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Benchmarking of Shipyards and Processes for Cost Effective Naval Shipbuilding

*Ajay K. Chhabra**

The article highlights the applicability of benchmarking methodologies to the shipbuilding industry, and how these could be utilized to improve the competitiveness of shipyards to enable delivery of cost-effective naval ships. Cost continues to be a major factor that characterizes the competitiveness of shipbuilding, and is cited as the main reason for the industry having moved from Europe to Asia over the last two decades. The author examines in detail the benchmarking system most commonly used by USA, Europe, Japan, South Korea and the UK, and brings out the advantages accrued as a result of the implementation of the recommendations of focused studies. He then analyses the various issues that plague Indian shipyards, especially the Defence Public Sector Units (DPSUs), and posits how benchmarking studies similar to those undertaken by leading shipbuilding nations elsewhere could help improve the Indian naval shipbuilding industry.

Benchmarking is defined as the process of comparing one's business processes and performance metrics to industry bests or best practices from other companies. In the process of best practice benchmarking, the best firms within an industry, or in another industry, are identified, where similar processes exist, and the results and processes of those studied are compared to one's own results and processes. A detailed analysis results in a comparison of one's own processes and metrics against the best in class, and areas where those of the best in class could be adapted.

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Benchmarking improves performance by identifying and applying best demonstrated practices to operations and sales. Managers compare the performance of their products or processes externally with those of competitors and best-in-class companies, and internally with other operations within their own firms that perform similar activities. The objective of benchmarking is to find examples of superior performance and to understand the processes and practices driving that performance. Companies then improve their performance by tailoring and incorporating these best practices into their own operations—not by imitating, but by innovating. The process of benchmarking involves selection of a product, service or process to be benchmarked; identification of key performance metrics; selection of companies or internal areas to be benchmarked; collection and analysis of data on performance and practices; and identification of opportunities of improvement. The final step is to adapt and implement best practices in areas identified. Benchmarking results in improved operational efficiency, better cost effectiveness and competitiveness.¹

The United Nations Educational, Scientific and Cultural Organization (UNESCO) defines benchmarking as:

A specialised method for collecting and reporting critical operational data in a way that enables relevant comparisons among the performances of different organisations or programs, usually with a view to establishing good practice, diagnosing problems in performance, and identifying areas of strength. Benchmarking gives the organisation (or the program) the external references and the best practices on which to base its evaluation and to design its working processes.²

Benchmarking is used to measure performance using a specific indicator (cost per unit of measure, productivity per unit of measure or cycle time of x per unit of measure) resulting in a metric of performance that is then compared to others.³

Sometimes referred to as 'best practice benchmarking' or 'process benchmarking', the process is used in management, and particularly strategic management, in which organizations evaluate various aspects of their processes in relation to best practice companies' processes, usually within a peer group defined for the purposes of comparison. This enables organizations to develop plans to make amends or adapt identified best practices, with the aim of improving performance in a specific

area. Benchmarking is often treated as a continuous process in which organizations continually seek to improve their practices.

Benchmarking is the systematic process of searching innovative ideas and highly effective operating procedures that lead to superior performance. It is essentially the process of identifying best practices and then adapting these innovatively in your business environment. Although adaptive innovation has been applied to businesses since the industrial revolution, benchmarking as a management concept has only gained currency since the 1980s.

The need for benchmarking has gained urgency due to increased globalization, which has forced organizations, and even nations, to increasingly examine their competitiveness in international markets. Industries that are unable to keep up with the ever-changing dynamics of markets are bound to lose their competitiveness and the relevant market.

Competitiveness of the shipbuilding industry is directly related to the ability of companies, industries, regions, nations and supranational regions to generate, while being and remaining exposed to international competition, relatively high factor income and factor employment levels on a sustainable basis. 'Manufacturing Competitiveness depends on two types of actions, one that is external to the manufacturing concern and the other which is internal to the company.'⁴ The important external policies that effect manufacturing are tax and duties structures, trade and monetary policies, policies related to raw materials and other inputs, infrastructure, foreign direct investment (FDI) policy, fiscal policy, labour policies, skill development, research and development (R&D), and technology policies. Insofar as the internal processes in the company are concerned, areas related to investments in R&D and technology, skill development and knowledge enhancement, adopting global standards and benchmarking their performance, adopting best manufacturing practices and production techniques, and, finally, increasing scale of operations and delivering products of global quality, are required to be addressed by the individual companies involved in the manufacturing sector.⁵

The primary purpose of the article is to highlight the benchmarking methodologies applicable to shipbuilding industry and shipyards and their applicability to the Indian shipbuilding industry, with special emphasis on naval shipbuilding. The article explains the essential elements of the benchmarking system followed by some of the leading naval shipbuilding nations to benchmark their shipyards, the peculiar problems being faced by the Indian shipyards building naval ships, and how these concepts

could be utilized by the Government of India (GoI) and the shipyards to improve productivity and competitiveness.

