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Growth of Shipbuilding in China: The Science, Technology, and Innovation route*

Abstract

Chinese shipyards from being mere shipbuilders in the 1990s are today the industry leaders. In the last three decades, the Chinese shipbuilding industry has transformed from a 'basic ship producer' to an industry, focusing on 'high technology' and 'support equipment'. This has allowed them to dominate the world market in both commercial and naval shipbuilding segments with 70 per cent of China's shipbuilding produce being exported to 91 countries and regions, including countries like Greece, Norway, US, UK, Japan, South Korea, and Germany. This enormous growth has been aptly supported by a judicious mix of public and private enterprises in the field of science, technology, and innovation that provides many a lesson for the world. This essay aims to identify these efforts and strategies that have supported the growth of shipbuilding in China and possible lessons to be drawn by developing maritime nations for their own growth.

Keywords: *shipbuilding; innovation; technology; China*

Introduction

Although China has had important shipyards since the 1940s, her maritime transformation that commenced in the 1990s, has been one of the most significant achievements of this century. When China began its market reforms in 1978, shipbuilding got special attention of the government. In an unusual decision, officials encouraged competition rather than protect the state-owned shipbuilding companies as was afforded to state companies in other sectors (SERI, 2007). In the long run, this environment of competition in the shipbuilding industry unlocked the huge growth potential that allowed shipbuilding to grow more rapidly than in any other country. As Chinese commercial shipbuilding output increased by nearly 13 times between 2002 and 2012, the broader goal of becoming the world's largest shipbuilder was achieved in 2010, much earlier than the planned 2015 (Erickson, 2016, p. 7). Though the Western world has been sceptical of the growth and the ensuing achievements made by the Chinese shipbuilding industry in this short period, one should not overlook the advancements made by China in the fields of science, technology and innovation, due to this industry. It is prudent to mention that shipbuilding is not an industry like any other, but is an amalgamator of the produce of various ancillary industries which include steel, cables, pipes, motors, engines, electronic equipment, weapons, and sensors all put together by a resource called 'manpower' to provide a final product 'ship'. So, when a nation's shipbuilding progresses, it is natural to deduce that it has a robust ancillary

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This essay is based on the presentation made at the 10th All India Conference on China Studies, 15-17 November 2018, organised by the Institute of Chinese Studies and Christ (Deemed to be University) in cooperation with the National Institute of Advanced Studies, Bengaluru, at Christ (Deemed to be University), Bengaluru, India industry that is well developed and adept at providing the necessary produce feed in the required quantity, quality and time. All this industrial prosperity, however, is not feasible if the business environment of the nation is not conducive. This brings us to the largest player in this chain of prosperity -- the 'government's involvement through policies and initiatives'. Conversely, one can say that the Chinese policy makers would have definitely done some things right that helped make the ancillary industries in China prosperous leading to the prosperity of the nation through shipbuilding.

It is with this thinking that the essay aims to discuss the 'rights' that the Chinese have done, that have led to the overall development of *science*, *technology* and *innovation* in the country. In doing so, we begin by looking at the development of shipbuilding in China over the years before discussing the advancements made by the country in these fields. Having developed the understanding of what and how things have unfolded for the Chinese shipbuilding development model, we will try to cull out some learning for other maritime nations who wish to use shipbuilding as a development engine. It is considered essential to mention here that the essay will avoid discussing advancements made in Chinese naval shipbuilding since a nation's dominance in shipbuilding is gauged by commercial shipbuilding orders alone[1] (OECD, 2007) which does not include 'naval shipbuilding'. Further, it is believed that 'naval shipbuilding' is a specialised, scaled up activity of commercial shipbuilding, which necessarily needs to be supported by the government and can proceed with substantial success with or without innovation in science and technology in the shipbuilding country.

Historical Developments

China as a nation has had a historical past which included shipping and shipbuilding. As a nation, China has been associated with shipbuilding for many centuries and its present status is an outcome of the efforts of many decades. Hence, to understand the developments in Chinese shipbuilding, it is essential that we look at the historical developments that have allowed the Chinese shipbuilding to become world leaders in shipbuilding.

Shipbuilding

Historically, Chinese shipbuilding has been known to exist for over 7,500 years (Schottenhammer, 2015). Their ships were known for strong hulls, navigational aids, large dimensions and capacity. Their ninth century wooden shipbuilding influenced the development of shipbuilding in other countries (Xi, 2000) and many countries learnt the art of shipbuilding from China to replicate it in their own countries. The introduction of 'Maritime Prohibition' (Wade, 2004) in the 15th century, led to the change in trading policies leading to reduction of foreign business that eventually caused the decline of the Chinese shipbuilding (Edwards, 2017; Hayk, 2008). In the modern world, the United States controlled shipbuilding till the commencement of the use of iron and steel in the 1850s, when the British

[1] Measured in Compensated Gross Tonnage (CGT) to provide a more accurate measure of shipyard activity than could be achieved by the usual gross ton (gt) and deadweight ton (dwt) measures, see OEDC, 2007 for details.

took over the mantel of shipbuilding leadership. With the changing technology in 1956, the top spot once again changed hands with Japan claiming this position. Since then the world has seen two more shipbuilding leaders in South Korea and the recent one, China, spurred on by low cost shipbuilding. When these nations became shipbuilding leaders, they simultaneously helped build their country's industrial capacity and achieve economic development by converting the shipbuilding enterprises into 'systemic industrial organisations' that focused on various types of ships and other related fields such as producing equipment and materials, academic research and education.

