Joint Project between GVCC and KIET

Chapter 4: Korea and the Shipbuilding Global Value Chain

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Chapter 4. Korea and the Shipbuilding Global Value Chain[1]

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Acronyms

AHTS	Anchor Handling Tug Supply
ANSI	American National Standards Institute
API	American Petroleum Institute
ASEAN	Association of Southeast Asian Nations
ASME	American Society of Mechanical Engineers
AWS	American Welding Society
B2B	Business to Business
CGT	Compensated Gross Tonnage
COGS	Cost of Goods Sold
DAB	Design and Build
DGPS	Differential Global Positioning System
DP	Dynamic Positioning
DSV	Dive Support Vessel
DWT	Dead Weight Tonnage
EPC	Engineering, Procurement and Construction
ERRV	Emergency Response and Rescue Vessel
ESWBS	Expanded Ship Work Breakdown Structure
EU	European Union
FLNG	Floating LNG Liquefaction Plant
FPSO	Floating Production, Storage and Offloading Vessel
FPSS	Floating Production Semi-Submersible
FPSU	Floating Production and Storage Unit
FPU	Floating Production (or Point) Unit
FSO	Floating Storage and Offloading Vessel (no production plant)
FSRU	Floating Storage and Regasification Unit
FTA	Free Trade Agreement
GT	Gross Ton/Gross Tonnage
GVC	Global Value Chain
HS	Harmonized System
HVAC	Heating, Ventilation and Air Conditioning
IACS	International Association of Classification Societies
ILS	Integrated Logistical Support
IMO	International Maritime Organization
IRM	Inspection, Repair & Maintenance
ISS	In-Service Support
KSE	Korea Stock Exchange
LGC	Large Gas Carrier
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LPH	Landing platform helicopter

LR2	Long Range 2
LSF	Landing ship fast
LST	Landing ship tanker
MGC	Medium Gas Carrier
MNC	Multinational Corporation
MODU	Mobile Offshore Drilling Unit (drillships)
MPSV	Multi-Purpose Support Vessel
MR	Medium Range
MSV	Multi-Support Vessel
NPD	New Product Development
OBO	Ore-bulk-oil
ODM	Original Design Manufacturer
OEM	Original Equipment Manufacturer
OSV	Offshore Support Vessel
PSV	Platform Supply Vessel
R&D	Research and Development
RoRo	Roll-on/Roll-off
SBSR	Shipbuilding and Ship Repair
SGC	Small Gas Carrier
SOLAS	International Convention for the Safety of Life at Sea
SPAR	Single Point Anchor Reservoir
STEM	Science, Technology, Engineering and Mathematics
SURF	Subsea, Umbilicals, Risers, Flowlines vessels
TEU	Twenty-foot Equivalent Unit
TLP	Tension Leg Platform
ULCC	Ultra Large Crude Carrier
US	United States
VLCC	Very Large Crude Carrier
VLGC	Very Large Gas Carrier
WTIV	Wind Turbine Installation Vessel

4. Korea and the Shipbuilding Global Value Chain

Shipbuilding in Korea has been a lynchpin of industrial development, national security, and source of employment and foreign exchange for the country since the 1970s. From relatively humble beginnings in 1972, when Korean national economic development plans identified shipbuilding as a key industrial sector for development, the big three Korean shipbuilding firms, Hyundai Heavy Industries, Samsung, and Daewoo have become dominant firms in the global shipbuilding industry, producing sophisticated commercial vessels for customers around the world. Today, the shipbuilding industry contributes about 2% to Korea's GDP (OECD 2015), directly employs approximately 200,000 workers, particularly in rural areas, and makes up between 7-8% of total exports (KOMEA 2016). Shipbuilding is routinely among the top three most valuable Korean export industries, competing with automobiles and electronics for the top spot (KOMEA 2016).

However, key market and competitive trends are affecting this important industry for Korea. China has emerged as an important producer of commercial vessels and is rapidly increasing its capability to produce large and sophisticated ships. China's global market share of commercial shipbuilding has grown from about 15% in 2006 to more than 35% in 2015 (IHS 2009-2016) and is increasingly entering the "very large" category of some commercial vessel types (i.e., containers and oil carriers) that have historically been the purview of Korean shipbuilders. As a result, Korean shipbuilders must remain at the forefront of technology development and production methods to ensure they remain the most competitive shipbuilder in higher value ship categories, like gas carriers, oil tankers, and the very large container ships they have traditionally dominated, while at the same time investing in ice-classed and oil-extraction related production vessels to diversify their product portfolio.

Increased competition from China is happening at a time of global shipbuilding overcapacity resulting from the aftereffects of the global financial crisis. Reductions in new orders have led to intense global competition, resulting in lower prices. While there are emerging signs of recovery, thanks to improved economic conditions and the need to comply with environmental regulations, shipbuilders across the world have shuttered docks and closed shipyards to reduce overcapacity. This has exacerbated the shift from higher cost shipyards to lower cost shipyards historically serving as periodic inflection points in the industry. For Korean shipbuilders to remain globally competitive, and not see their industry leadership fade as Japanese, European and American ones before them, the country has focused on production technology to increase productivity, emphasized ship component technology development and trade, and has continued to invest in workforce development in the shipbuilding industry. As it moves forward, in addition to product and process upgrading, Korean shipbuilders may also need to pay more attention to financialization and other business model changes occurring in the industry. In particular, servicificaiton of the chain, through ship financing and leasing may become increasingly important competitive factors in the industry.

In the upcoming sections, we investigate the shipbuilding value chain and Korea's position in the regional and global industry. In section 2, we expand on the market and competitiveness issues faced by the global industry, map the value chain, identify leading shipbuilders and component firms, discuss important standards and institutions in the value chain, and identify skill requirements and upgrading trajectories. In section 3, we turn our attention to discussing how different countries in the region have developed unique niches in the shipbuilding value chain. This is followed by section 4, in which we focus on Korea's position in the chain and suggest approaches to industry upgrading. One important lesson about Korea's shipbuilding industry is that it is well-positioned in the industry to remain globally competitive in certain final product categories and component parts; in many ways, the industry remains the envy of many of its competitors in other countries. However, the changing dynamics of the chain could very possibly affect the ability of its builders to remain attractive to customers and retain its global leadership.