BENCHMARKING OF NAVAL SHIPBUILDING INDUSTRY

In the shipbuilding industry, factors that characterize competitiveness are the cost, delivery time, quality, post-commissioning delivery, customer service, and the fiscal environment. While all the factors are important, cost continues to remain one of the major factors in shipbuilding competitiveness. This can be cited as one of the main reasons for the shipbuilding industry to have moved to Asia from Europe during the last two decades. Benchmarking of prospective shipyards is therefore increasingly being undertaken by respective governments, as a part of their naval shipbuilding and procurement strategy, especially in the West, to improve the cost effectiveness of their naval shipbuilding and ensure the timely delivery of quality ships.

The adoption of the modular construction system for shipbuilding, developed by the Japanese, came as a result of the benchmarking concept of studying parallel industries. In the case of the Japanese shipbuilding, following World War II, the head of Japanese aircraft industry was appointed head of shipbuilding. In those days, the traditional method of building ships was to lay the keel and then build the ship from the bottom up. Aircraft construction, however, used the modular construction method, wherein large movable sections were constructed individually and then welded or bolted together. This method required greater accuracy in the manufacture of the units but, at the same time, reduced construction time by a factor of 10. The same improvement resulted when the method was applied to shipbuilding. As a consequence, by early the 1960s, in less than 10 years, Japan replaced the United Kingdom (UK) as the leading shipbuilding nation, a situation from which the British industry never recovered even when it adopted the same methods many years later.⁶

The benchmarking system most commonly used by most Western naval shipbuilding nations, including the United States (US) Department of Defense (DoD), is designed by a UK-based independent consulting firm, the First Marine International (FMI), a division of Royal Haskoning UK Ltd. The system covers the shipyards' internal processes, establishing a shipyard's current competitive position, and provides an evaluation against international best practice of the applied technology and practices in key areas. Assessment of the use of best practices helps to explain

why performance is at the level it is, and identifies the areas that require attention if the overall performance of the shipyard is to be improved. The FMI system has been used in more than 150 shipyards worldwide and has formed the basis of industry studies in the US, Europe, Japan, South Korea, and the UK. This provides a significant database for comparative purposes.⁷

The benchmarking system is essentially a three-step process which is first used to evaluate the individual shipyard manufacturing and best practices, followed by an estimation of the shipyard's current productivity. The third step is to compare use of best practices and productivity among shipyards to identify areas of improvements.

Evaluation of Manufacturing and Business Practices

The FMI benchmarking system divides the shipbuilding sector into seven technology groups comprising of steelwork production; outfit manufacturing and storage; pre-erection activities; ship construction and outfitting; yard layout and environment; design engineering and production; and organization and operating systems. These technology groups were assessed in five levels of best practice in each of the 50 elements of the above-mentioned seven technology groups. At the lowest end of the scale, level 1 represents basic technology and, at the highest end, level 5 represents advanced technology associated with high levels of productivity. The benchmarking system does not necessarily advocate the highest level being the best, but states that as a general rule the lowest cost is achieved by a shipyard that has an appropriate level of technology for its product mix.⁸

Establishment of Shipyard Productivity

The benchmarking system includes a normalized measure of shipyard productivity, which accounts for disparate ship complexity and varying customer profiles. The ship complexity factor (compensated gross tonnage or CGT factor) quantitatively corrects for differences in production work content of various ship types. The customer factor adjusts for different administrative and operational requirements of different customers. A naval ship would therefore have a much higher CGT factor, as also a much higher customer factor, due to increased requirements of oversight, reporting and monitoring than a commercial ship (for detailed definitions and explanations of these terminologies, see Appendix 1).

Benchmarking Report

A typical benchmarking report combines graphical representations of the survey results with an outline of the processes used, and contains the following:

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

Benchmarking therefore allows the users to:

1. Compare the practices of local shipyards with the best practices of the selected international shipyards.
2. Identify specific changes to shipbuilding industry processes and specific defence shipbuilding aspects of naval design and acquisition practices that will improve the performance of the shipyard.
3. Guide future investments.
4. Provide the shipyards with an independent assessment of the present status of their processes, practices and performance in an international context.
5. Assess the capabilities of the shipyard to design and build naval ships, as per the requirements of the navy, in a cost-effective manner.

GLOBAL INITIATIVES IN SHIPYARDS BENCHMARKING

Benchmarking of US Shipyards

Benchmarking of the US shipyards for naval shipbuilding has been a continuous process since it was initiated in 1999–2000. The US DoD commissioned a benchmarking study to address the problems of time and cost overruns experienced by shipyards for naval ships on order. Although the primary reasons for the above-mentioned state were identified by the DoD as construction with immature designs, material and other

schedule delays, inexperienced labour, and drops in productivity due to new construction facilities or the introduction of a new series of a given combatant, it was felt that despite actions to address these by DoD and industry, very little had been achieved to address the problems. The DoD, therefore, commissioned the 'Global Shipbuilding Industrial Base Benchmarking Study' (GSIBBS) as an independent survey of current manufacturing and business practices and productivity in major US shipyards as well as in selected global shipyards in June 2004. A study with a similar benchmarking methodology was carried out in 2001 by the Naval Shipbuilding Research Program (NSRP).