For Chinese shipbuilding, it is not that everything fell into place from the word 'go'. Efforts by the Chinese government to encourage shipbuilding before 1949 were unsuccessful due to substantial war debts. After 1949, the new PRC government supported the shipbuilding industry by rebuilding many shipyards in the 1950s that were capable of building general ships such as small passenger ships, bulk carriers and tankers for the domestic market. To improve on these ships, the shipyards began to imbibe foreign technology in the 1960s to help them build larger vessels for the deep-sea. The implementation of the 'Open Door Policy' in 1978 focused on comprehensive economic reforms, modernisation and social development that helped the shipyards to start to learn advanced technologies and begin building ships for export (Wu, 2005). By 1990 things began to change for the Chinese shipbuilding due to a strong national economy; development of technology; and the support of the government that promoted business opportunities for the shipyards. Additionally, massive investments in research and development were made to increase sophistication in the ships being built. To achieve self-sufficiency in moving domestically manufactured produce and food for China's own population as well as foreign exports, ships built in China were used to the extent feasible. Once self-sufficiency was achieved, the focus shifted towards the needs of the international market. As an example, one sees that when China Petrochemical Corporation (Sinopec) wanted to import LNG from Australia, it wanted LNG carriers which were ordered on Chinese shipyards. This forced the industry to acquire technology, through technological support and supervision from countries like Japan and France in 2008 and subsequently bagged international orders for LNG carriers from companies including CNOOC Energy Technology & Services, China LNG Shipping, Teekay LNG Partners and British Gas Services beginning in 2013 (Murray, 2014). Yet another example is the construction of cruise liners, which the Chinese shipbuilder Shanghai Waigaoqiao Shipbuilding Co is currently building in collaboration with Italy-based Fincantieri SpA for a Hong Kong based buyer which will eventually improve many sectors of the domestic shipbuilding ecosystem and the global supply chain (Zong, 2017).

Ancillary Industries

The Chinese ancillary industry largely relied on the Soviet Union (1960 to 1980). After a brief nine year access to Western support (1980 to 1989), it once again started to depend on Russia and Ukraine for technical assistance which has continued since 1989 till date. This assistance was however never comprehensive and was marred by the diplomatic relationship of the countries with China, leaving several running projects in China, gasping midway for equipment and components at times. These intermittent stoppages forced China to develop frontier technological programmes such as the nuclear programme on its own. In addition, China's export activities with countries such as Pakistan and elsewhere exposed it to advanced Western technologies and helped it develop its own industries.

With the end of the Mao era turmoil, China embarked on a 'two-track approach' of development of the ancillary industries. These approaches included:

(a) Indigenous development based on reverse engineering followed by modifications, with the Soviet designs being the starting point.

(b) Use of Western technology obtained through the Foreign Military Sales (FMS) route. This allowed infrastructure upgrades and access to new Western knowledge for the Chinese experts.

With the Tiananmen Square crackdown on 4 June 1989, all exchanges from the West suddenly stopped including the on-going projects that were halted midway. Fortunately for China, the demise of the USSR in 1991 and the cash-strapped economic situation of the newly formed Central Asian countries opened up an opportunity of importing technology from the Russians and the unfinished shipbuilding projects from Ukraine.

All these, notwithstanding, China has not yet managed to achieve a satisfactory level of self-reliance. For Chinese built simple commercial ships, the per cent of indigenous components is considerably low which reduces further for complex vessels. The major sub-components which the Chinese industry seems to be effectively producing are 'low tech' products such as pumps, gears, and fixed pitch propellers while the more complex electronics, and navigation equipment are imported from foreign suppliers (Collins and Grubb, 2008:13)

Since research, technical knowledge and resources such as trained manpower, material and manufacturing machinery to develop complex equipment has been lacking in China, manufacturing capability of complex equipment like marine propulsion systems has been a major obstacle for them. Traditionally, China imported diesel engines from the Soviet Union (direct imports, built under licence or reverse-engineered). Other sources of supply have been East Germany, Czechoslovakia, Poland and Yugoslavia (Kirchberger, 2015: 143). Chinese efforts to indigenise these engines have been partly unsuccessful as seen with the engines China supplied to Egypt in 1983-84 that needed major refurbishment after their delivery (Collins and Grubb 2008:34). This has forced China to depend on imported or licence-produced diesel engines mostly supplied by the French SEMT-Pielstick (PA and PC series), MTU Friedrichshafen GmbH, and the German Shaanxi diesel engines. Further, with the Siemens AG office in close physical proximity to the Guangzhou shipyard, a licence agreement production of diesel engines seems to be suggestive. In the slow speed diesel engine segment, Chinese designed engines account for less than one per cent. Gas turbines that are relatively expensive for procurement, maintenance and fuel consumption are a major high-tech area for which the Ukrainian supply is the only viable alternative through imports and licence arrangements. At the moment, only the nuclear propulsion systems aboard Chinese submarines are completely of Chinese origin, which in itself is considered a remarkable achievement (Kirchberger, 2015: 144) but that too has been tainted with crew safety issues (DTE, 2016).

Shipbuilding Yards in China

All this was possible to be achieved by a dedicated focus of the government on the shipbuilding industry that put all the shipyards in China, both state-owned and private, under the control of the Sixth Ministry of Machinery Building and the Ministry of Communication in 1950. In 1982 the China State Shipbuilding Corporation (CSSC) was formed and became responsible for the Chinese shipbuilding industry while the Ministry of Communications retained control of a number of smaller yards producing coastal vessels. In the 1990s due to the size of the shipbuilding industry and China's intent of entering the World Trade Organisation (WTO), the Chinese government initiated further reforms in the shipbuilding sector and the China Shipbuilding Industry Corporation (CSIC) was created in 1999 out of the CSSC as an independent entity.[2] This reorganisation permitted partnerships and joint-ventures with foreign enterprises with an intention of attracting necessary investments and skills from abroad that were considered essential for the progress of the Chinese shipbuilding industry.