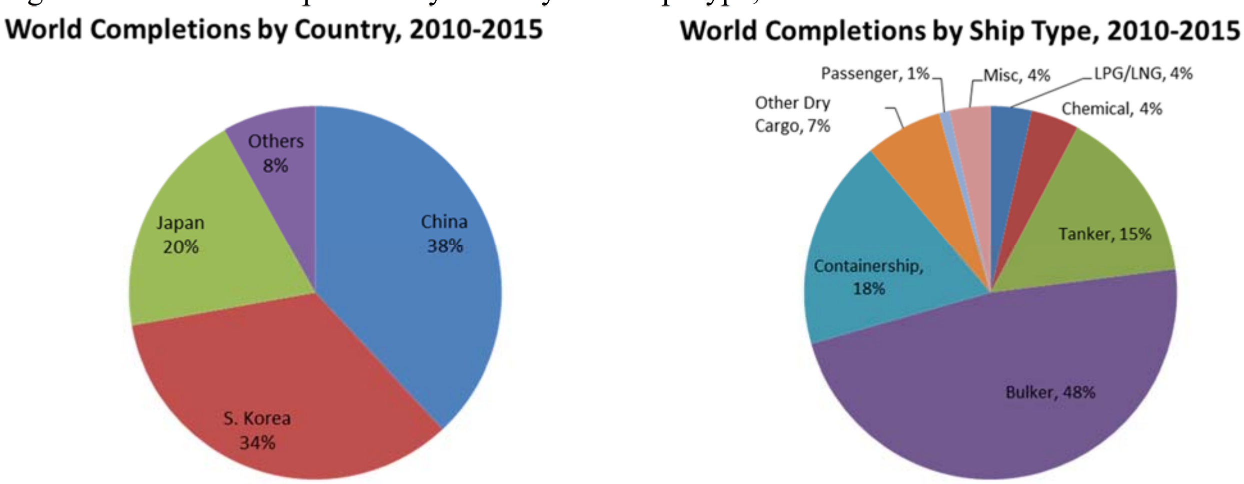
This chapter analyzes commercial shipbuilding and the role of Korea in the industry. The chapter is structured as follows: First, it analyzes the shipbuilding value chain, including an extended discussion on market and competitiveness issues in the shipbuilding industry, followed by a description of the key segments of the chain, the countries that participate in each, and how key stakeholders in the chain interact. It then offers a focused discussion of the role of China, Japan, and Korea in the industry and concludes with an assessment of the industry in Korea.

4.1. The Shipbuilding Global Value Chain

4.1.1. Introduction

In the 20th century, shipbuilding was dominated by European nations and the US until the mid-1960s, when Japan became the premier shipbuilding nation, followed by Korea in 1999, and China in 2010 (Stopford, 2015). Today, commercial shipbuilding – the construction of seaborne vessels with the primary purpose of moving large quantities of goods, commodities, or people – is controlled by these three East Asian countries each completing about a third of the global commercial shipbuilding market, for a combined 90% of global commercial ship production (based on gross tons) (Figure 4-1). This report is primarily about commercial shipbuilding, which is distinct from naval shipbuilding, used for national defense and other sovereign purposes, and recreational vessels, which are ships used for personal use.

Figure 4-1. World Completions by Country and Ship Type, 2010-2015



Note: Completions measured as percent of global gross tonnage. Ship coverage is 100GT or over.
Source: Authors, calculated from (IHS, 2009-2016)

Commercial shipbuilding is comprised of several vessel categories. Most production (80% based on GTs) occurs in three types of vessels: containerships, oil (crude) tankers, and dry bulkers. Containerships, making up about 18% of annual commercial ship production, are vessels optimized to carry containers (called TEUs, for Twenty-foot Equivalent Units) that hold components and final goods used in international commerce and production. Crude tankers, making up about 15%, carry crude oil from global production sites to national and regional refinery sites. Dry bulkers, making up approximately 48%, are designed to transport unpackaged bulk cargo, such as grains, coal, ore, and cement in large cargo holds. The balance of production (20%) within the commercial shipping category are general cargo ships used to transport refrigerated goods ("reefers") and cars ("RoRos"), gas tankers carrying compressed gasses (LPG/LNG carriers) used for energy production, passenger and fishing vessels, and "offshore" vessels used primarily to support oil extraction and undersea construction.

4.1.2. Market and Competitiveness Issues

Five major trends shape the current commercial shipbuilding market. They are:

- overcapacity and declining prices
- lower order volumes and changing product mix
- financing new orders
- changing ship design and environmental regulations.
- production technologies.

Overcapacity and declining prices: Overcapacity is a major trend affecting prices and profits in the shipbuilding industry. Persistent overcapacity, in two (container and dry bulk) of the three major market segments is the result of a related stream of events including reduced transportation prices, reduced profits for shippers, cancelled ship orders, increased idling and demolition of existing ships, and market consolidation among shippers occurring as the result of the 2008 global financial crisis.

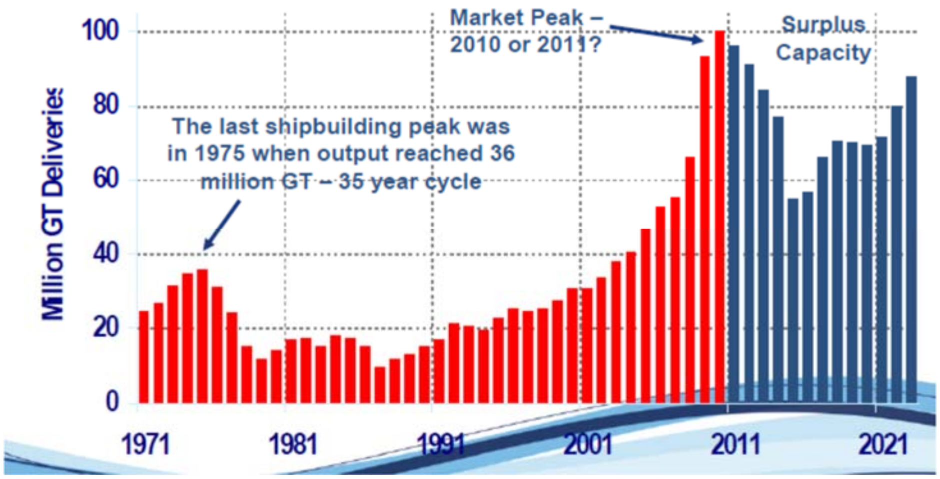
The global shipyard capacity utilization rate in 2016 is estimated at approximately 78%, down from 92% in 2008 (DSF, 2016). Of the three major shipbuilding countries, China utilized 68%, Japan 83%, and Korea 94%, of its shipyards in 2016. Major shipbuilders around the world are reducing the number of active yards through complete shutdowns and bankruptcies. The number of active yards is predicted to decline to 260 in 2017, down from 1,130 in 2010 and 780 in 2015. Newbuild prices for all major vessel categories have declined by at least 25% since their highs in 2009 (DSF, 2016).[2]

A major cause of overcapacity in the shipbuilding industry is weak demand for shipping and the existing stock of relatively young vessels in the three major shipbuilding market segments. As shipping demand declines, freight rates drop, ship prices decrease, newbuild demand decreases, demolitions increase, leading to an eventual recovery in freight rates and newbuild demand

[2] Newbuild and secondhand prices for major vessel categories are provided by DSF (2016). Newbuild prices in 2015 declined by 2% for containerships, crude carriers, and gas carriers; 11% for bulk carriers.

(OECD, 2015a). These long-term market cycles may be 30-40 years, with the current period indicative of a cycle which saw its last 2011 peak in 1975 (see figure below).

Figure 4-2. Cyclical Demand in the Shipbuilding Sector



Source: *World Shipbuilding Scenario* from Clarksons (2013)

Reduced prices for transportation services have led to container and dry bulk shippers operating at or below operating costs, creating ripple effects throughout the shipbuilding market. Shippers have responded to excess supply by reducing demand (or cancelling orders) for newbuilds, and increasing the demolition rate of older ships. Increased demolition rates in containerships removed 201,000 TEUs of older ships from the global fleet (BRSGroup, 2016), but still only accounted for 12% of newbuild deliveries over the same period, exacerbating overcapacity. In the dry bulk segment, scrapping accounted for almost three-fourths of global scrapping activity, reducing fleet growth to its lowest level in 15 years (Clarksons, 2016; UNCTAD, 2016b). Idling ships has also been used in the bulk market, accounting for a reduction of 5 million DWT (DSF, 2016; UNCTAD, 2016b). However, these responses were still unable to balance supply and demand and return the container and dry bulk shipping sectors to profitability.[3]

To increase profitability, market consolidation among shippers has occurred. Japan's three biggest shippers, Nippon Yusen KK, Mitsui OSK Lines, and Kawasaki Kisen Kaisha, announced a merger in November 2016 as a way to remain competitive and avoid bankruptcy.[4] Additional consolidation among shippers is ongoing, both in Asia and Europe (Park, 2017). Insolvencies and liquidations among shipping companies, including those of Hanjin Shipping in August 2016, has led to greater concentration in the market, reducing the ability of smaller companies to operate, and which may result in an oligopolistic market (UNCTAD, 2016b). Strategic partnerships have also occurred, with shipping alliances developing in both the container and dry bulk markets to coordinate chartering and transportation services. Capesize Chartering, for example, originated in the bulk carrier market during 2015 to share information and optimize fleet costs (Alix Partners, 2016; UNCTAD, 2016b).

