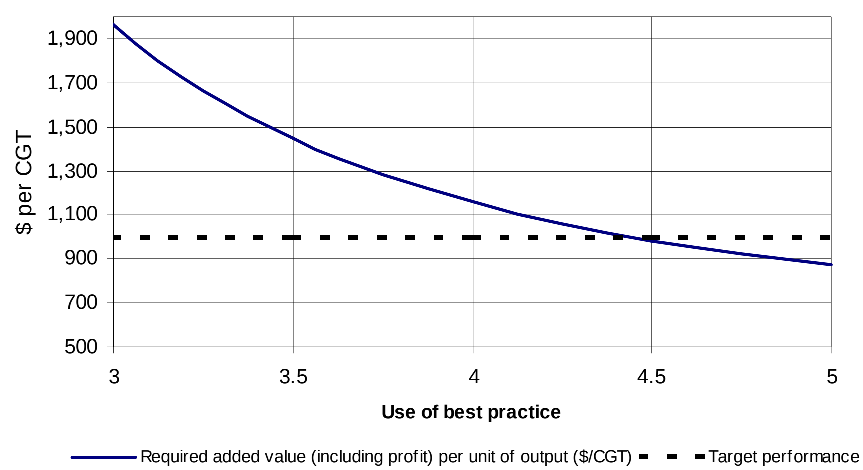

Figure 5 – Minimum use of best practice

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

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

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

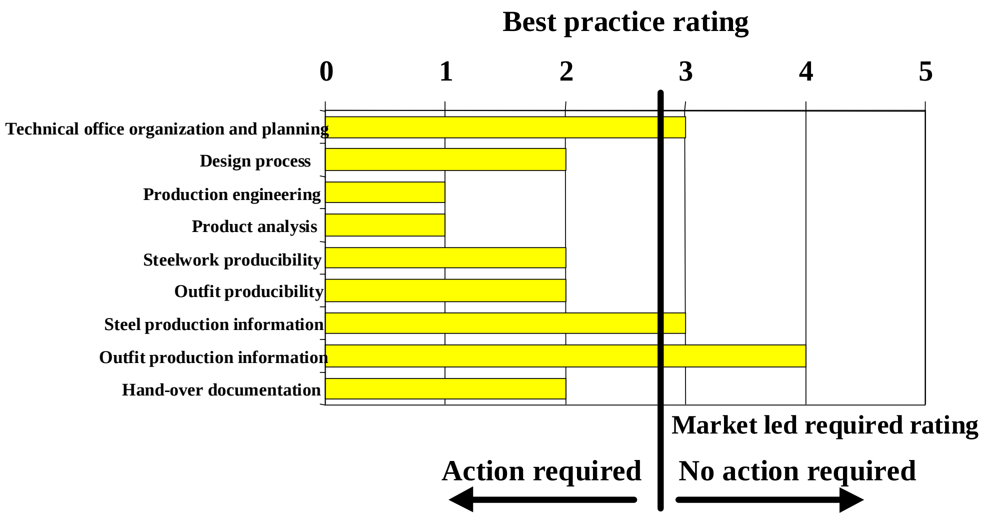

Figure 6 – Identifying the gaps in the use of best practice

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

A description of the processes and procedures that will yield the required level of performance is derived by overlaying the minimum use of best practice onto the descriptions of the levels of use of best practice in the benchmarking system.

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

APPENDIX 2 – BEST PRACTICE IN COMMERCIAL SHIPBUILDING

The 1992 KPMG/ FMI Study of the Competitiveness of European Shipyards identified significant differences in the adoption of best practice across EC and Far Eastern yards. The features which typify the above average and below average performers in seven key areas of company activity have been extracted from the 1992 report, and are quoted below:

"On **strategy and management** issues, the above average performing yards have a high degree of focus on a specific target market. This focus links through to clear management objectives and actions in each functional area. In contrast, the below average yards stress the need for flexibility and tend to be trying to service a number of different markets with a mix of one-off builds and short series. This leads to confusion in co-ordinating departmental organization structures and in the allocation of resources."

"On **marketing**, the higher performing yards tend to have clearly identified and targeted owners, have a policy of pro-active contact with shipowners, see after-sales as another contact opportunity not just a cost, and use their own resources with minimum use of agents. The below average yards tend to be totally re-active to enquiries, view orders as one-offs rather than part of a long term relationship with shipowners, have no clear product development priorities and have very few resources in sales and marketing."

"In **purchasing**, the above average yards tend to have reduced to only two or three suppliers in each area, to operate with few sourcing restrictions and to have explored economies of scale by linking purchasing with other yards. The below average yards tend to operate within more constraints imposed by their lack of knowledge of external financing sources and to use traditional buyer / seller relationships."

"In **human resources**, the major differences between above and below average yards are in four key areas:

- the emphasis on upgrading skills,
- the effort to restructure the workforce through recruitment,
- the degree of employee empowerment, and
- multi-skilling and re-skilling."

"On **design and engineering** issues, above average yards have invested heavily in CAD/CAM systems and equipment with careful implementation, the production of specific workstation information and increasingly full CAD/CAM generation of production information with DNC links. Some of the average and below average yards have made the investment but implementation has been ineffective and not integrated with other operations."

"In **planning for production**, the high performing yards have de-centralized multi-level planning systems with clearly defined outputs at each level, a work package approach to organization of work, formal build strategy documentation, computerized material control systems and pre-production marshalling of kits of parts. The below average yards are ineffective in these areas."

"On **production**, above average yards have short build cycles to maximize the use of facilities. This is achieved by implementing workstation concepts with clearly defined process flows, superior build sequences and early outfitting techniques. There is a high priority on accuracy control and on both designing and organizing out needless work. Below average yards tend to use a more traditional sequential approach to ship construction."

NSRP ASE

An industry collaboration working with government and academia to manage and focus a new national technology strategy for shipbuilding

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