The CSIC and the CSSC hold shares in their respective shipyard groups and are not expected to be involved in the daily affairs of these subsidiaries. They are responsible for choosing the leaders of their major shipyards and for reviewing major capital expenditures, such as shipyard expansion and relocation. The CSIC[3], concentrating on commercial vessels greater than 300,000 dwt and naval vessels (mainly submarines), was given the control of the activities of the shipyards in the north and the west of China and the CSSC[4] controlled the shipyards in the east and the south of China concentrating on commercial vessels up to 300,000 dwt and naval surface warships. Though these two complement each other like 'brothers in arms', they aim to create a fair competition among themselves in the domestic and the international market and for access to both domestic and international capital. The CSIC is the larger of the two conglomerates. It designs, manufactures, and sells both military and civil ships, marine engineering and marine equipment. It has ten main product sections: shipbuilding, marine engineering, diesel engines, storage batteries, large steel structure fabrications, port machinery, turbochargers, tobacco machinery, gas meters and automated distribution systems (RAND, 2005: 123). The main products of CSSC include, various categories of commercial ships of up to 300,000 dwt, including special purpose vessels, workboats, and offshore units, many types of naval ships, and marine equipment, such as marine diesel engines, diesel gensets, deck machinery, that produced under licence or co-production agreements with international

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[2] After the division, CSSC had the responsibility of more than 48 industrial enterprises and 28 research institutes while the CSIC controlled a total of 25 big and middle-sized shipyards, 57 maritime supply enterprises, 36 research institutes, three universities and four training centres.

[3] The CSIC is based in Beijing and controls 48 shipyards in the north with a focus on the major ports in Liaoning and Tianjin. Some of the main shipbuilding companies it controls are Dalian Shipyard, Dalian New Shipyard, Qingdao Behai, Liaoning Shipyard and Tianjin Shipbuilding Corporation

[4] The CSSC has headquarters in Shanghai, controls 30 shipyards in the south including those in Anhui, Guangdong, Jiangxi and Shanghai. Some of the main shipbuilding companies it controls are Guangzhou Shipyard, Guangdong Shipping, Jiangnan Shipbuilding, Hudong Shipbuilding, Shanghai Shipyard and Shanghai Global Container.

manufacturers (RAND, 2005: 124). Both these conglomerates are state owned enterprises (SOE) which are supervised by the State Council, a state authorised institution of investment, to combine investment with industry, industry with trade, and research with production.

As seen in Figure 1 (major shipyards indicated in red), the Chinese shipbuilding and ship repair industry comprises yards big and small, coastal and inland, with the shipbuilding and repair activities concentrated primarily in Shanghai, Guangzhou and Dalian. These activities have developed at the mouths of the Yangtze and the Pearl River with some limited development on the eastern coastline between these two rivers and the coastal areas bordering the Bohai Gulf and the mouth of the Yellow river, both in the north. The largest shipbuilding cluster in the country is located in the Yangtze River Delta region and has shipyards in the provinces of Shanghai, Jiangsu, Anhui, and Hubei. The Pearl River is the longest river in South China and is home to shipbuilding facilities around Guangdong, Guangxi, Guizhou and Yunnan provinces. Other than these there are many other shipyards that are not under this conglomerate. These include:

(a) Provincially owned shipyards, which are at least partially owned and operated by the governments of Fujian, Guangzhou, and Jiangsu of which the largest provincial shipbuilding company is the Fujian Shipbuilding Industry Group Corporation (FSGIC).

(b) Shipyards owned by Chinese shipping conglomerates such as the COSCO Shipyard Group, the China's Shipping Industry Company (CIC), the Joint-venture shipyards [namely two Nantong-Kawasaki-COSCO shipyards (Japan), Shanghai Edward Shipyard (Germany), Yantai Raffles shipyard (Singapore), Samsung-Ningbo shipyard (Japan)], and the PLA Navy factories/shipyards [4804, 4805, 4806, 4807, 4810].

(c) There are also a number of smaller shipyards that are owned and operated by municipalities in various provinces.

Government Support

In any development process that encompasses more than one sector in a nation, the role of the government and its support is but natural. Similarly, in the case of China, the development of Chinese shipbuilding towards becoming a world leader in this industry is also an effort where the Chinese government has played a very important role which needs to be discussed in detail.

Through Policy Changes

As discussed earlier, Chinese shipbuilding has seen many major policy changes since 1980 which have resulted in enterprise reforms. Broadly, these reforms can be categorised in four stages (Solinger, 1986; Smyth, et al. 2004) that include:

(a) *The profit-retention reform during 1979-83:* In this period, the enterprises were granted autonomy in decision-making (after meeting the minimum targets of the state) and permitted to retain part of their profits for their own use while the remaining share went to the state authorities.

(b) *The tax-for-profit reform during 1983-86:* During this period all enterprises were made responsible for their own profits and losses that gave them an opportunity to participate in market competitions. However, since the state was collecting taxes and dividends from these enterprises, such a hands-off approach was difficult. Hence an ‘adjustment tax’ (rate negotiated with individual enterprises) was introduced that allowed equal footing to all the enterprises and created a market of competition while ensuring necessary monetary support to and from the government.

(c) *The adoption of the contract management system during 1987-92:* This system aimed to fix a base tax-and-profit for the state and permit the enterprises to keep the remaining share thus creating the separation between ownership and control. Such a system allowed enterprises to expand in good times and look for re-negotiations over profits during bad times which the State found it difficult to check.