The GSIBBS methodology comprised of the following:

1. Survey of the current manufacturing and business practices and productivity of selected international shipyards, leveraging benchmarking work completed in previous studies.
2. Assessment of the US private shipyards using a standardized benchmarking system.
3. Provision of specific site and comparative analysis of each major US private shipyard.
4. Comparison of the US shipbuilding industry against leading international shipyards and identification of key opportunities for improvement.
5. Identification of DoD, Navy and industry actions necessary to implement remedies in the US shipbuilding industrial base.⁹

Results of GSIBBS

The benchmarking study brought out a list of proposed actions of individual shipyards, the shipbuilding industry as a whole and the DoD in particular, that would improve the overall performance of shipbuilding industry. In order to make the most efficient use of resources and minimize industry disruption, the Office of Naval Research (ONR) carried out a study simultaneously in mid-tier shipyards. The study indicated the following:

1. There has been an improvement in the rating of the first-tier yards since the industry was last benchmarked in 1999–2000.
2. With reference to the high overall average rating of the international shipyards, the US mid-tier yards average lagged significantly behind the first-tier yards average.
3. A majority of naval shipbuilding programmes are allocated to

first-tier shipyards. It is not always correct to assume that a highly competitive commercial yard will be able to outperform a naval builder on a similar naval vessel.

4. For naval construction, the strategy of using mid-tier yards has many positive features, like an increased shipbuilder sourcing option and competition in the industrial base.
5. A change in culture in commercial mid-tier yards is required for their success in the warship-building sector, but it may result in degradation of their commercial competitiveness.
6. The smaller size of the mid-tier yards makes them easier to manage, inherently more efficient, more flexible and able to adapt more quickly to change than the larger yards. However, as they tend to be lean, they have limited resources to effect changes.
7. An industry-wide analysis of the priorities indicates that the top priority areas for improvement vary by shipyard and are shown in Table 1.

Table 1 Priority Areas for Shipyard Improvements

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

Source: FMI, 'Findings for the Global Shipbuilding Industrial Base Benchmarking Study, Part 2: Mid-tier Shipyards', 6 February 2007, available at http://www.acq.osd.mil/mibp/docs/fmi_redacted_benchmarking_report-part2-feb2007.pdf, accessed on 13 August 2014.

Based on the benchmarking study, the following was recommended to improve productivity in the US shipyards:

1. Gain a more in-depth understanding of the relationship between ship specification, complexity and work content, and work with the design authorities to reduce the inherent work content of naval vessels without compromising on the functionalities.
2. Work with industry to develop the pre-production processes to reduce first-of-class performance drop-off.
3. Review the acquisition rules, regulations and practices to determine if each adds value and work with the shipyards to find ways to reduce the effect these have on work content. In other words, reduce the customer factor.
4. Stabilize the ship acquisition programme.
5. Improve the shipyard incentives.
6. Continue to support performance improvement initiatives such as NSRP.¹⁰

The study for major yards observed that in the period between 1999 and 2004, there was a significant increase in performance improvement activity with substantial investments in facilities, plant and equipment by some yards. The report suggested that this may have been motivated by pressure from the government to give better value for money, increased competition brought about by the reduction in naval demand and pressure brought to bear by the yards' managing corporations to produce higher returns. On the same lines, the study on mid-tier yards observed an increase in performance improvement activity as a result of implementation of benchmarking recommendations. It was also observed that competition in the domestic market and the desire of some yards to improve international competitiveness had provided the motivation to improve.

Table 2 shows the change in the average best practice rating of the US yards and the comparison with the average rating for the international sample in 2006. It can be seen that the overall average best practice rating increased from 2.6 to 2.9.¹¹

Benchmarking of Canadian Shipyards

Canada's National Shipbuilding Procurement Strategy (NSPS), promulgated in June 2010, sought to establish a strategic relationship with two Canadian shipyards for large naval ship construction in Canada,

Table 2 Mid-tier US and International Industry Best Practice Rating by Group

<i>Section</i>	<i>Group</i>	<i>US Yards Average Rating 1999–2000</i>	<i>US Yards Average Rating 2005–2006</i>	<i>International Yards Average Rating 2006</i>
(a)	Steelwork production	2.2	2.4	2.9
(b)	Outfit manufacturing and Storage	2.5	2.6	3.4
(c)	Pre-erection activities	2.4	2.5	2.8
(d)	Yard layout and environment	2.5	2.6	3.6
(e)	Design and production engineering	2.7	3.2	3.4
(f)	Ship construction and outfitting	2.7	3.1	3.3
(g)	Organization and operating systems	3.2	3.4	3.4
Overall Industry Rating		2.6	2.9	3.3

Source: FMI, 'Findings for the global shipbuilding industrial base benchmarking study, Part 2: Mid-tier shipyards'.

selected through an open and fair national competition, and designate them as sources of supply, one for combat vessels and the other for non-combat vessels. The selection process involved an independent process to select the shipyards. As a part of the strategy, the NSPS Secretariat required independent technical advice on assessing the capability and potential of the short-listed shipyards. FMI conducted a benchmarking and capabilities assessment of the short-listed shipyards. Its benchmarking assessment established the shipyards' current level of applied technology as a basis for productivity improvement, while its capacity assessment measured the strengths and weakness of their capability to deliver the vessels in the combat and non-combat packages in an efficient manner. FMI thus identified the shipyards' current state and established the target state that the yards would require to efficiently build the federal ships identified in the combat and non-combat work packages.