[3] Information about profitability levels across major market segments is provided in (DSF, 2016).
[4] Nippon Yusen president Tadaaki Naito stated "the aim of becoming one this time is so none of us become zero" as reported in (Chandran, 2016).

In addition to the cyclical decline in demand, there are structural and non-market causes for overcapacity in shipbuilding. Among structural causes of overcapacity are factors common in capital-intensive industries with long investment horizons. These include the long delivery times of vessels (approximately two years), long lead times in adding or reducing shipyard capacity, and push from buyers to add shipbuilding capacity during periods of tight capacity. Non-market factors causing overcapacity in the shipbuilding sector include strategic capacity expansions by incumbents to discourage new entrants, industrial policies favoring new capacity investment or limiting restructuring, and protectionist policies, including cabotage polices. In the current period, policies providing government financial support for maintaining capacity, including production subsidies, capital participation, tax benefits, and lax regulations on the use of lands and facilities are limiting the elimination of shipyard overcapacity (OECD, 2015a). Overcapacity in the shipbuilding and shipping industry will exist for the foreseeable future (Clarksons, 2013; DSF, 2016; UNCTAD, 2016b), recovering only as existing in-service vessels are scrapped or retired after an average of 23 years of service (OECD, 2015a).

<u>Lower volumes and changing product mix:</u> Future vessel requirement estimates by OECD indicate that the major shipbuilding sectors – tankers, bulkers, and containers – will not return to levels seen in the last decade until the 2030's, if at all. Tanker completion volumes of those seen in 2008 (20 million GT) are not expected to return until 2028. Bulker deliveries peaked at 50 million GT in 2011, and are not expected to return through the predictable future (2035). The high containership volumes of 2008 and 2014 (approximately 15 million GT) are not expected to return until 2033. While reduced vessel requirements are partly the result of the existing inventory of vessels discussed above, more persistent changes are expected with longer-term trends reducing the linkage between GDP and trade growth (UNCTAD, 2016b). These trends include demographic shifts, shortened GVCs, and IT-related efficiency and productivity gains occurring as the result of Industry 4.0 technologies which could signal structural changes in the demand for shipborne transportation (DSF, 2016; UNCTAD, 2016b). These changes will impact the product mix; although the majority of production in commercial shipbuilding has been in bulkers and oil tankers, growth will likely be in LNG/LPG gas carriers, RoRos and ferries, and the offshore market (Kent, 2016).[5] Although participation in the offshore market involves large risks (OECD, 2015a), it is an increasingly large share of shipyard production, and is composed of vessels that tend to have higher unit values.

<u>Financing new orders:</u> Access to finance has been a limiting factor in the shipbuilding industry since the 2008 economic crisis when Western commercial banks reduced their exposure to shipbuilding finance (Albertijn et al., 2011; Liu, 2016). This was in part due to capital requirements under the Basel III Accords (Liu, 2016) which introduced new banking regulations to enhance the sector's ability to absorb financial and economic shocks (BIS, n.d.). Stepping into the breach have been Asian lenders, typically with state-backed funds (Aw et al., 2016; Liu, 2016) and shipbuilders seeking to secure orders in a buyer's market (DSF, 2016). Shipbuilders have provided generous payment terms to potential shipowners to maintain their orderbooks and shipyard activity. New terms reduce payments from the traditional 20% payments over five years to four 10% payments and one 60% payment at the end of five years, resulting in a "heavy tail" for ship finance (Hyun, 2013). However, these payment and financing arrangements have affected shipbuilders' profitability. Shipyards with limited ability to provide financing options,

[5] The fleet age for RoRos is higher than other product categories, with about half older than 20 years (p. 18).

particularly refund guarantees and export credit guarantees, are at a disadvantage when compared to large, state-affiliated shipyards with better financing options.[6] Nevertheless, even shipyards in countries traditionally providing state-backing are experiencing financial challenges in the current environment. In Korea, the "big three" shipyards - Samsung Heavy Industries (SHI), Hyundai Heavy Industries (HHI), Daewoo Shipbuilding and Marine Engineering (DSME) - and STX Offshore & Shipbuilding all announced the need to restructure. In China, five shipyard bankruptcies were announced in 2016 with a sixth restructuring (Kent, 2016).

Changing ship design to increase efficiency and comply with environmental regulations: Ships have become larger, more fuel efficient, and compliant with stricter environmental standards since the early 2000s. Larger vessels have become attractive to shipowners because they can achieve economies of scale in transportation, which have been made possible by the physical expansion of the Panama Canal and Suez Canal. Ship designers have also increasingly focused on fuel efficiency as an important factor affecting profitability, as ship fuel costs ("bunker prices") have become an increasingly large portion of operating costs, especially before the rapid decline in bunker costs from 2014 to the current period. As a result, vessels in the global fleet have become more fuel efficient, while the use of alternative fuels, especially LNG, to power ships may also become increasingly common.[7]

Finally, the implementation of environmental regulations has affected shipbuilders. Most notable of these is the ballast water convention (2004 International Convention for the Control and Management of Ships' Ballast Water and Sediments) requiring the bilge to be free from fouling organisms by September 2017, and the International Maritime Organization's (IMO) adoption of enhanced environmental regulations, including reductions in the emission of air pollutants from ships. Marine pollution ("MARPOL") conventions, including the Energy Efficiency Design Index (EEDI), require reductions in carbon dioxide (CO_2) emissions. Specifically, the EEDI requires stepwise reductions in CO_2 emissions from 2000 levels, including 10% in 2015, 20% in 2020 and 30% in 2025.[8] Conventions under MARPOL Annex VI also establish emission control areas (ECAs) for sulphur oxide and nitrogen oxide emissions in specific geographic areas.[9]

Construction Technologies: since the 1980s modular approach to shipbuilding ("block construction") developed in Asia. In modular shipbuilding, pieces of the hull of up to 300 tons are separately built and assembled in blocks on land before assembled in docks, dramatically increasing efficiency and reducing the costs of shipbuilding. Korean firms, like HHI and SHI, rose to prominence by building large shipyards capable of block construction and vertically integrating the steps of the shipbuilding process, including the integration of major systems. Today, the efficiency of the block construction method has been enhanced by automated welding. Large ship blocks are quickly constructed by programmable robots made by ABB and

