



Review of Global Naval Shipbuilding Trends and Lessons for Indian Shipbuilding Industry

P.R. Kulkarni*

It is estimated that over the next two to three decades, the global naval shipbuilding industry could see an investment of over US \$835 billion in new warship and submarine construction. In an ambitious effort, many countries are now analysing the strengths and weaknesses of their respective naval shipbuilding industries in order to renew their naval fleets. Towards this end, specialist studies and research have been commissioned by various stakeholders, to take a strategic look at the shipbuilding industry to determine lessons from some recent naval construction programmes, identify capacity limitations (in terms of infrastructure, skills and character of the workforce, and suppliers who constitute the ecosystem) and explore policy options that are open to the government and the industry to overcome any limitations. This paper presents a review of a few of these studies and identifies the factors that are likely to impact on future naval construction and acquisitions. The paper also examines trends in naval design and construction technologies and presents possible lessons for the Indian naval shipbuilding industry.

*Captain P.R. Kulkarni, PhD, is currently the Officer-in-Charge of the Naval Construction Wing, Department of Applied Mechanics, at the Indian Institute of Technology, Delhi. The views expressed are his own and do not reflect the official policy or position of the Indian Navy or the Government of India. He can be reached at prk_iitd@yahoo.co.in

The naval acquisition plans of major maritime nations over the next 30 years are likely see an investment of over US \$835 billion into new warship and submarine construction.¹ A break-up of this investment into various categories of naval vessels is shown in Table 1.

The ambitious effort to produce new warships and submarines for upgrading respective naval fleets over the next two to three decades has led many maritime countries to analyse the following issues:

1. Can the existing shipbuilding industrial base in the country meet future demands?
2. Do problems exist with the numbers and types of facilities, infrastructure and shipbuilding methods employed in the shipyards?
3. Are the numbers and skills of the workforce enough to sustain the naval shipbuilding programme?

Table 1. World Naval Market Forecast 2013–2032.

Vessel Type	In progress		Planned		Projected		Total	
	No. of Hulls	US\$B	No. of Hulls	US\$B	No. of Hulls	US\$B	No. of Hulls	US\$B
Aircraft carrier	9	49.8	2	4.0	2	3.0	13	56.8
Amphibious	129	29.5	204	33.9	33	3.4	366	66.8
Auxiliary	57	8.1	112	40.1	16	3.1	185	51.3
Corvette	51	7.1	43	13.1	23	5.8	117	26.0
Cruiser	2	2.6	6	3.6	-	-	8	6.2
Destroyer	55	55.3	90	113.8	3	2.9	148	172.0
FAC	147	5.5	45	3.5	34	2.8	226	11.8
Frigate	193	68.8	75	42.4	44	17.0	312	128.2
MCMV	28	4.5	71	6.4	28	2.6	127	13.5
OPV	121	12.5	139	16.7	31	3.1	291	32.3
Patrol craft	1121	9.7	482	7.5	157	1.6	1760	18.8
Submarine	154	142.3	142	100.7	27	11.5	323	254.5
Total	2067	395.7	1411	385.7	398	56.8	3876	838.2

Source: AMI International, "2013 Naval Market Forecast", September 6, 2013, www.amiinter.com (accessed January 25, 2015).

4. Are there any lessons to be learnt from ongoing or recently completed naval construction programmes?

Review of Global Naval Acquisition Plans

A forecast of construction of naval ships, globally over the next 25–30 years by market analyst AMI International,^{2,3} indicates that about 522 new construction programmes totalling more than 3800 new ships, submarines and craft, is expected to cost US\$ 838 billion. This forecast indicates a steady rise in spending on new naval acquisitions worldwide, despite declines in US and European shipbuilding sectors, highlighting the increasing priority given to naval and maritime security capabilities in the overall defense budget by different countries. These acquisition plans by different regions of the world are briefly reviewed below.

US Naval Acquisition

The US Navy, under the 2014 plan, would buy a total of 268 ships over the 30-year period from 2013 to 2042, which will include 222 combat ships and 46 logistics and support ships.^{4,5} This includes building one carrier every 5 years, two future ballistic missile submarines, and two advanced destroyers every year, at an annual expenditure of US\$ 12 billion per year, in the period 2013 to 2017, which increases to US\$ 18 billion per year in the period 2018 to 2022. It is also interesting to note that submarines would require more funding than surface combatants over the next 20 years.