FMI visited the short-listed shipyards in 2010, and conducted a rigorous assessment of 159 aspects of shipyard operations in each of the qualified shipyards. Draft reports were provided to the shipyards in January 2011. This was followed by another visit by FMI to the shipyards to discuss the draft reports. The final reports were provided to the shipyards in March 2011.

The short-listed shipyards used their respective reports as input towards the development of plans to upgrade their facilities and improve their shipbuilding practices. These plans were submitted to the government as a key element of their bids. The result of the initial benchmarking were intended to be used to measure the two selected shipyards' productivity improvements over time and to ensure value for money over the duration of the long-term strategic sourcing relationship.¹²

STATE OF THE INDIAN SHIPBUILDING INDUSTRY

There are 20 well-known shipyards in the country, out of which eight are in the public sector and the remaining 12 are in the private sector.¹³ GoI, in its *Maritime Agenda 2010–2020*, formulated in January 2011 by the Ministry of Shipping, recognized that in the face of global recession, the Indian shipyards were languishing for want of new orders. It further added that Indian yards could book very few orders for domestic shipping lines as compared to foreign yards: especially the Chinese yards have been outbidding them consistently.¹⁴ GoI extended the shipbuilding subsidy scheme, which was in vogue since 1981 and underwent revisions in 1997 and 2002. It was extended for both export and domestic orders to the private sector Indian shipyards in 2005. This resulted in the share of Indian shipbuilding in the global order book rising from less than 0.1 per cent in 2002 to 1.3 per cent by 2007–08. The subsidy scheme was, however, withdrawn on 14 August 2007. The lack of price competitiveness as a result of this withdrawal contributed to the Indian share of new orders for ships of 100 gross tonnage in the global order book coming down to 0.1 per cent in 2009 and 0.2 per cent in 2010. The current Indian share of world new orders in the global order book is almost negligible. In comparison, the Japanese were able to retain their share of global orders, which was 12 per cent in 2007 and 13.2 per cent in 2013. The South Koreans, despite the onslaught of the Chinese competitiveness, only marginally slipped from 40 per cent in 2007 to 35.4 per cent in 2013. The Chinese, despite the global recession, managed to increase their share of the global order book for new orders from 36.2 per cent in 2007 to 42.4 per cent in 2013.¹⁵ The *Maritime Agenda 2010–2020* highlights that the decline in global share for countries like China and Korea is not evident due to direct and indirect support that they receive from their respective governments. It further adds that the cost profile in the shipbuilding industries in China and Korea, and the supporting evidences for the key items impact on the cost differential, is to the tune

of 46–54 per cent for China and 31–39 per cent for Korea for export sale.¹⁶

The document clearly highlights that government policies on taxes and duties structure have a direct and indirect impact on the competitiveness of the shipbuilding industry, and thus on the capability to compete in the global market. The other problem areas identified by the Ministry of Shipping that require attention and need to be addressed at the industry level are: the manufacturing gap; technology gap; resources gap; and the skill development gap. The need for ships to invigorate the shipbuilding industry has been acknowledged by GoI, as is evident from the various policy documents. The improvements in the overall shipbuilding ecosystem would have a direct impact on the competitiveness of the naval shipbuilding.

Notwithstanding this, every nation enjoys unique competitive advantages. Specific to the shipbuilding sector, the key advantages that can be leveraged by the shipbuilders in India are low labour cost, strong domestic demand, long coastline and supporting industry infrastructure for some components.¹⁷ Despite the obvious advantages, the industry has not been able to tap this potential.

The Department of Scientific and Industrial Research, Ministry of Science and Technology, GoI, commissioned a 'Study on Innovative Interventions Required in Manufacturing Sectors to Make them Globally Competitive'. The report was submitted in March 2013. With respect to the shipbuilding sector, a productivity and efficiency benchmarking was undertaken. The benchmarking results formulated by the study are as follows:¹⁸

1. *Cost factor:* India has an edge over other countries in terms of labour costs (a key factor accounting for over 10 per cent of the total costs). The labour cost per worker in India is estimated to be approximately 10–20 per cent of those of Korea and Singapore. China has about 50 per cent of those of Korea and Japan. However, raw material costs and financing costs put a huge disadvantage on India. Both China and Korea remove any burden on the shipyards by providing sovereign refund guarantees. As per a Federation of Indian Chambers of Commerce and Industry (FICCI) report, a shipyard typically requires a working capital of around 25–35 per cent of the cost of the ship during the entire construction period. The interest rates on working capital in India are in the

average range of 10–10.5 per cent. In contrast, the interest rates presently offered to shipbuilding yards overseas are significantly lower. They stand at 5–6 per cent in Korea and around 4–8 per cent in China. In addition, the export credit in these countries is offered at much lower interest rates.