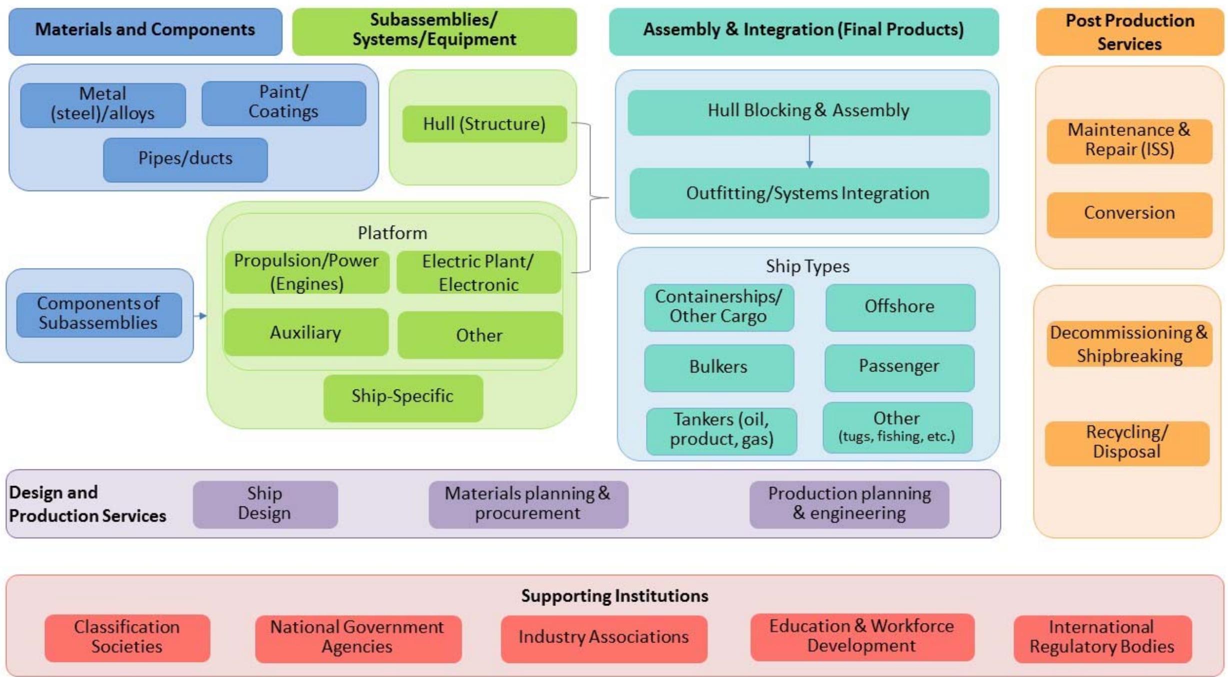
[6] Refund guarantees provide for a return of pre-delivery payments made by the shipowner to the shipbuilder, typically as security against the insolvency of the shipbuilder (Heward, 2010). Export credit guarantees, typically provided by governments or quasi-governmental entities, ensure that an exporter receives payment for goods shipped overseas in the event the customer defaults, reducing the risk to the exporter's business (Davis, 2012).
[7] See www.marineinsight.com/future-shipping/shipbuilding-technologies
[8] The Ship Energy Efficiency Management Plan (SEEMP) is a complimentary convention regarding the energy efficient operation of ships.
[9] For more information, see www.imo.org/en/MediaCentre/hottopics/ghg/Pages/default.aspx

Inrotech, among others. SHI's [Geoje shipyard] in Korea is particularly well known for achieving efficiency gains in shipbuilding due to its adoption of these welding robots.[10]

4.1.3. Mapping the Shipbuilding Global Value Chain

Modern shipbuilding involves multiple actors to design, construct and maintain a ship. Figure 4-3 illustrates the complex set of design, production, and post-production activities involving multiple actors across the shipbuilding value chain. The purpose of this section is to illustrate the shipbuilding process using the value chain as an orienting framework.

Figure 4-3. Shipbuilding Global Value Chain



Source: Authors

The shipbuilding value chain is comprised of three major phases: pre-production, production, and post-production. The *pre-production* phase of shipbuilding includes the phases of design and project management. The *production* phase includes hull construction and equipment/systems purchasing and integration. Hull construction components and activities are those required to build the structure of the ship. All ships require these systems, however their relative importance varies by ship type. *Platform or standard* systems/equipment account for a similar share of equipment purchases on most types of ships. *Ship-specific* systems are those needed to make the vessel perform the tasks for which it is designed and account for a larger share of total equipment purchases Finally, *post-production* activities include in-service support (ISS) of the vessel after its final construction, customer support. ISS may be comprised of repair, conversion and maintenance activities. As a ship reaches the end of its service life, which for commercial vessels

[10] See for example, www.kranendonk.com/shipbuilding/double-hull-welding-line

is about 25 years, they are disassembled ("ship breaking") and recycling/disposal occurs. Next each major segment is described in turn.

Design: The major design phases, comprising of concept, preliminary, contract, and detailed designs, have different objectives and may be conducted by different firms. In the *concept phase*, the design process begins with a decision, usually by the ship owner, about the mission requirements of the vessel. A ship architect can then begin the process of defining the parameters and features of the ship. In the *preliminary design phase*, major equipment needs are determined, and the general arrangement of the hull and equipment is made. In the *contract design phase*, specification of the hull form is conducted and initial selection of systems and major equipment suppliers is made. In the *detailed design phase*, the goal is to design the construction of the vessel. This design phase includes designing the details of compartment arrangements, specifications of equipment integration, shock specification and maintainability. For some vessels,[11] a full engineering analysis may be conducted, including analysis of the ship's structure, noise and vibration, weight and stability. This phase also covers construction standards, including how factory automation, cutting of parts in the factory, and data management will be conducted in a specific shipyard as part of the construction (or "build") design.

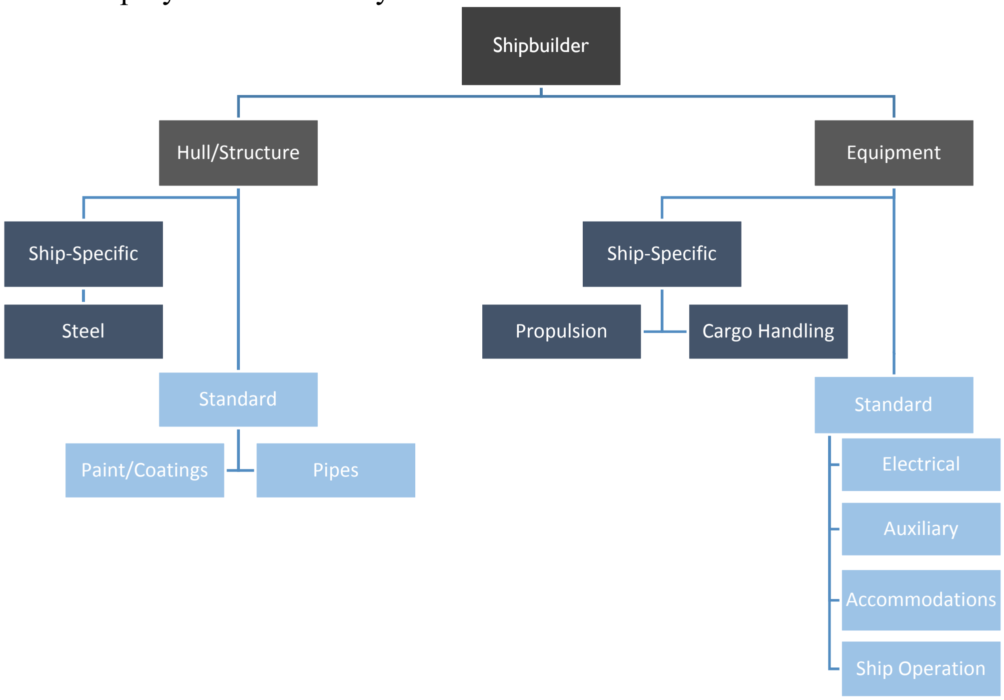
Component production and subsystems assembly: The main systems and subsystems for a ship are illustrated in Figure 4-4. The three main categories are:[12]