(d) *The corporatisation of SOEs after 1992:* This reform centred on ownership and aimed to transform large and medium-sized SOEs into joint stock companies or limited liability companies on a trial basis. A similar exercise for small and medium-sized enterprises was initiated in 1994 to relieve small loss-making firms off their debts and to find new jobs for redundant workers. As a result of these reforms, the SOE share of gross industrial output declined sharply with increased marketization. Not deterred by this decline of gross industrial output, the central government, to develop large and medium-sized SOEs, started to focus on bigger enterprises while letting go of the smaller ones and announced three major policies in 1997. These were:

(i) Develop a number of enterprise groups.
(ii) Develop a modern enterprise system in large-scale SOEs.
(iii) Entrench three to five large firms in the world’s biggest 500.

The rationale behind developing large scale SOEs and enterprise groups was to develop economies of scale and avoid excessive duplication, with economies of scale for shipbuilding being possible through series production. With this restructuring, the government aimed to be able to build larger ships which were not possible till then in China.

In 2006, China identified shipbuilding as a ‘strategic industry’ (as part of the eleventh five year plan[5] of 2006-2010) and introduced a slew of plans for its development. These included a 20-billion Yuan investment in establishing large production bases in Waigaoqiao, Changxing and Longxue. Within a short time span, China’s market share doubled from 25 per cent to 50 per cent due to construction of the new shipyards and the support of hidden government subsidies.

To make the shipbuilding industry a comprehensive and strategic industry to achieve national defence, maritime development, economic development, increased exports, and to relate to other strategic industries such as iron and steel, metallurgy, electronics, petroleum, and manufacturing industry, the State Council passed the *Plan on the Adjustment and Revitalization of the Shipbuilding Industry* on 11 February 2009 (Guo Fa, 2009). The plan emphasised the need to revitalise the shipbuilding industry, mainly towards the following three targets from 2009 to 2011 (Mu Yang and Hong Yu, 2011):

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[5] It was also the first five year plan that referred to the ‘maritime sector’.

(a) Sustaining the declining demand; taking active supporting policies to sustain the existing orders and stabilize new orders, and reduce the risk of companies.
(b) Promoting mergers and acquisitions (M&A) and restructuring; promoting CSSC and CSIC, strengthening large enterprises through value chain integration, and restructuring the business scopes of small and medium-sized enterprises (SMEs) through M&A.
(c) Encouraging indigenous innovation and R&D; expediting the technology assimilation and indigenous innovation process, and dedicating more R&D to infrastructural and high value-added shipbuilding and equipment.

As part of the twelfth five year plan (2011 to 2015), seven key development directions and major tasks were defined. Those related to shipbuilding included; high-end equipment manufacturing industry; the development goal for marine engineering equipment; the development of offshore oil and gas exploration equipment including design and manufacturing of deep-water exploration equipment, drilling equipment, production equipment, and operating and auxiliary ships; industrialization of offshore wind energy equipment, desalination equipment and seawater utilization equipment; and strengthening of international cooperation. This allowed the Chinese marine equipment market to grow rapidly. Many marine equipment industry clusters were formed in Shanghai, Jiangsu, Liaoning, Shandong, Zhejiang and other coastal provinces and cities. Further, the Chinese government announced an intention to infuse US $ 600 billion in strategic sectors. Of this, CSIC and CSSC got US $30 billion as loans from, among others, the Export-Import Bank of China in 2009, which in return got equivalent stake holdings.

In the on-going thirteenth five year plan (2016-20) the government is pushing the state-run and dominated industrial-base to overcome lingering technological shortcomings (Grevatt, 2017). For these advancements to be achieved, several underway and planned major reforms need to be successful. To bridge capability gaps and develop the necessary modern technologies, the focus now is on ‘innovation’. Accordingly, the Chinese government plans to further strengthen the marine economy by optimizing the marine industry structure.

In 2015, China’s State Council unveiled the country’s 10-year national plan, ‘Made in China 2025’ that aims to turn the country into a ‘manufacturing superpower’ over the coming decades through innovative manufacturing technologies (‘smart manufacturing’) (Wübbeke et.al, 2016). The plan emphasizes the importance of developing marine engineering equipment and high-tech ships and aims to become one of the world’s most powerful manufacturing nations by 2025, a mid-ranking position in this system by 2035, and a leading position by 2045/2049. To achieve this, the targets for the Chinese maritime industry are (Tan, 2017):
(a) To raise local content for Offshore Engineering Equipment and High-Tech ships to 40 per cent and 60 per cent respectively by 2020; 50 per cent and 80 per cent respectively by 2025.
(b) The raise the global market share of independent design and construction to 35 per cent and 40 per cent by 2020 and 40 per cent and 50 per cent by 2025 respectively.

(c) To build a complete industry standard system of design, assembly construction, equipment supply and technical service for Offshore Engineering Equipment and High-Tech Ships by 2025.
(d) To have more than five Chinese companies as well-known international manufacturing enterprises with leading design and manufacturing technology in some fields.

Through Financial Reforms

Facing this ambitious industrial policy the Chinese government has over the years put forth a variety of financial measures to support the shipyards. These include:

(a) *Income tax benefits*: If a shipyard has made investments before 2010 in China, they can be exempted from income tax for a maximum of five years after making the investment, on the profit which has been generated by the investment. The tax exemption may, however amount to a maximum of 5 per cent of the effected investment.
(b) *Export tax rebates*: For ships constructed for export the shipyard can assert discounts on export tax.
(c) *Fundraising reforms*: If a ship leasing company order ships for domestic or foreign operators, they will enjoy preferential shipbuilding loan terms, insurance guarantees and a preferential business tax regime from their start. They would be exempt from profit tax for the first five years since their establishment and pay only one per cent of their net income as tax between years six and ten of their operations.
(d) *Fundraising through stock market*: In 1998, nearly 61 per cent of state owned enterprises were in debt. The Chinese government began to encourage the SOE to raise capital from the domestic stock markets through public issues or corporate bond sales to reduce dependence on state funding. This listing of companies on the stock market allowed the SOEs to successfully bid for Western companies of interest without concerns being raised in the West for being fully taken over by state-owned Chinese companies. Such M&A of firmly established businesses permitted further infusion of advanced technologies and managerial knowledge in the Chinese shipbuilding industry. Some successful bids included Chongqing Helicopter's acquisition of the US based Enstrom and the Aviation Industry Corporation of China (AVIC) acquisition of the German aircraft engine manufacturer Thielert in 2013, COSCO Shipping Holdings Co Ltd and Shanghai International Port (Group) Co Ltd acquisition of the Orient Overseas (International) in 2017.
(e) *Stabilisation of material costs*: To ensure that there is a steady supply of shipbuilding quality steel for the industry, the government is supporting the technological modernisation of the Chinese steel companies. Such a modernisation aims to deliver nearly 80 per cent of the steel requirement of the shipbuilding industry.
(f) *Creation of Joint Ventures*: Chinese maritime suppliers were encouraged to create joint-ventures with foreign partners, including setting up of production plants of foreign maritime suppliers in China with up to 100 per cent foreign ownership.
(g) *Incentive to ship owners*: In order to boost the domestic shipbuilding industry, Chinese ship owners building vessels in the domestic shipyards are

subsidized by 17 per cent of the cost of making the ship. On top of that, the construction of large oil tankers is being encouraged with discounted government loans. Such preferential policies ensure that most of the new ships are built at home.

(h) *Fund availability*: The Chinese government provides funds through government agencies, policy banks and various programmes to support the industry and the buyers. Such incentives are focused primarily towards larger entities such as CSIC and CSSC.

(j) *Discouraging foreign imports*: In order to discourage companies from importing ships, the Chinese government maintained a 9 per cent tariff and 17 per cent value added tax on imported ships (Zhang 2002).

(k) *Subsidies*: China provides industry subsidies in the form of free or low-cost loans, as well as subsidies for inputs (including energy), land and technology. These subsidies are often transferred through financial institutions, most of which are provided by the central and provincial governments.

Developments in Science and Technology

The technology is yet another area where the Chinese have focused to ensure development of the shipbuilding industry. The areas of focus have been primarily on; National R&D investments; foreign technologies; and 'soft technologies' such as establishing industry clusters and improving shipyard's operational management (Yu Xie, 2012). Keeping this in mind, the technology development for the Chinese shipbuilding industry was addressed in the following three ways:

(a) *Introducing-Learning-Innovation*. In this method, the technology was introduced (bought) and applied by shipyards directly with learning coming by continual usage. This method was considered a better way for developing technologies in a short time and was seen in the 1950s, when Chinese shipbuilding benefited from the technology and support of the Soviet Union, such as patents, equipment, design, direct capital and financial investments, professionals and skilled workers. With the Soviet support being withdrawn in the 1960s, the Chinese government started looking west for shipbuilding technologies and learnt hull constructing methods from Europe in 1970.

(b) *Cooperation-Learning-Innovation*. This method came into use starting the 1990s, when the Chinese government released restrictions on foreign investments in Chinese shipbuilding. In this method the shipyards made cooperation with foreign companies for learning technologies, and then led to the self-innovation of new technologies. By 2000, cooperating with foreign shipbuilding countries became more and more important in developing shipbuilding technologies. With companies like Samsung Heavy Industry establishing shipyards in China in 1996 for hull section construction (RAND, 2005), Chinese shipbuilding technologies received the required stimulant. Similarly, cooperation with many European countries in producing ship equipment such as engines (based on Rolls-Royce Marine AS) (Rolls Royce Corporation, 2016) and ship electric systems (based on Kongsberg Maritime) enhanced the technologies in these areas helping the Chinese marine associated manufacturers to learn and build their own ship equipment. Further, CSSC organized study-abroad for its designers, invited

foreign experts to lecture in China, and established partnerships with foreign design firms leading to 'development and optimization' of over 500 new designs (RAND, 2005: 131).
(c) *Reverse Engineering*. For Chinese firms, the aim of foreign agreements is to absorb and reverse engineer these technologies and then produce copies under a Chinese label. This approach has had some success that has allowed China to produce marine diesel engines of all sizes, and they are known for their reliability. (RAND, 2005: 132)

Technical cooperation between Chinese yards and foreign shipbuilders provided Chinese shipbuilders with access to R&D techniques, production technologies, and management practices, which have helped to raise the design and production capabilities at various Chinese shipyards. This has helped China to develop organisations that supported the development of science and technology in China that include:
(a) The Marine Design & Research Institute of China (MARIC) is China's oldest and largest shipbuilding R&D institute which is on the cutting edge of all of China's merchant ship designs. Its design facilities are supported by various testing facilities, including a towing tank, an ocean engineering basin, a cavitation tunnel, and a wind tunnel (RAND, 2005: 119).
(b) The Shanghai Ship Design and Research Institute (SDARI) is another ship design organisation under CSSC. (China State Shipbuilding Corporation E-government Website group)It is smaller than MARIC and is viewed as the second best design institute in China. SDARI specializes in developing cargo vessels, engineering ships, harbour boats, and offshore and military support vessels.
(c) Hudong Heavy Machinery is a large diesel-engine manufacturer in China under CSSC. It is part of the Hudong-Zhonghua shipbuilding group that was formed out of the merger of the main engines divisions of the Hudong and Shanghai Shipyards.
(d) The China Ship Research and Development Academy one of the premier organizations involved in commercial and military ship R&D under CSIC.
(e) The Shipbuilding Technology Research Institute (STRI) is an R&D organisation under CSSC.
(f) Guangzhou Marine Engineering Corporation (GUMECO) is a design and scientific research organization under CSSC engaged in naval architecture and marine projects and deal with disciplines such as naval architecture/hull, outfitting, structure, mechanical, power system, auxiliary system, electrical, communication, navigation, weaponry, project management and computers etc. (China State Shipbuilding Corporation E-government Website group).