2. *Productivity*: Benchmarking of the productivity (ratio of gross value added [GVA] to the number of workers) of Indian shipbuilding industry vis-à-vis competing countries indicates India's labour productivity as almost one-tenth of both Japan and Korea. There exists acute shortage of basic skills required for the Indian industry. There is lack of educated manpower with techno-economic specialization in shipbuilding.
3. *Process time*: Long process time (time taken from contract to delivery) is a major source of lack of Indian competitiveness in shipbuilding. Major reasons are poor infrastructure support in terms of transport and logistics facilities, leading to delays in the supply chain and entire production cycle for Indian shipbuilding industry.
4. *Capacity utilization*: Indian yards lack the capability to build large and modern ships. The manufacturers in India also suffer from the disadvantages accruing from small scale of operations. The shipbuilding sector in China and South Korea has received government fiscal and policy support, enabling them to develop scale as well as a cluster of ancillaries. These advantages of scale are not available to Indian shipbuilding industry, which imports most of its input materials and is therefore unable to leverage advantages offered by bulk purchases and just-in-time supplies.
5. *System improvement*: India has disadvantage in terms of poor infrastructure, innovation and less investments in R&D as compared to Korea, Japan and China. Lack of ship designs and limited investment in R&D in ship designing and innovation hamper the Indian shipbuilding industry.

The GoI study highlights major industry weaknesses of the shipbuilding industry as a whole, and recommends innovative interventions like the setting up of dedicated special economic zones (SEZs) for shipbuilding sector, a focused scheme for fostering domestic components and ancillary industries, and fostering of R&D and design capabilities of Indian firms.¹⁹

Indian Shipyards' Operations Analysis

An analysis of shipyard operations carried out by Joshin John, Vijaya Dixit and Rajiv K. Shrivastava²⁰ highlights the problem areas with respect to operations practices in Indian yards. Some of the problem areas relate to product strategy, project initiation and planning, ship design, shipyard layout, production scheduling, supply chain management, construction method, outsourcing/subcontracting and employee training and development. The authors have compared the above-mentioned processes with the best practices of the international shipyards and have recommended measures at the tactical levels for the short term and strategic levels for the long term.

WHY BENCHMARK DEFENCE SHIPYARDS?

Differences between Commercial and Naval Shipbuilding

Benchmarking of defence shipyards should ideally precede a look at differences in commercial and defence shipbuilding. A shipyard with a high overall best practice rating for commercial shipbuilding may not measure up to the requirements of naval shipbuilding due to differences in processes involved in naval ship construction with high user involvement, exacting standards and complexity of construction with high equipment density. Some of these differences are:

1. *Ship size and complexity:* The average commercial ship is about three times as big as the average military ship, and thus cannot be built in facilities sized for military ships. At the same time, the average commercial ship is much simpler with no weapon systems than the average combat ship.
2. *Acquisition process:* Commercial shipowners are accustomed to much simpler contracting, designing, construction and testing processes than those that pertain in the military world. This adds a high customer factor to the overall productivity, and thus needs to be factored during setting best practice standards.
3. *Design and construction:* Commercial ships are, for the most part, large steel boxes with relatively small and simple propulsion and navigation systems. Designing naval ships takes longer time because of their high equipment density, the large number of sophisticated systems involved and a desire to at least match the current state-of-the-art. Construction of commercial ships

is therefore mostly a volume business that depends on simple steel-forming and welding processes repeated over and over. The construction of warships involves the use of exotic materials (to reduce the radar cross-section, or to reduce the noise, etc.), the installation of large amounts of high-value, sensitive equipment and the satisfaction of more exacting standards. The testing process for military ships is more involved because it has to reflect the high technology and technology density of the ships and take account of multiple possibilities for mutual interference of advanced electronic systems.