- **Hull**: Hulls are built in sections called blocks, primarily from steel. Hull fabrication is a labor-intensive process involving welding. Steel plates are cleaned, straightened, shaped, and cut by specialized plate-burning machines to build the ship's outer surface, or "skin". The framework, to which the skin is attached, consists of the ship's structural components, specifically the keel, girders, frames and beams.
- **Standard/Platform Systems**: These, for the most part, will be found on all ships. They are labeled here as 'standard' because they account for a lower, more stable share of equipment purchases across ship types. These include ship operation, basic accommodations, electrical systems/plant and electronic navigational and communication systems, and auxiliary systems, notably HVAC and environmental pollution control.
- **Ship-Specific Systems:** These depend on the intended use and purpose of the vessel. In large commercial carriers, the propulsion system is the most important, because the purpose of the ship is to move as quickly and efficiently as possible for long distances. Alternatively, cargo handling equipment is more important on offshore production and drilling vessels as these primarily remain stationary. Accommodations (e.g. furniture) are more important in cruise ships and passenger vessels (Brodda, 2014). For research/survey vessels, advanced sensing, navigation and communication technologies are needed (e.g. radar apparatus, radio navigational aid devices, and radio remote control apparatus).

[11] Military and passenger ships in particular.

[12] Additional information on each of the assemblies and subassemblies may be found in Gereffi et al. (2013). An alternative categorization is offered in (EC, 2014). It divides materials, major systems and services into three segments: 1) external services and contractors; 2) materials (steel, pipes, ducts, paint/coatings); and 3) ship operation systems, cargo handling and processing equipment, accommodation systems/equipment, propulsion/power generation systems, auxiliary systems, electrical plants and electronic systems.

Figure 4-4. Ship Systems and Subsystems

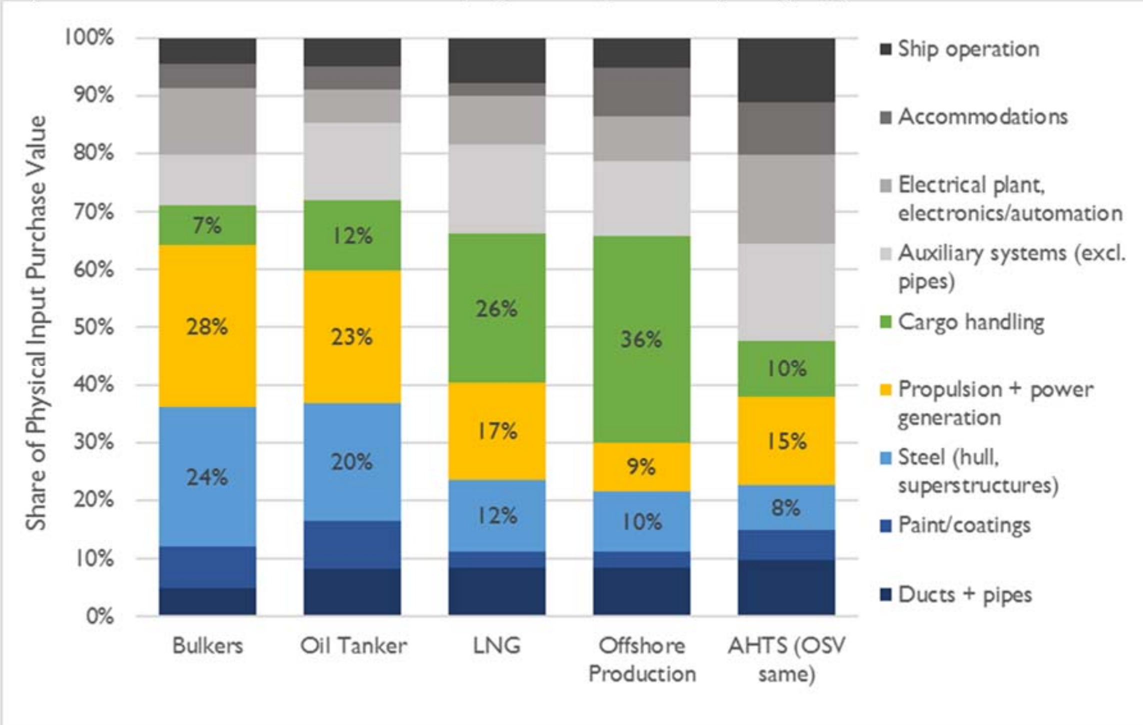


Source: Authors; ship-specific subassemblies and components account for the largest shares of input costs, but the specific ones of most importance to a particular ship depend on the type of ship produced.

The distribution of physical input costs can be divided into two parts: materials (steel, pipes and ducts, paint and coatings) and systems and equipment. Materials account for approximately 25% of goods purchased and systems and equipment 75% (EC, 2014). These shares vary depending on the size, configuration and purpose of the ship. Within materials, piping and paint make up relatively stable shares of input costs across all ship types, and in equipment/systems, all ships have similar shares for ship operation, accommodations,[13] electrical plant and auxiliary systems. The main variations are in steel/structural components, propulsion and cargo handling. Steel and propulsion systems are the primary inputs for bulkers, containerships and oil tankers, whereas cargo handling equipment is significant for LNG and offshore production vessels. Smaller offshore vessels (AHTS and PSV) have the lowest share for material components, and the widest variety/most eventually distributed need for equipment (Figure 4-5).

[13] For passenger vessels, the share for accommodations is significantly higher, but these are not a particular focus in this report.

Figure 4-5. Cost of Materials and Equipment/Systems by Ship Types



Source: Authors, calculated from (EC, 2014), which is based on purchase forecasts for 2013-17. Note: The "materials" category consists of steel, painting/coating, and pipes + ducts. The "equipment/systems" category consists of all other physical input categories.

Ship assembly and integration: The main activities in assembly and integration are:

- **Hull blocking and assembly**: Hull subassemblies are coated with protectant or specialized marine coatings, welded together to form large prefabricated units, and welded into position to form the ship. Once assembled, the ship is ready for launch and outfitting.
- **Outfitting:** After launch, the ship is berthed for completion. The main machinery, piping systems, deck gear, lifeboats, accommodation equipment, insulation, rigging and deck coverings are installed. The tendency is to schedule the outfitting of a vessel in sections, to synchronize fitting work in the different sections and compartments.
- **Systems integration:** Systems integrators install platform and ship-specific systems and ensure cross-functionality of subsystems. As subsystems become increasingly complex, the integrator's role becomes increasingly important.

Production support services: Production support consists of materials selection and procurement, and production planning and engineering.