Naval Acquisition in the Asia-Pacific Region

As per the forecast by AMI International in 2013,⁶ the Asia-Pacific naval market will overtake the US to become the world's largest naval market by volume, comprising 1066 vessels or approximately 28% of the market over the next 20 years. This includes over 650 major and minor surface combatants and 116 submarines worth over US\$ 167 billion in the next two decades, as illustrated by the following trends:^{7,8}

1. About 1048 naval vessels, worth about US\$ 200 billion, are scheduled to be ordered in the next 20 years, which would include nuclear and conventional submarines, aircraft carriers, a balanced mix of destroyers, frigates, smaller units, amphibious and logistics vessels, and ships for Coast Guard and maritime patrol forces.

2. India and China lead the Asia-Pacific region in projected naval spending. These countries are expected to order 100 new naval ships and submarines, each, by 2032. The two countries combined would account for 30% by volume and 45% by value of these 1048 naval vessels worth US\$ 200 billion. China is forecasted to add 16 conventional and nuclear-powered hulls to its fleet over the next 5 years, the greatest number of new hulls by any Asia-Pacific country for this period.
3. Other “Top Five” naval buyers in the Asia-Pacific region include South Korea, Japan and Australia. These countries are expected to acquire 220 new vessels worth US\$ 62 billion. Singapore, Malaysia, Indonesia and Vietnam are also active purchasers in the market with new ship and submarine acquisition programmes.
4. The ordering of about 100 submarines over 20 years makes Asia-Pacific the single region buying more submarines than anywhere else in the world.

According to research commissioned by the US Congress, China’s overall fleet of frontline combatants has expanded and improved substantially in qualitative as well as quantitative terms. “Defining modern submarines” as those able to employ submarine-launched intercontinental ballistic missiles or antiship cruise missiles, and “modern surface ships” as those able to conduct multiple missions or those that have been extensively upgraded since 1992. It is projected that by 2020, about 85% of surface combatants (frigates and destroyers), 75% of diesel submarines and 100% of nuclear submarines in the PLA People’s Liberation Army Navy Fleet could be “modern vessels”^{9,10,11}.

Naval Acquisition in Europe

In this time of tight defence budgets, the increase in cost of defence technology has led to a decrease in the number of ships planned to be deployed by European navies.¹² Many NATO North Atlantic Treaty Organization countries (excluding the US) continue to restructure their navies and realign new ship programmes to optimise fleet structures in a resource-constrained environment. Future procurements remain relatively flat with 524 ships and submarines forecasted to be built up to 2032, totaling US\$ 179 billion.¹³ Turkey is the only country in NATO Europe, which is expected to be procure almost 100 new hulls worth an estimated US\$13 billion, in this period.

Business Plans

In order to maintain the military industrial base in the respective countries in the face of reducing defence budgets, a review of their business plans indicates a thrust on the following business strategies:¹⁴

1. Combined multi-national naval projects
2. Thrust on R&D Research and Development
3. Focus on market for export
4. Multiple-shipyard, modular-build strategy.

Combined Multi-National Naval Projects

This strategy is illustrated by the multi-nation naval projects like FREMM (European multipurpose frigate) (French *Frégate Européenne Multi-Mission* or Italian *Fregata Europea Multi-Missione*), *Scorpène* class submarines and *Horizon*-class frigates. Working on joint programmes in such European cooperation projects sustains skills and capabilities in the naval shipbuilding industry of France, Italy, Spain and Germany.

Thrust on R&D

Notwithstanding the decline in British and other European shipbuilding, the ancillary industry in Europe, with its strong focus on R&D, has delivered quality and reliable equipment required by the global shipbuilding industry. This capability is one of the reasons for Europe's continued supremacy in the global naval shipbuilding ecosystem. China has managed to get European hardware and know-how locally in China, which has been instrumental in supporting the success of its indigenous naval shipbuilding.¹⁵

Export Market

The export market has become the thrust area of many naval shipbuilding nations and is largely a market for modestly priced frigates and small conventionally powered attack submarines. The following are the salient points which have been observed:

1. The export market will witness the development of less expensive warships that reflect the needs of potential buyers.
2. Export contracts often require that most ships in an order are built in the importing country.