4. *Workforce character:* Naval shipbuilding requires a much higher ratio of white to blue-collar workers than that found in commercial shipbuilding, as naval shipbuilding demands much more engineering support as well as the need to interact extensively with the government overseeing teams. Military shipbuilding also requires more highly skilled and specialized workers. Such high overheads and high skill base cannot be sustained by any yard that expects to build typical commercial ships at competitive prices.²¹

DPSU Shipyards—Challenges and Opportunities

Ministry of Defence (MoD)-owned shipyards enjoy a unique set of advantages with their long exposure to warship building, enabling them to acquire certain naval-specific construction skills, design capability and technology. These skills are crucial for naval shipbuilding, given the complex nature of marrying a vast amount of weapons and sensors. However, the major disadvantages that public sector undertaking (PSU) shipyards face are the decision-making constraints. The key weakness of the Indian defence shipbuilding industry is the inefficiency and constraints of PSU shipyards which constitute the backbone of warship building. The inefficiency is largely due to the lack of competitive environment in which they operate, having been treated as captive production agencies to meet the requirements of the armed forces. Because these are nominated agencies and get orders in a non-competitive environment, they have little incentive to improve their efficiency. The PSU yards are often found lacking in the areas of build period, inventory management, labour utilization, and costing procurement, among others.²²

Warship building in the Indian environment has many peculiarities. The PSU shipyards have limited operational and financial decision-making powers. They have to follow strict government procurement

rules which sometimes delay their modernization programme. One of the crucial operational limitations of the shipyards is in actual warship building of large ships. For the large warship projects, the shipyards do not have complete control over the ships they are supposed to build, primarily because of the Indian Navy's deeper involvement in crucial decision making in the shipbuilding process. Unlike the some other navies in the world which rely on the shipyards for the entire task of shipbuilding, the Indian Navy takes a deep interest in warship construction, particularly in design and procurement of equipment, weapons and sensors.²³ The major shipbuilding projects have suffered from time and cost overruns. The cost escalation in two crucial projects, namely, P-15A and P-17, have been 225 per cent and 260 per cent, respectively.²⁴ The time overrun is also significant and is higher than the international standards, as noted by the Comptroller and Auditor General (C&AG) of India: 'as against the international timelines (for the construction of a the first ship of a class) ranging from 66–84 months, the indigenous construction of P-15 by MDL and P-16A by GRSE took 116 and 120 months, respectively.'²⁵

Although the shipyards are ably supported by the navy's in-house design organization that has state-of-the-art facilities and trained manpower, in terms of the man-hours utilized and time to commissioning, the Indian shipyards take about 10 times the man-hours taken by the Japanese shipyards, and three times the calendar months. The infrastructure in defence shipyards is ancient and not suited to modern shipbuilding within optimum cost, quality and time frames. As the shipyards are not optimally located geographically, the modernization will be limited to availability of space and other constraints. Some of factors that adversely affect the shipbuilding efficiency are: non-placement of orders for series production; decision-making delays even for pre-production activities like model testing; too many workers and too many trades in shipyards; lack of modern infrastructure; and lack of coordination in design, planning, material and production management in the shipyard.²⁶

The Indian warship building has a come a long way since the time the Leander class were built by Mazagon Dock Limited (MDL) during the late 1970s. Today, Indian shipyards are building the most modern and potent platforms comparable to the best in the world. However, the Indian shipbuilding industry is inefficient, lacks competitiveness and suffers from many shipyard and industry-specific inadequacies, as has been brought out in various reports of the government. Although the Indian defence

shipyards have been receiving orders through nomination, and therefore remain financially healthy, they can be assumed to be as inefficient and uncompetitive as their civilian counterparts. The infrastructure and other structural shortfalls thus need to be addressed so that the navy gets its warships at most optimum cost and without delays, and they are able to tap its real potential with the country-specific competitive advantages.

BENCHMARKING OF SHIPYARDS FOR NAVAL SHIPBUILDING

Inadequacies in Naval Shipbuilding Processes

Defence Procurement Procedure 2013²⁷ includes a separate chapter on indigenous shipbuilding as it is a capital and technology-intensive complex activity that does not fall under any one of the normal categories of procurement. Globally, defence shipbuilding is considered a strategic activity and thus follows the nomination route. While a commercial ship can be ordered on a competitive basis, a complex warship building requires a continuous interaction and/or hand-holding from the requirement specification stage to delivery with a large customer factor. The cost of a warship therefore cannot be compared with that of a commercial ship. However, in the case of Indian shipbuilding, this customer factor is increased due to lack of detailed design capability of shipyards and the ships being designed in-house by the Indian Navy design organization. C&AG carried out a performance audit of indigenous construction of Indian naval warships in 2011 and highlighted major weaknesses in shipbuilding processes and shipyard capabilities that lead to time and cost overruns. The key findings of the report were:²⁸

1. Delays in shipbuilding are primarily due to delay in the finalization of the structural drawings, timely availability of steel and inadequate infrastructure of the DPSU shipyards.
2. Poor cost estimation due to non-existence of a professional mechanism to provide reliable and accurate data regarding costs to the decision-making authority.
3. Poor contract management.
4. Lack of shipyard infrastructure due to non-initiation of effective steps for augmenting such infrastructure.
5. Significant design delays due to non-freezing of design prior to start of production, delayed decisions on main systems and delay in receipt of binding data.

6. Procurement inadequacies by the shipyards resulting in price inadequacies, lack of competition and non-transparency.
7. Inadequate financial management.