Technical interactions with foreign shipbuilders have been extensive and have permitted:
(a) China's major ship-design houses and large yards to use computer-aided design and manufacturing (CAD/ CAM) systems.
(b) R&D institutes are able to forge linkages with Chinese universities and improve their cooperation with shipyards in their R&D and production processes.

(c) Increased funding for R&D that have in return assisted national technology research projects, and establishing many new national engineering research centres and laboratories.

Developments in Manufacturing Industry

Starting from a very low point of the technological curve, China has made phenomenal technological progress since 1980 with the three technology development processes discussed in the previous section. In spite of these technological developments, a 2005 RAND study report had indicated that, the qualitative and design capabilities of China have not kept pace with the quantitative progress in commercial shipbuilding with the main problems being quality and delays, thereby indicating a slower than expected rate of development. This view, notwithstanding, let us look at the advancements that have been made in the manufacturing industry of China.

Machinery

Though Chinese shipbuilding companies have remained weak in manufacturing facilities and parts for large ships and have had to rely on importing many of the core facilities, including navigation systems, communications equipment, staterooms, automation facilities, engines and electric power for deep-sea vessels, they still have made a substantial advancement in the field of marine equipment manufacture. These include:

(a) By the late 1980s the major yards of CSSC manufactured a large diversified range of products. These yards in addition to the expected marine-related products, were building equipment such as complete sets of machinery and assembly line equipment, including loading and unloading machinery for coal terminals, generators and blast furnaces, high pressure vessels for various gases and chemicals and heavy duty hydraulic lifts, presses and cranes (Moore 2002: 226).

(b) The Chinese institutes and factories have co-produced numerous models of marine engines and other marine equipment such as diesel engines, gas turbines, and gearboxes through joint production arrangements based on original designs by firms from Germany, Denmark, Switzerland, Austria, Norway, Japanese, French, Swiss[6] and other countries.

(c) China has been able to absorb some key submarine technologies from the Kilo-class vessels purchased from Russia. This expertise was revealed in the production of the new Yuan class submarines which are considered to possess attributes of both the Song- and the Kilo-class submarines, thus indicating the understanding of the technology by the Chinese (RAND, 2005: 148).

(d) China has been producing crankshafts for ships since 2005 (Collins and Grubb, 2008).

[6] The imported technology being provided by companies such as Howaldtswerke-Deutsch Werft AG (Germany), Sulzer (Switzerland), Wartsila (Finland), SEMT France, and Kawasaki Heavy Industries Co. Ltd. (Japan) for marine diesel engines

(e) They have been able to meet close to 90 per cent of the domestic demand for low-speed diesel engines through in-house manufacturing with some units been even exported to Korea (China Report, 2016).

(f) In June 2007, Dalian Diesel Engine Factory joined Korea and Japan in diesel engine manufacturing for large ships by successfully producing 49,680-horsepower diesel engines (SERI, 2007: 11).

(g) In 2015, the output of marine diesel engines in China rose to 16.99 million kilowatts, with the output of low-speed, medium-speed, and high-speed engines accounting for 41.2%, 40.1%, and 18.7%, respectively. The marine diesel engines are mainly produced through patent licensing with the low-speed engines dominated by MAN, Wartsila, and Mitsubishi Heavy Industries; the medium-speed engine by Wartsila, MAN, and Caterpillar; and the high-speed engine brands by MTU, Deutz, MWM, SACM, Pielstick, Ruston, and Paxman[7] (China Report, 2016). However, since many Chinese manufacturers are weak in core technologies, they need to import certain key components from these manufacturers.

Shipbuilding Methods Including Design

Some of the advanced shipbuilding methods that the Chinese shipbuilding industry developed with foreign technology include:

(a) Capability to build large vessels effectively in dry docks.

(b) Ability to develop the advanced hull section construction technology and the hull outfitting technique from Japan and Korea that allowed them to build large ships (over 150,000 DWT) with high efficiency.

(c) Ability to establish mechanization and assembly line works to reduce the shipbuilding time.

(d) With the major ship-design houses and large yards using computer-aided design and manufacturing (CAD/ CAM) systems, China too developed the art of using CAD/CAM for constructing complicated vessels. This knowledge allowed them to accept new building orders for an LNG Carrier at 147,000m^3 and for an FPSO at 300,000 DWT in 2006 (Tian, 2009).

(d) For the design of VLCCs, the Chinese shipyards approached the Japanese and the Korean shipyards for supply of technology, which was refused at all costs. Finally, the Chinese shipyards approached the South Korean research design institute (Korea Marine Technology Consulting Company) that designed the technologies for the South Korean shipbuilding companies and procured the technologies in 1999, just before their first order for VLCCs to Iran was signed (Smyth, et al. 2004).

Shipbuilding Industry Cluster

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[7] In China's low-speed diesel engine market, Hudong Heavy Machinery, Dalian Marine Diesel, and Yichang Marine Diesel Engine accounted for an aggregate market share of roughly 95.9%; in medium-speed diesel engine market, Weichai Heavy Machinery and CSSC Marine Power made up a 58.9% market share; high-speed diesel engine manufacturers mainly include Weichai Heavy Machinery, Shaanxi Diesel Engine Heavy Industry, and Henan Diesel Engine Industry, of which Weichai Heavy Machinery has a market share of around 26%.