- **Materials selection and procurement (sourcing)**: As the design for a ship develops, the shipbuilder identifies suitable suppliers or subcontractors to supply items the shipyard does not produce. Materials planning and procurement requires coordination between the design and procurement functions of the shipbuilding value chain. The design team provides the material needs and estimates for steel, pipes, and cables, subsystems, mechanical and electronic components, and optional equipment, while the procurement team gathers technical product information to create a database of potential suppliers. Selection of equipment in the design and build (DAB) phase has implications for post-production services. For example, propulsion systems made by two manufacturers may have similar prices, meet design specifications, yet have different maintenance costs and schedules. Evaluating systems based on total cost of ownership is one reason why coordination between the DAB team and ISS provider has become increasingly common. A second reason is the creation of the technical data package; this "owner's manual" lists the specifications and maintenance schedules for the ship's systems and subsystems.

- **Production planning and engineering**: Given the long build time for large commercial vessels, production planning is a critical and complex undertaking involving design, assembly, and installation. It ensures that individual parts and equipment are allocated to the appropriate stage in the production hierarchy of assemblies and subassemblies. Production planning and engineering includes assembly and production planning, cut and weld planning, and approval and release of designs. Specialized firms are often retained for production planning and engineering, though some shipbuilders maintain this capability in-house.

Post-production services and end-of-life: Post production services include in-service support (ISS), conversion, and technical training. ISS provides the maintenance, conversion and repair of the vessels, and generally occurs at planned intervals required by classification societies to ensure the ships remain seaworthy and in good condition. ISS is the responsibility of the ship owner, and typically performed by the original shipbuilder or specialized service provider contracted to conduct maintenance and repair. Under normal operation, post production services in the commercial shipbuilding sector account for approximately 30% of the selling price of a ship. This percentage does not include significant conversions, for example, those required for LNG bunkering or for meeting MARPOL standards. Technical training is needed to teach personnel on the operation and maintenance of the vessels' systems. The operational expense of onboard training makes companies specialized in virtual reality and training simulation attractive alternatives.

Shipbreaking and recycling: At the end of ship's useful life, it is purchased by a shipbreaking or demolition shipyard where it is disassembled. Largely due to the high quality standards for materials used in shipbuilding, nearly all of a ship (estimated 95%) can be recycled or reused (SBC, 2008). Ships are recycled primarily to recover their steel, which makes-up approximately 75% to 85% of a ship's weight, or "lightweight."[14] Some steel plates and beams can be extracted and directly reused by the construction industry or they can be re-rolled and reused (without melting),[15] and irregular scrap pieces can be melted into crude steel and reprocessed using an electric arc furnace (EAF) method. Ship steel scrap is attractive for steelmaking because it is high quality steel due to its high yield strength, ductility and impact strength. The annual average of 3.6 million tons of melting steel scrap from the global ship recycling industry (not including steel that is reused or only rerolled) accounts for around 1.5% of the global steel making industry

[14] Lightweight (LDT) is the mass of the ship's structure, propulsion machinery, other machinery, outfit and constants. Another way of defining LDT is as the displacement of a ship when fully equipped and ready to proceed to sea but with no crew, passengers, stores, fuel, ballast, water or cargo on board.

[15] The re-rolling process is simpler and uses less energy compared to melting steel scrap.

from old steel scrap (Mikelis, 2013). Other equipment still operational can be taken offboard and repurposed in another vessel.

Types of Ships/Vessels and Ship Owners/Buyers

There are several types of oceangoing vessels that can be described in terms of purpose or the type of cargo they are intended to carry (which relates to construction), size, and the main ship buyers or owners. Ships are typically designed to serve one of the following purposes: transport various types of cargo, conduct an activity at sea (extract oil or other resources, construction, research), and defense. In terms of cargo, ships are designed to transport dry goods (bulk raw materials, component/intermediate goods in containers, or large unpackaged general cargo), liquids/gases (oil, natural gas/petroleum, chemicals, beverages), and/or people.

Categories of ship owners/buyers are aligned with the different ships functions and types of cargo. Commercial shipping companies buy ships that transport dry goods (particularly containerships), oil and gas companies purchase liquid/gas carriers and offshore oil exploration units, and cruise lines purchase large passenger ships. Governments purchase a range of vessels used to conduct various duties and activities related to defense (warships, destroyers, frigates, corvettes, patrol vessels, fast attack crafts), research/survey (research vessels, icebreakers, and search and rescue), offshore oil exploration, and smaller passenger vessels for domestic transportation and shipping needs (Table 4-1).

The scope and terminology used to describe the shipbuilding industry varies based on the data provider. For example, the term ‘tanker’ may refer to any ship carrying liquids/gas, including oil, gas, chemicals or other products. Similarly, the term ‘cargo ship’ may combine containerships and general cargo ships or even bulk carriers. Offshore vessels are often included in an ‘other’ category, however this also often includes large passenger ships, ferries, fishing boats or smaller, multipurpose cargo/passenger vessels. Some sources include recreational vessels and boats (or more generally smaller vessels less likely to be used to travel across the ocean), research vessels or government/military-related production (see Box 4-1).

Table 4-1. Ship Types and Characteristics

Type	Sub-Type/Alt. Names	Description	Type of Cargo	Size (Unit, Range, Terms)	Newbuild Price (US$, Mil, 2016)
Bulk Carriers	Bulkers	Unpackaged bulk cargo; separate areas if more than one product	Dry-grains, coal, ore	DWT: 10-100,000 Handysize, Handymax, Panamax, Capesize	$20-42
Container		Carry load in truck-size containers, in a technique called containerization.	Dry-containers	TEU: < 1-12,000 Feeder, Intermediate, Neo-Panamax, Post-Panamax	$12-$109
Tankers	Gas LPG, LNG, FSRU	LNG larger than LPG	Liquid/Gas	Cu.M/m3: < 5-160,000 SGC, MGC, LGC, VLGC	$42-71; $192
	Oil/Crude		Liquid/Gas	DWT: < 55-320,000 Handy, Panamax, Suezmax, VLCC,	$33-85

Type	Sub-Type/Alt. Names	Description	Type of Cargo	Size (Unit, Range, Terms)	Newbuild Price (US$, Mil, 2016)
				ULCC	
	Chemical/Product		Liquid/Gas	DWT: < 25-125,000 SR, SH, MR, LR1, LR2	--
General Cargo	Cargo; other dry cargo; barge; reefer (refrigerated); Pax/General/ RoRo; RoRo	Carry various forms of cargo or cargo and ≤ 12 fare paying passengers (Pax). Barges are non-propelled (must be towed or provide stationary support).	Dry/People	# of cars Reefer: cubic feet RoRo: Lane m.	RoRo: $45-58
Passenger	Ferries, Cruise ships	Carry passengers; for transport purposes only or where the voyage itself and the ship's amenities are part of the experience.	People	Cruise: # of berths	
Other	Fishing		N/A	Generally below size threshold to be included. Small, 30 up to 100 meters	
	Tug	Designed for towing or pushing; increasing share used in the offshore segment.	N/A		
Offshore	See Box	Designed for exploration and extraction of natural gas and oil.	N/A	Drillship: water depth AHTS: HP Dredger: GT	

Source: Authors. Newbuild Prices: 2016 (Dec) based on average of all sizes: Clarksons (2017b).

Newbuilding prices increased during the early 2000s, but have declined across ship types since 2009 (Clarksons, 2017a; UNCTAD, 2011). The decline has more significant for bulkers and mid-size containerships than tankers and LNG. LNG carriers are the most expensive (US$192 million) and bulkers are the least expensive (US$20-42 million). Oil tankers and LPG carriers have similar price ranges (US$40-80 million), and containerships have the largest variation based on size (US$12-109). Bulkers and general cargo ships can be constructed in roughly 6-9 months and tankers in 14-16 months. A large passenger ship or LNG/LPG carrier may take two years to complete.