3. UK and US warships are, in general, found to be too sophisticated and expensive to make, which does not make them attractive to potential importers. Therefore, UK and US shipbuilders face strong competition from European shipbuilders, particularly from Germany, France and Russia.
4. Germany and France together have more than 60% of the military export market of naval shipbuilding contracts. Ships and submarines account for 46% of German arms exports.¹⁶
5. Russian shipyards continue to have a thriving export business. Their shipyards, in the post-soviet era, are in the process of transformation and their biggest customers have been India, Vietnam and Algeria.
6. China's shipbuilders are becoming increasingly competitive in terms of the ratio of cost to combat power they can deliver.¹⁷

Multiple-Shipyard, Modular-Build Strategy

The changes in the demand for ships – particularly resulting from diminishing commercial demand at US and European shipyards, as well as the military demand for fewer but more-sophisticated ships, has led to shared-build decisions to maintain shipbuilding capacity. Five examples of ships built in multiple shipyards using a “modular-build strategy” are presented below¹⁸ and shown in [Figure 1](#).

1. Zumwalt Class Destroyers: The construction of 15,000-ton DDG-1000 destroyers of the Zumwalt Class is shared between NGSB-GC Ingalls and Gulfport shipyards in Mississippi and the General Dynamics BIW yard in Maine.
2. Virginia-class submarines: Large sections of Virginia-class submarines are built by Electric Boat (EB) and Northrop Grumman Shipbuilding–Newport News (NGSBNN), with the two shipyards alternating final assembly and testing.
3. Type 45 Destroyers: The Type 45 programme in the UK builds some modules in Portsmouth that are shipped to BAE Systems' Govan shipyard on the Clyde, where other modules are built, for final assembly.
4. Queen Elizabeth class aircraft carrier: The UK's new aircraft carrier, the Queen Elizabeth Class (QEC, also known as the future carrier), is being built at multiple shipyards, with final assembly at Rosyth.
5. Mistral-class LPH: France used modular building on its Mistral-class landing-platform helicopter (LPH)/landing-platform dock (LHD) amphibious ships;