A shipbuilding industry needs various industrial supplies such as human resources, land, energy resources and transportation facilities for development. If these resources are co-located then the manufacturing and supply chain management becomes simpler and cheaper. In order to encourage such a cohesive environment, industry clusters need to be created. The Chinese shipbuilding industry realising the importance of such a cluster has relocated the existing associated manufacturers as well as shipyards so developed[8] since 1990.

An example of this cluster is that of Dalian established in 2007 that consisted of the Dalian Shipbuilding Heavy Industry at the first-level, supported by three associated manufacturers (Dalian Maritime Diesel Engine Company, the Dalian Maritime Propeller Company and Dalian Maritime Valve Company) in the second-level and another 120 sub-factories, 37 ship repair yards and 15 maritime logistics companies supplying to the second-level manufacturers. Similarly the Jiangnan shipyard Group has been relocated to Changxing Island along with a whole new shipbuilding base in 2009.

Developments in Innovation

As part of innovation and the possibility of using their existing civilian fleet as a defence platform, the Chinese have undertaken some major innovations. These include:

(a) Draft plans to refit merchant ships to transport military troops and supplies, carry out maintenance, provide medical care, and assist with shore-bombardment, anti-submarine and air-defence operations.

(b) Converted a Ro-Ro cargo ship into China's first 'defence mobilization vessel' to perform functions such as navigation, helicopter training, and defence-mobilization drills. This ship could be further used as a 'floating hospital' and to carry resupply containers in support of long-range naval operations (Wanjun and Guofang, 1997).[9]

(c) China's air-cushion/hydrofoil boats, which are commonly used as passenger ferries on the Yellow River, have also been utilized by the PLAN as troop-transport vessels, during the military exercises of March 1996 (RAND, 2005: 179).

Limitations of Chinese Shipbuilding Industry

Despite the consistent improvements in the Chinese shipyards over the past 25 years, which made it the leading shipbuilder in the world in 2010, these shipyards still suffer from financial, technological, and managerial problems. There is poor cost control; production still uses out-dated and inefficient equipment and technologies, and there is poor control of the process. Some of the issues that plague the Chinese shipbuilding industry are:

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[8] About 252 new marine associated manufacturers were established up to 2006.

[9] The CSSC and the PLA Navy jointly modified the vessels with a naval inspector on-site at the Quixin Shipyard during construction.

***Technological*:** The following technological issues mar the making of China as a powerful shipbuilding nation.

(a) The advanced shipbuilding technologies that helped the Chinese shipbuilding industry to become powerful in the world market in the 2000s are not available in all shipyards. Small and mid-sized shipyards still continue to struggle to get these technologies due to insufficient financial resources (Zong, 2016). So as a nation, Chinese shipbuilding still remains weaker than that of Japan and Korea.

(b) The Chinese ship design is weak in designing advanced ships. Shipyards still lack core technologies in designing ships such as LNG and drilling vessels [Yu Xie, 2006].

(c) Though China's shipbuilding steel industry is strong, it is not able to produce specialised steel for vessels such as LNG, needing imports.

(d) The cluster support from the ancillary industry is still being developed and at times a major chunk of the specialised equipment need to be imported as there are no suppliers in the country (Jiang, 2012: 12; Tsai, 2011: 53).

(e) Though the research and development is being progressed in the country, it is limited to certain pockets and not available to small and mid-sized shipyards.

(f) Use of information technology (IT) is limited, though computers have been put to use for design and building processes. IT for activities such as online parts purchasing, service information and facilities that can run on an automated, 'intelligent' and digital basis still need to be put in place (Jingyun et. al., 2001).

(g) More than adequate R&D investment funding but plagued with corruption has put Chinese ship producers well below the level of advanced nations in technology (Guilford, 2014).

(h) Some ship parts designed by Chinese companies are substandard in quality and can be used only for small domestic ships (Knodell, 2016).

***Financial*:** As wages and the cost of equipment rises (Xi, 2012: 55), there is a need for better financial prudence. Financial issues that affect the Chinese shipbuilding are:

(a) China has reached a stage of over-capacity in its shipyards which means that nearly one-third to one-half of the yards will have to merge or close due to non-availability of funds to pay workers, buy raw materials, and provide financing for clients. To support their conglomerates, the Chinese government is undertaking major consolidations in both CSSC and CSIC (Bloomberg, 2018), along with relocation of longer-established yards to modern, larger capacity, newly developed shipyards (WMN, 2013). The goal of the consolidation is to be able to move up the complexity chain and challenge South Korea and Japan by building high-value, complex ships such as LNG tankers. In some cases, older shipyards of CSSC and CSIC have merged and integrated with the government ensuring orders through military workloads.[10]

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[10] The group is able to design and build many different types of naval ships, including submarines, missile destroyers, and fleet replenishment vessels.

(b) With the majority of the Chinese shipyards focusing on bulkers, and with the world market of bulkers being slow, most of the shipyards in China have to restart their learning due to limited diversification and innovations within.
(c) The Chinese innovation in shipbuilding has been limited to 'copying' at times, which has not permitted them to learn, research and invent for new ships, leading to import, rather than become technologically independent leading to higher cost of construction when compared to similar platforms made by Korea and Japan (König et.al., 2018).
(d) Due to high content of imported items both construction cost and time are high for Chinese platforms.
(e) Even though the shipyards have done significant cost reductions to get orders, the customers have been careful in placing orders based on the financial status of the shipyards and their track record of quality construction, creating further financial problems for the existing shipyards leading to the likelihood of closures.
(f) Shipyards lack detailed accounting procedures as they do not engage in detailed financial accounting. They then have difficulty in tracking costs and taking corrective steps to reduce unnecessary expenditures.