In terms of complexity, bulkers and general cargo ships are the most basic, followed by tankers, then containerships, and lastly LNG/LPG carriers as the most complex (G. Collins & M. Grubb, 2008). Offshore vessels, particularly large platforms research vessels, can be quite complicated and would be on par with LNG/LPG. The level of complexity is reflected in average newbuild prices, time to complete, as well as the type and cost of materials. For instance, over half of the cost of materials in bulkers and oil tankers are steel and engines, whereas LNG/LPG and offshore have higher shares in ship-specific systems.

4.1.4. Global Production and Trade in the Shipbuilding GVC

Most commercial shipbuilding and construction activity occurs in three countries. Japan, Korea, and China routinely account for over 90% of annual commercial ship production, a competitive advantage resulting from the continued development of block construction techniques during the 1980s in which large pieces of a ship are constructed on land before assembly, and more recently, access to inexpensive inputs, including steel (China). Within the “big three” segments of commercial shipbuilding - containerships, bulkers, and oil tankers - Japan and China specialize in building containerships and bulkers, while Korea is especially competitive at building tankers. European shipbuilding nations are specialized in passenger ships, dredgers, and ice classed vessels, which are typically higher value vessels (per CGT) than other commercial vessels. Italy, and to a lesser extent Germany, is particularly strong in designing and building passenger cruise vessels, the Netherlands and Belgium are specialized in dredgers, while Norway has particular strengths in designing and building ice-classed vessels and offshore vessels (EC, 2014). Shipbreaking, the demolition and scrapping of vessels, occurs primarily in South Asian countries, especially Bangladesh, India, and Pakistan, and China.

Box 4-1. Unique Aspects of Shipbuilding Data

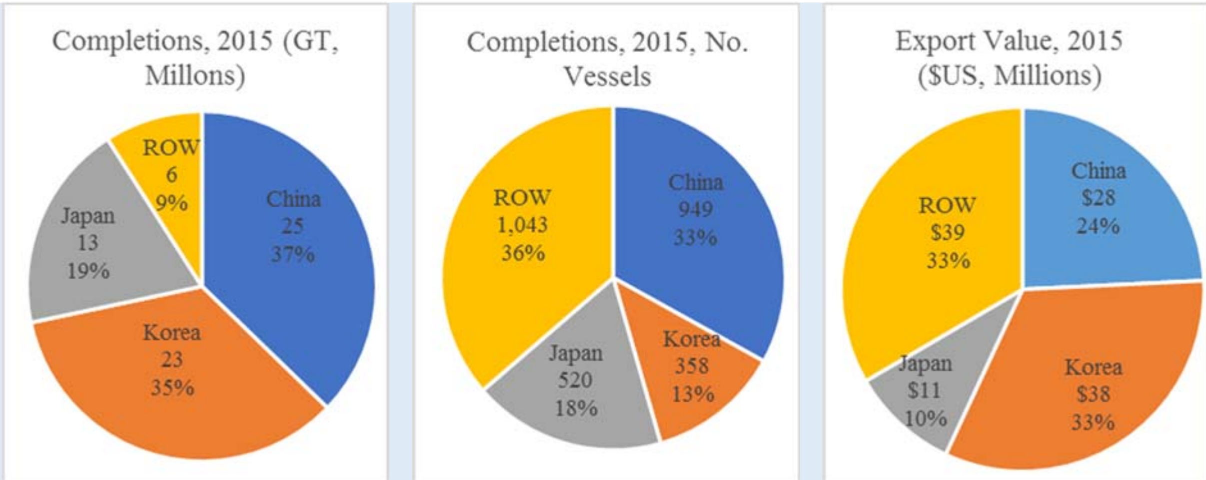
There are several caveats to measuring the size and scope of the global shipbuilding industry that are important to take into consideration when evaluating this GVC.

The first is related to data providers. Generally, the primary source of industry statistics related to production, trade, number of firms and employment is typically compiled by national statistical offices and customs (trade) based on international classification systems. While these are available for shipbuilding, the main sources used are private, third parties such as Clarkson, IHS, Lloyds, and Dewry that have access to ship production data. Due to the strong regulatory requirements for oceangoing commercial vessels, detailed production, ownership and service information must be collected by international classification societies. This data is collected for safety purposes, but it also useful for market research purposes. As such, several of these societies have separate units that sell this information via a separate business unit. That data collected by these agencies covers the entire population of shipyards (as opposed to samples in national statistics), and the level of detail is much higher. All three types of data are used in this report, and efforts to point out differences are made when possible.

Second, the size of any segment also varies depending on the unit of measurement; the market is commonly described in terms of weight/carrying capacity of ships with common units including GT, CGT, DWT or TEUs. Market statistics are also produced based on orders, completions and deliveries (which can alter top categories and countries as well). The actual number of vessels produced and value are less commonly used, however the importance of the relative segments and top companies changes when using these indicators. Employment data also varies due to high use of temporary or contract workers (subcontractors). The minimum size of a ship to be included in statistics from IHS, UNCTAD and Clarkson’s is typically 100GT.

The third important feature is geographic concentration of both demand and supply. Production is highly concentrated in a few countries, and a significant share of this is purchased by domestic buyers. As such, production and trade data will provide different perspectives. Furthermore, ‘ship exports’ are convoluted by the fact that ships are often ‘flagged’ by a country that is not the ship owner/buyer, and the fact that ships are never ‘consumed’ in one country. Therefore, import statistics are not particularly pertinent.

Figure 4-6. Leading Producers and Exporters in Shipbuilding, 2015



Sources for figures above: Completions from IHS (GT and #); Exports (UNComtrade)