C&AG recommendations encompass shipbuilding aspects ranging from single-point accountability to institutionalized mechanisms for cost estimations based on best practices, and from modernization of shipyards to inclusion of private sector for building of warships. C&AG has thus adversely commented on shipbuilding aspects related to shipyards internal capabilities as also on external factors that affect shipbuilding times and costs.²⁹

Global Best Practices for Innovative Adaptation in Shipbuilding

Lean Manufacturing

The purpose of lean manufacturing is to improve product cycle time, cost competitiveness and quality by eliminating waste/wait in the manufacturing process through continuous improvement by the workforce. For lean manufacturing to be successful, the workforce needs to be flexible, motivated and highly capable.

Ship Production Management

Improved ship production management results in better planning, supervision, inspection and physical facility/equipment provision.

Worker and Manager Training

Successful global shipyards spend 1–1.5 per cent of revenues on training of workers and managers to ensure continuous updating of skills.

Multi-tiered Hierarchical Line Organization

The shipyards need to have flat, free-form, flexible organizations which empower workers at all levels and assume proper feedback and feed forward of information.

Digital Shipbuilding and Virtual Reality with Product Life Cycle Management (PLM) Software

Digital shipbuilding innovation and virtual reality through software solution like the PLM improves collaboration/integration between design/engineering and shipbuilding manufacturing.³⁰

Best Practice Build Strategies

World-class shipyards have been exploiting build strategies that have enabled them to dramatically lower their costs, improve construction quality, and extend ship design features and capabilities. The strategies can be divided into the four general categories, namely, improved manufacturing and assembly methods; improved procurement and material control; improved business processes; and, lastly, improved ship designs and engineering.³¹

Applicability of Benchmarking Concepts to Defence Shipbuilding

Benchmarking of shipyards and shipbuilding industry has been undertaken by many leading shipbuilding nations' governments with encouraging results. The studies have been conducted by the respective governments to enable capability assessments of the prospective shipyards before entrusting them with warship orders. Most global navies carry out benchmarking as a part of shipyards assessment process as warship building, and thus capability building of the shipyards is considered a strategic activity which enables them to make warships in a cost-effective manner. Benchmarking is tasked to experienced independent agencies with vast amount of best practices data gained by them through benchmarking studies at regular intervals. Availability of historical 'best practices' data of the 'best-in-class' shipyards with the benchmarking agency tasked to conduct the study is therefore a must.

Various shipbuilding professionals have highlighted inadequacies in internal and external processes related to defence shipbuilding. The benchmarking of defence shipyards, in addition to surveying the internal processes and production aspects, must also include assessment of acquisition procedures and processes being presently followed by the Indian Navy and MoD. The aspect of design capabilities of shipyards need to assessed, as provision of ship design by the customer is unique to the Indian naval shipbuilding and leads to high customer factor in the delivered cost of the ship. The shipyards should build up capabilities so as to develop ship designs based on the operational specifications given by the user.

The process and contents of shipbuilding specifications and the contract need to be specifically evaluated against the industry best practices, so as to remove all ambiguities of interpretation by the shipyards. The differentiation between different forms of specifications should be made to ensure that the risks and responsibilities are assigned

to different parties for each different form of specification. Similarly, for design development, the transfer of decision-making authority from the Indian Navy to the shipbuilder should be clearly spelt out.³²

There has been lack of motivation for DPSU shipyards to improve productivity and cost efficiencies due to assured orders from MoD. Lack of effective cost estimation tools, as brought out by C&AG, has aggravated the problem. With many shipbuilding orders, especially for low combat ships, being awarded on competitive basis, DPSUs are finding it difficult to compete with the private shipyards.

AN ASSESSMENT OF DPSU SHIPYARDS

DPSU shipyards mainly suffer from technological obsolescence due to non-upgradation of infrastructure to undertake shipbuilding with contemporary construction techniques. The lack of competent design department capable of undertaking detailed design has been an area of serious concern resulting in undue delays. The ship production management, planning scheduling and workflow optimization are also areas that require attention in DPSU shipyards. Shipbuilding in DPSU shipyards is undertaken using conventional construction methods, with major part of outfitting work being carried out after the launching of the ship, resulting in unacceptable delays and cost increases. Modular and integrated construction technologies, wherein major amount of outfitting is undertaken at block stage thus resulting in higher percentage of outfitting prior launch, will ensure major reductions in the build periods.

In addition to the infrastructure and workforce in shipyards, some of the other problem areas that have adversely affected the shipbuilding efficiencies of shipyards are equipment nomination and ordering and design-related aspects. The lack of financial and other decision-making powers of the shipyards has also been adversely commented upon by various authorities. The equipment nomination and frozen operational requirements, especially for weapons and sensors, are unduly delayed, thereby adversely affecting construction schedule. Even after the equipment is nominated, every ordering of equipment requires specific approval of the customer. This results in delays in the availability of equipment for installation on the ship.