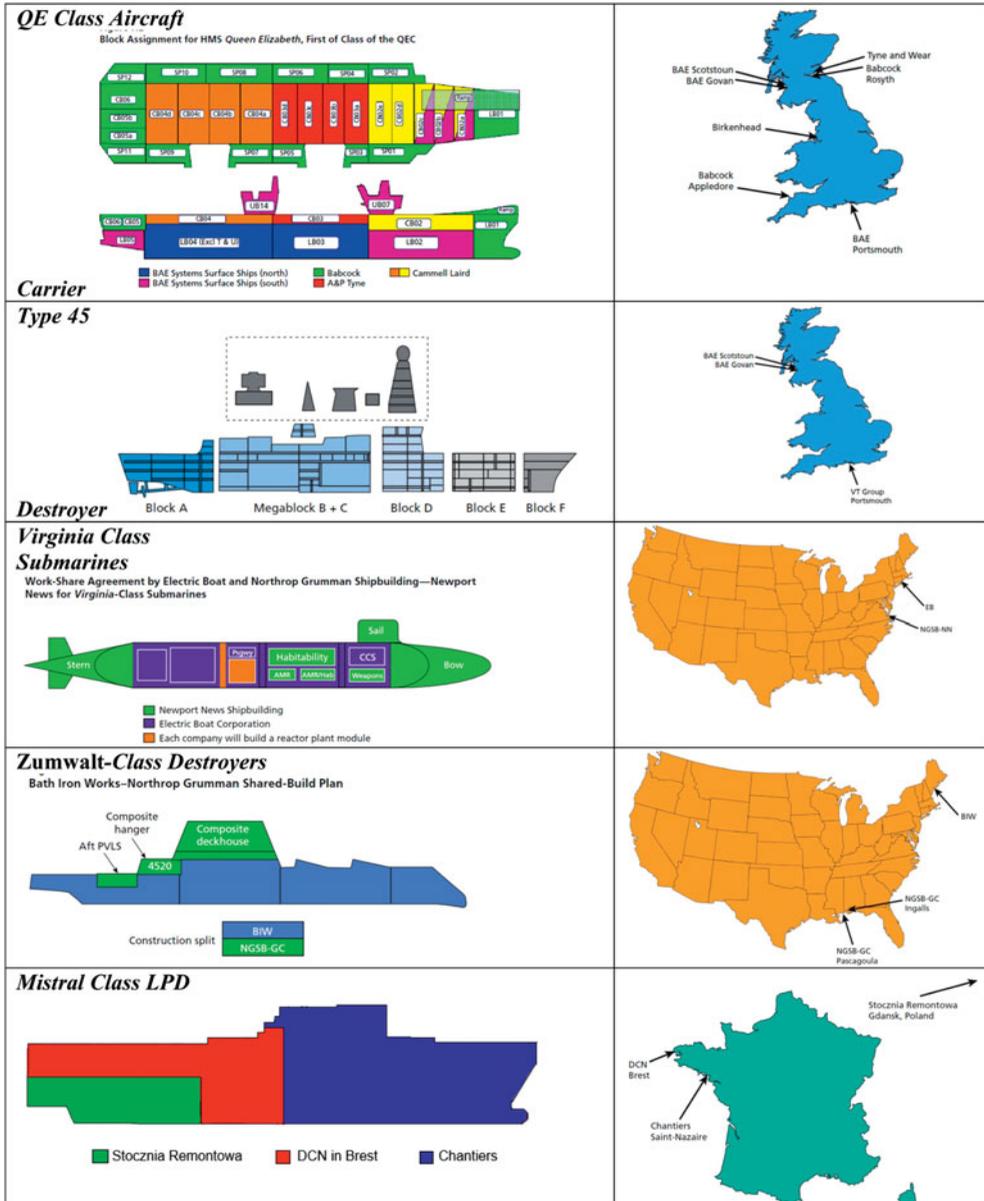


Fig. 1. Ships Built in Multiple Shipyards Using “Modular-Build Strategy”. Source: *Shared Modular Build of Warships: How a Shared Build Can Support Future Shipbuilding*, RAND Report, 2011. (Reprinted with permission from RAND Corporation).

the first two ships of the class were built in two halves at different shipyards and brought together in Brest.

Commissioning Research on Naval Shipbuilding

Specialist studies have been commissioned by many stakeholders globally, to strategically look at the future of their respective naval shipbuilding industry over the next 20 to 25 years in order to identify capacity limitations (in terms of infrastructure, skills and character of the workforce, and suppliers who constitute the ecosystem) and what policy options are open to the government/industry for overcoming such limitations. A review of the literature originating from these studies is presented in this section.

(a) Commissioning research prior to embarking on an acquisition programme: In 2001, as the UK was embarking on an ambitious naval acquisition programme for the next 20 years, the UK Ministry of Defence (MoD) commissioned a series of studies¹⁹ to examine many key aspects of its shipbuilding industry. Together, the following reports generated in the period 2002 to 2005 represent a significant body of work, which has proved influential for making policy decisions on the future of UK's shipbuilding industrial base:

- (i) *The United Kingdom's Naval Shipbuilding Industrial Base: The Next Fifteen Years*²⁰
- (ii) *Differences between Military and Commercial Shipbuilding: Implications for the United Kingdom's Ministry of Defence*²¹
- (iii) *The Royal Navy's New-Generation Type 45 Destroyer: Acquisition Options and Implications*²²
- (iv) *Outsourcing and Outfitting Practices: Implications for the Ministry of Defence Shipbuilding Programmes*²³
- (v) *Options for Reducing Costs in the United Kingdom's Future Aircraft Carrier (CVF) Programme*²⁴
- (vi) *Monitoring the Progress of Shipbuilding Programmes: How Can the Defence Procurement Agency More Accurately Monitor Progress?*²⁵

(b) Documenting lessons learnt: The lessons learnt from previous submarine construction programmes of the US, UK and Australia have been documented in four volumes, as shown below:

- (i) *Learning from Experience – Volume 1. Lessons from the Submarine Programs of the United States, United Kingdom, and Australia*²⁶
- (ii) *The United Kingdom’s Nuclear Submarine Industrial Base, Volume 2: MoD Roles and Required Technical Resources*²⁷
- (iii) *The United Kingdom’s Nuclear Submarine Industrial Base, Volume 3: Options for Initial Fuelling*²⁸
- (iv) *Learning from Experience, Volume IV: Lessons from Australia’s Collins Submarine Program*²⁹

(c) Research originating from observations by watchdog agencies and legislature: In view of the large outlay of public money for naval acquisition projects, the cost overruns have invited scrutiny and criticism by the watchdog agencies of the legislature – the National Audit Office (NAO) in the UK and the Government Accountability Office (GAO) in the US (the counterparts of CAG (Comptroller and Auditor General) in India). This has led to the commissioning of research to address issues of cost estimation, cost and time overruns as well as inefficiencies in the procurement process.^{30,31,32}

In addition, research on naval shipbuilding has been commissioned by countries like Canada,³³ Australia³⁴ and the EU.³⁵

Review of Findings from Research on Naval Shipbuilding Industry

The salient findings that have emerged from a review of the abovementioned studies are presented in this section.