Managerial: The managerial problems that plague Chinese shipyards are:
(a) Production management and quality control are below the levels found in Korea and Japan (Samsung, 2007) which leads to prolonged construction periods and delayed delivery, thereby hurting their reliability.
(b) The cheap labour pool of China, which propelled her rise in the world of shipbuilding will not remain cheap for long, due to increasing expectations, and hence such increasing costs have to be catered for (OECD, 2008).
(c) With IT use being limited, the shipbuilder is losing on the benefits that can be acquired from modern project scheduling and monitoring systems and automatic purchase and delivery procedures (Jia and Jinke, 2007).
(d) Lack of continual training and education disallows raising the construction standard of the industry and its competitiveness (Jia and Jinke, 2007).
(e) The shipbuilding industry has been tasked with some non-shipbuilding related activities such as running of school, bus services etc. which are eating into their resources and effort which could be better utilised elsewhere (Smyth et. al., 2004, p.124).
(f) Lower output from the available workforce, which has been estimated to be 1/6th to 1/4th of that of Japan and Korea (Tsai, 2011, p.50; OECD, 2008, p. 15).

Analysis / Lessons Learnt

One has to understand that neither the economies nor the state of industrialisation and policies of any two countries are the same. It is primarily because of this that what works for one country may or may not be effective for another. Hence, blindly trying to copy a model of success, for prosperity of the nation, may or may not reap the desired results for another country. This is substantiated by the fact that even though China followed the government funding policies like that in South Korea, the Chinese concept of shipbuilding was very different from the South Korean concept of shipbuilding as the South Korean shipbuilding was export oriented while the Chinese was focused towards self-sustainment. These different approaches were based on the respective country's economic considerations, which supports the thinking of 'different rules for different people'.

From the foregoing discussion on Chinese shipbuilding, one may argue that China is more of a fabricator and still has miles to go to become a complete shipbuilder. Though this argument holds water, one must not overlook the fact that in spite of being only a fabricator, it still controls the shipbuilding industry as on date. In most cases, new vessel designs are being handed over to the Chinese shipbuilders for manufacture, which is in effect honing their skills and providing them with new designs for free.

Further, with the right support and incentives from the government, it is only a matter of time before the Chinese shipbuilding becomes entirely self-reliant and achieves the goal of being a 'complete' shipbuilder rather than being just a fabricator. In the mind of the authors there is no doubt that this is surely possible for China, as has been shown by them in achieving their laid out targets well in advance. The present initiative of 'Make in China 2025' will change the way things are today for the Chinese shipbuilding. This essentially means that there are some key takeaways for nations and governments that aspire to achieve a prosperous nation through shipbuilding. These are:

(a) Government involvement through handholding, policies, incentives, subsidies, developing ancillary industries, and creating a conducive business environment are essential to achieve this goal. Though increasing government subsidies may lead to high debts, but a calculated risk needs to be taken to weigh growth and debts.

(b) A certain sense of 'dictatorship' to ensure success of 'Made in the country' may be required. The essence of the thought here is not to brand the Chinese system as 'dictatorial' but to indicate that the government of the country needs to mean business and ensure that the timelines are adhered to so as to achieve self-reliance and accountability.

(c) Since the government cannot actually get into the day to day running of an industry, an umbrella authority that can guide and interface with the outside world while supporting the industry is essential. This authority needs to be answerable and accountable both to the government and the industry.

(d) Foreign collaborations where essential need to be arranged by the authority rather than the government.

(e) Since information technology is the future to stay, it should be made the start point of new endeavours and upgrades to existing industries necessarily need to be provided.

(f) Economy of scales has to be encouraged within the country to support the development of ancillary industries.

(g) Though the transfer of technology, joint ventures, foreign collaborations may be good for the development of technology in the country, they cannot make a nation 'great'. For achieving greatness, R&D within the country is a must which needs the involvement of universities, academia, industry houses and the research organisations. This R&D needs to be time bound and necessarily accountable.

(h) To increase productivity, if the need exists the working organization should be reorganized along with the wage structures which should be performance based rather than be uniform.

Conclusion

In the current essay we have seen the developments in governance, science and technology, and innovation that have spurred China to the top position as a shipbuilder in the world. Though China has made phenomenal progress, there are miles to go before they can really command the global shipbuilding market. In effect the development and prosperity of China due to shipbuilding are a work in progress. This, notwithstanding, we have also seen some lessons which the world can draw from the efforts of China if they wish to use shipbuilding for prosperity and development of their own country. In the words of Bao Zhangjiang, director of the China Shipbuilding Industry Research Centre, for China, '*… to move from a shipbuilding country to shipbuilding power*,' it has to focus on quality above quantity (Rajan, 2013).

The results of China's initiatives such as 'Made in China 2025' and its Science and Technology policy duly supported by adequate funding are helping the growth of technology in the country. Since, shipbuilding is an agglomerator, it is only time before these newer technologies will make their way into the shipbuilding industry. But for the time being, what is important to see is if China can emerge from its branding of 'copying' and 'reverse engineering' and deliver technological innovations of its own.

It is certain that China will not remain a shipbuilding leader for perpetuity and her decline is inevitable, but what will be of consequence is the duration of its leadership and the technological changes it will be able to infuse in the shipbuilding industry for other to follow. For the present, China is an icon for other nations to learn from, and imbibe in their system, if they want to develop their shipbuilding and eventually prosperity for their nation.

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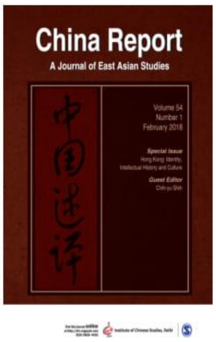

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