The design development and validation system followed for shipbuilding is long-winded and requires validation by the customer

at a number of stages. The system followed for design development is a telescopic approach wherein the detailed design runs concurrently with the ship construction. During the detailed design stage, the equipment-related data are transposed into the system and layout drawings by the shipyard, followed by validation by customer. Based on the approved drawings by the customer, the production drawings are generated by the shipyard. The process is therefore long-winded and entails delays. It is observed that the production normally commences even before the design is frozen. The shipyards should therefore take up the complete responsibility for detailed design to enable single-point accountability for equipment ordering, obtaining of equipment design data and drawing generation and production schedule. The customer's design team's role should ideally finish once the contract is signed. The design infrastructure and manpower of shipyards would require major beefing up.

THE WAY AHEAD

While industry bodies and GoI have undertaken benchmarking of the shipbuilding industry as a whole, little effort has gone into benchmarking of individual shipyards to enable specific shipyard-level initiatives to improve competitiveness. Similarly, the inefficiencies at the procedural levels in the government have not been addressed so far. While efforts may have been made by individual shipyards to commission experts to identify specific problem areas to improve their efficiencies, very little seems to have been achieved because of involvement of multiple agencies on which the shipyards may have very little control. The studies, if any, are not in the public domain, and thus cannot be commented upon.

The GSIBBS undertaken for the US DoD was motivated by the need to control the spiralling costs of naval shipbuilding. The Indian scenario is no different, and thus a similar study would evaluate individual shipyard manufacturing and business practices in the chosen benchmark elements using the benchmarked best practices of the chosen international shipyards. The areas specific to Indian environment related to contracting procedures, design control, etc., may have to be factored in the benchmarking study. It is therefore imperative that all the shipyards that aspire to build naval ships must be benchmarked by a professional consultant familiar with the best practices of global shipyards that build

both commercial and naval ships in a competitive environment. Specific recommendations on improvements required in various elements of shipbuilding processes should be sought with recommended timelines and cost implications. In addition, other elements that contribute to cost and time overruns, like the shipyard internal management processes, operational and financial decision-making policies, accountability and responsibility structures, skill development and HR policies, supply chain philosophies and contractual provisions, should also be assessed and specific recommendations sought from the consultant. The implementation of the accepted recommendations should be closely monitored in a project mode.

Naval shipbuilding must be considered as a national strategic activity. MoD should undertake with urgency the development of DPSU shipyards and other shortlisted PSU/private shipyards into cost-effective and efficient entities. Towards this end, the shipyards internal processes, acquisition procedures, supply chain management, human resource (HR) and workforce development policies and decision-making structures should be benchmarked through an independent professional agency with a global database of shipyards and other industry best practices. The report must clearly and specifically recommend feasible improvements in infrastructure and business practices not only at the shipyard levels but also at the level of the Indian Navy and MoD. The implementation of the accepted recommendations must be monitored at an appropriate level.

The benchmarking agency would determine the elements that need to be benchmarked after a preliminary survey of the current processes in shipbuilding from inception to delivery as well as discussions with the stakeholders. Although the system implemented in the US DoD benchmarking study took into account seven technology groups for survey, additional groups relating to HR to include skill development, innovation orientation, procurement, supply chain and logistics and acquisition procedures could also be taken up for survey, as these have a major impact on the overall cost of the ship.

APPENDIX A

Terminologies Used in Estimation of Shipyard Productivity³³

Compensated Gross Tonnage

The compensated gross tonnage (CGT) is used to normalize the production work content within a vessel by multiplying the vessel's gross tonnage (a measure of internal volume) by a factor that accounts for vessel's complexity. This complexity factor (or the CGT factor) is determined by characteristics such as vessel specifications (combat systems, survivability, shock, etc.), design standards, outfit density, average compartment size and complexity of structural arrangements.

$$\text{Compensated Gross Tonnage} = \text{Vessel Gross Tonnage} \times \text{CGT Factor}$$

The CGT factor varies from a low value of 0.3 for bulk carriers to a high of 80 for fast-attack nuclear-powered submarines. The CGT factor is therefore relevant in the case of naval shipbuilding projects. While the CGT factors for commercial vessels have been developed and refined over more than 30 years by leading international shipbuilding organizations, there are currently no agreed CGT factors for naval vessels.

Total Work Content

To complete the process of comparisons of shipyard productivity, a customer factor also needs to be considered. A customer factor is used to normalize the amount of work necessary for differing customers. Generally, the differences between two commercial owners are trivial and can be ignored. However, the difference between naval and commercial owners is so large that compensation factors need to be applied to take this into account. The customer factor is based on factors such as customer oversight, reporting requirements and unique administrative requirements. This total work content for a shipyard involved in building naval ships is calculated by multiplying the CGT with the customer factor. Typically, the customer factor for a commercial ship is 1.0, against 1.2 for a warship.

$$\text{Total Work Content} = \text{CGT} \times \text{Customer Factor}$$

Shipyard Productivity

Productivity can be compared between different shipyards producing different ships for various customers by dividing the total shipyard man-hours expended by the total work content.

$$\text{Shipyard Productivity} = \text{Total Shipyard Man-hours Expended} / \text{Total Work Content}$$

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