(a) Lessons learnt from previous programmes:

- (i) Understand the cost and schedule impacts of using different technologies when setting the operational requirements.
- (ii) Incentivise the contractor to achieve cost, schedule and performance goals.
- (iii) Develop realistic cost and schedule estimates.
- (iv) Develop a timely decision-making process to manage change.
- (v) Complete the majority of the design drawings before the start of construction.

- (vi) Specify and manage adequate design margins.
 - (vii) Design for removal and replacement of equipment.
- (b) IT (Information Technology) systems: When multiple shipyards collaborate to share build on a hull, data exchange is crucial, and thus the ease with which the IT systems of the shipyard can be linked is of critical importance.
- (c) Human resources: Naval shipbuilding requires highly skilled personnel.
- (i) Finding and recruiting experienced professional engineers who are naval architects and systems engineers is difficult. Therefore, the MoD needs to nurture these design and engineering skills to bridge current and future gaps.
 - (ii) Detail designers involved in various stages of surface ship and submarine acquisition and support also need to be nurtured.
 - (iii) It takes 6 to 8 years for all skills to reach 90% of the optimum level of productivity.
 - (iv) To recruit experienced technical workers, especially for roles that relate to combat systems and other warship-specific areas, former armed forces personnel are most suitable.
 - (v) Naval shipbuilding requires a much higher ratio of white- to- blue-collar workers than commercial shipbuilding because it demands much more engineering support, as well as the need to interact extensively with the government/navy oversight team. This workforce character adds to the overheads. Such a high overhead and high skill base need to be sustained by the shipyard that builds naval ships.
- (d) Outfitting: Performing outfitting tasks at the block and grand block level requires 25% fewer labour hours than doing them on the completed ship. The key findings are:
- (i) US and EU shipbuilders typically outfit their blocks and grand blocks up to 80%, which shows that a goal of 80% outfitting at the super block stage is reasonable and achievable.
 - (ii) Ensure production designs are nearly complete before construction begins and

that the necessary equipment and materials are available in a timely fashion to facilitate advanced outfitting.

(iii) Involve all shipyards in the design process and encourage the sharing of information on advanced outfitting practices.

(e) Outsourcing: The key points to be noted are:

(i) Encourage shipbuilding programmes to identify subcontractors as early as possible and to subsequently include them in the design process. (These may include foreign firms.)

(ii) Ensure that production designs are nearly complete before construction begins.

(iii) Ensure shipyards have adequate manufacturing plans and processes that include the integration of any necessary subcontractors.

(f) Bulk purchases of materials for a group of ships: Costs can be reduced by allowing bulk purchases of many materials, across shipyards, for a group of ships that are to be acquired over a specified number of years, instead of individual purchases of those materials each time a ship is authorised. Such multiyear procurement reduces administrative costs and provides incentives to improve efficiency in ship construction by negotiating better prices for ships.³⁶

(g) Cost estimation: Statistical modeling of the cost estimation, risk and uncertainty and sensitivity analysis are best practices for arresting schedule and cost overrun in naval shipbuilding.^{37,38,39}

(h) Shipbuilding inflation: It is important for acquisition planning to determine the quantum of gap between shipbuilding inflation and price inflation. If this gap grows indefinitely, the price of ships would eventually outstrip the Navy's ability to pay for them.⁴⁰

Technology Trends in Future Naval Design

Development of generation-skipping designs of naval systems and equipment is underway due to investments in R&D by shipbuilders and marine equipment suppliers as well as governments. A revolution in naval affairs (RNA) originating from such trends in naval technology will drive the induction of the following capabilities and features into the next generation of combat ships:

1. Increased ballistic missile offensive and defense capabilities: More sophisticated and miniaturised weapon electronics will have an impact on the sensors. Advanced radars shall be larger and more powerful than those on earlier generation of warships. Such improvements in weapons electronics shall require an increasing amount of installed electrical power and cooling requirements.
2. Improved stealth of warships and submarines: The next generation of naval combatants shall be quieter and more difficult to detect.
3. Unmanned vehicles: Unmanned vehicles – both UAVs (Unmanned Aerial Vehicle) and AUVs (Autonomous Underwater Vehicle) deployed from warships shall play an increasing role in naval warfare. The X-47B (of the US Navy), a tailless, strike fighter-sized unmanned aircraft designed to be deployed from an aircraft carrier, and the A2 AD programme (of the French Navy) are some of the futuristic UAVs, trials of which are currently underway.⁴¹
4. More efficient propulsion: Efficiency in propulsion will be driven by breakthroughs and innovations in motor technology, which shall drive the proliferation of electric propulsion.

Considerations for the Indian Shipbuilding Industry

Based on a review of global trends presented, the following multi-pronged inputs for policy makers and stakeholders of the Indian naval shipbuilding industry emerge:

1. Commissioning research and documenting lessons learnt: There are not many examples of commissioning research (on the scale and depth seen in this review) on the nation's naval shipbuilding industry. Another area that requires attention is the ability to document and audit technical capability as well as "lessons learnt" which spell out policy options to the government/industry.
2. Joint Ventures: Adopt the "multi shipyard–modular block build strategy" (with 80% targeted pre-outfitting) to overcome the existing capacity/infrastructure constraints of shipyards through joint ventures between shipyards (in private and public sectors) along the lines of models in the US and European shipbuilding.
3. Export of Indian Warships: Over the long term, export of Indian warships (along the lines of the business strategy adopted by European shipyards)

could be set as a national goal. Setting up maritime clusters, shipbuilding parks or SEZs (Special Economic Zone) for the shipyards as well as equipment suppliers should be considered.

4. Consortium Approach: Collaboration at a multi-national level by the Indian shipbuilding industry along the lines of the European multi-national naval projects (like FREMM and *Horizon* frigates etc.), and similar to successful projects such as BRAMHOS, should be considered, to achieve the above objective of exporting Indian-made warships.
5. Equipment suppliers to manufacture in India: More than half the cost of a naval vessel is due to equipment suppliers other than the shipbuilder. China has managed to get these equipment suppliers from Europe to set up manufacturing in China, which has been instrumental in supporting the success of its indigenous naval shipbuilding. As a part of the “Make in India” campaign, this model of China should be emulated.
6. Integrated construction: Modular and integrated construction is an oft-used but seldom-understood term in Indian naval shipbuilding industry. Being used to assembling warships piece by piece from the keel up, achieving even 50% pre-outfitting seems farfetched at the moment. The structured approach to achieve to global standards of up to 80% pre-outfitting as seen in the “Multi shipyard–modular block build” strategy of the European and US naval shipbuilders demands a complete “culture change” by the industry, where one of the prerequisites is to complete the majority of the design drawings before the start of construction. Injecting this “culture change” should be a priority.
7. Benchmarking: It is important to benchmark the practices of naval acquisition and its decision-making system, as well as the entire ecosystem supporting the naval shipbuilding industry (skill development, infrastructure, systems/processes, subcontractors, policies etc.) against the US or European standards. In order to undertake an audit of the availability of skill levels in the industry, shipbuilding should be benchmarked against automobile, heavy engineering, civil construction, etc. What is most important is that such benchmarking studies should be leveraged for initiating policy changes and for improving productivity.

8. Outsourcing: Provide incentives for developing capable vendors and a better approach to outsourcing by having a consortium approach by shipyards with capable vendors.
9. Shipbuilding inflation: Develop tools to quantify “shipbuilding inflation” in India, and determine the quantum of gap between the shipbuilding inflation and (gross domestic product [GDP]) price inflation. If the import component in indigenous naval shipbuilding is not brought down significantly from the current levels, the gap will widen, and the price of ships will eventually outstrip the defence budget allocation for naval acquisition.
10. Cost estimation: The methodology of cost estimation using statistical tools represents internationally accepted best practice adopted even by the UK MoD (Ministry of Defence) as well as the US DoD (Department of Defence). There is strong case for the Indian shipbuilding industry, navy and MoD to employ powerful statistical tools for cost estimation and related best practices of project management.
11. Academia–naval shipbuilding industry interaction: Academia–naval shipbuilding industry interaction for innovation in design and construction, as well as development of human resources, should be strengthened.⁴².

Conclusion

The Indian Navy has witnessed the highest degree of indigenisation of its supply chain, entirely due to the country’s naval shipbuilding industry. This paper has attempted to flag a few issues that have emerged from a review of research on the naval shipbuilding industry of different countries. It is hoped that the findings and recommendations will contribute to the ongoing debate on improving build times and costs by the Indian shipbuilding industry.

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