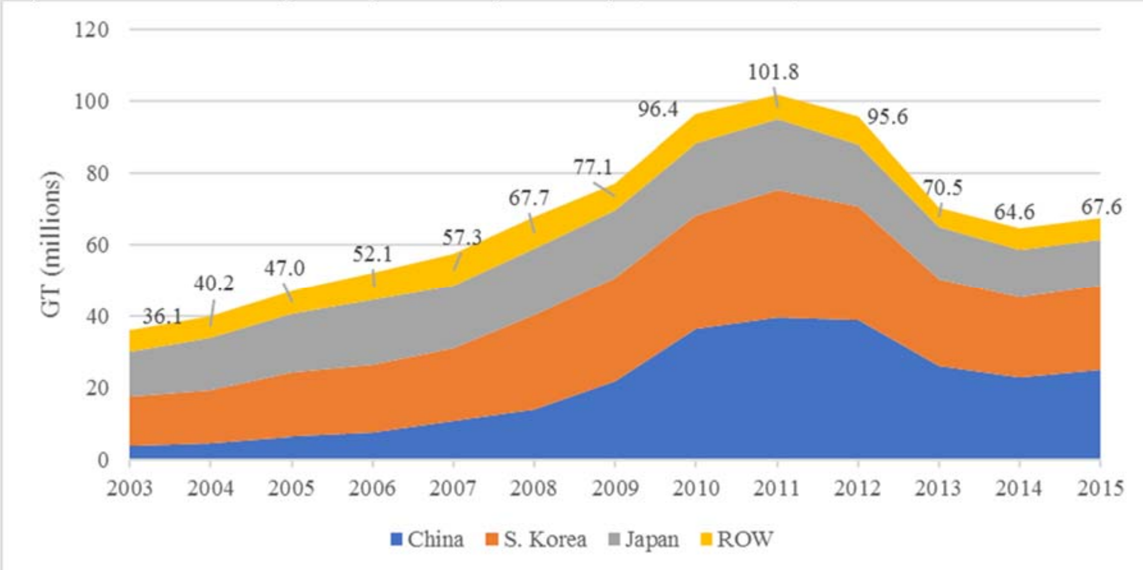
Global Statistics on Shipbuilding

- Deliveries (2016): 1,664 vessels; 66.3 million GT; 34.7 million CGT; 100.5 million DWT; value: US$80.2 billion (Clarksons, 2017b)
- Exports (2015): US$117 billion (UNComtrade, 2016)
- Revenue (2016): US$175 billion (IBIS, 2016)
- Production (Completions, 2015): 67.6 million GT; 2,870 ships (IHS, 2009-2016)
- Production (Deliveries, 2015): 64.1 million GT (UNCTAD, 2016b); based on Clarkson (UNCTAD matches Clarkson in 2014; IHS matches in 2015)
- Contracted (2015): 38 million CGT (DSF, 2016)
- Active Shipyards (2015): 730 (DSF, 2016)
- Shipyards with new orders (2015): 240 (DSF, 2016)

The expansion of global new ship orders since the early 2000s was hit by the 2008-2009 economic crisis. New orders dropped from 170 million GT in 2007 to 34 million GT in 2009.[16] The economic recovery since 2010 has rekindled demand for new ships, raising new orders to 77 million GT in 2015.[17]

[16] Gross tonnage (GT), a measure of ship size, is calculated based on "the molded volume of all enclosed spaces of the ship" and is used to determine a ship's manning regulations, safety rules, registration fees and port dues.
[17] Based on IHS (formerly Lloyd's Register) *World Shipbuilding Statistics*, which only includes ships 100GT or over.

Figure 4-7. World Ship Completions by Country (GT, million), 2003-15



Sources: IHS (2009-2016)

In terms of vessels completed, China (37%), Korea (34%), and Japan (19%) accounted for 91% of the world's approximately 68 million GT of ships completed in 2015 (see Figure 4-7). Korea completed 358 ships totaling approximately 23.3 million GT, equivalent to 34.4% of the world's total tonnage (see Table 4-2).

Table 4-2. Top 10 Shipbuilding Countries (based on GT Completed), 2015

Rank	Country	No.	'000 GT	No. Share (%)	GT Share (%)	No. Change	GT Change	GT (000)/ Ship
		2015	2015	2015	2015	2010-15	2010-15	2015
	World Total	**2,870**	**67,566**			**-23%**	**-30%**	**24**
1	China	949	25,160	33.1	37.2	-33%	-31%	27
2	Korea	358	23,272	12.5	34.4	-32%	-27%	65
3	Japan	520	13,005	18.1	19.2	-10%	-36%	25
4	Philippines	42	1,865	1.5	2.8	24%	61%	44
5	Taiwan	56	749	2.0	1.1	167%	29%	13
6	Vietnam	90	591	3.1	0.9	-32%	6%	7
7	Romania	39	485	1.4	0.7	-9%	-21%	12
8	US	75	427	2.6	0.6	-1%	79%	6
9	Germany	10	384	0.3	0.6	-72%	-59%	38
10	Brazil	32	361	1.1	0.5	52%	668%	11
Top 10 (based on GT) Share				76	98			

Source: IHS (2016)

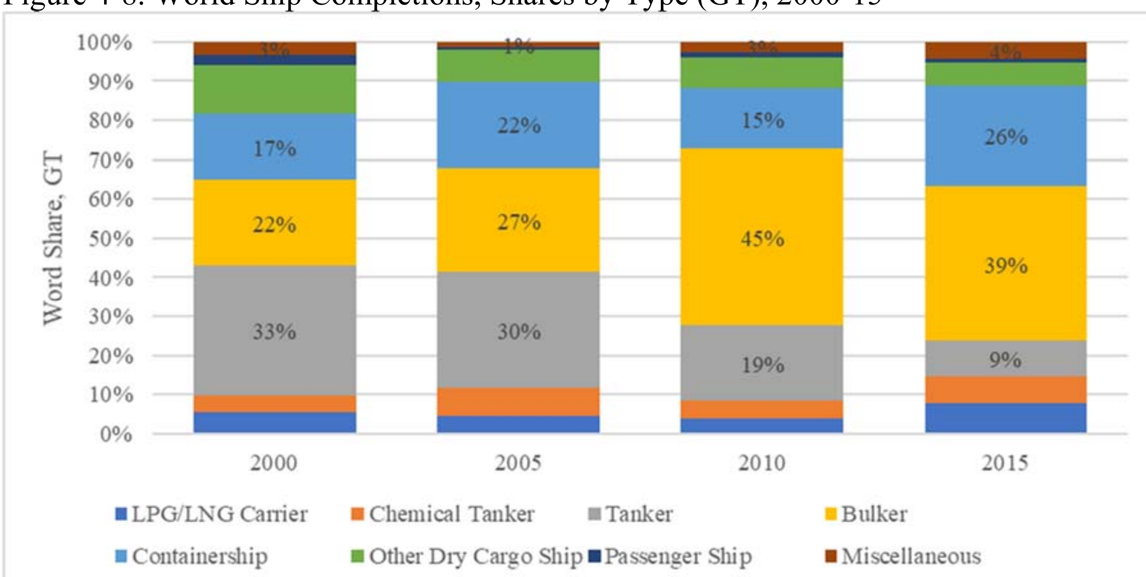
Regarding the type of vessels completed in 2015, product carriers dominated the market. Bulkers (39%), containerships (26%), and oil tankers (9%) are the top three vessel types in terms of world ship completions by gross tonnage (see Table and Figure). The share of LPG/LNG gas carriers has been rising in recent years (based on GT and numbers), indicating the growing markets for these vessel types. Offshore vessels account for less than 5% of GT, however, they are much more important based on value.

Table 4-3. World Completions by Type (No. & GT), 2015

Rank	Type	No.	GT ('000)	No. Share (%)	GT Share (%)	No. Change	GT Change	GT (000)/ Ship	Countries
		2015	2015	2015	2015	2010-15	2010-15	2015	
	World Total	**2,870**	**67,566**			**-23%**	**-30%**	**24**	
1	Bulker	645	26,520	22%	39%	-35%	-39%	41	China, Japan
2	Container ship	212	17,339	7%	26%	-18%	18%	82	Korea
3	Other Dry Cargo	332	3,876	12%	6%	-42%	-49%	12	China
4	Oil Tanker	130	6,384	5%	9%	-61%	-66%	49	Korea
5	LPG/LNG (Gas)	114	5,226	4%	8%	30%	42%	46	Korea
6	Chemical Tanker	208	4,588	7%	7%	-36%	1%	22	China
7	Miscellaneous	1,182	2,976	41%	4%	3%	16%	3	
8	Passenger Ship	47	656	2%	1%	4%	-48%	14	
Bulker/Containership/Cargo				**41%**	**71%**				
Tankers (oil, gas, chemical)				**16%**	**24%**				
Offshore			*2,500*		**4%**		*4%*		

Source: IHS (2016); p. 7, p. 35 (for offshore). Offshore classified under 'miscellaneous' in IHS data, however Clarkson's includes offshore as a category.

Figure 4-8. World Ship Completions, Shares by Type (GT), 2000-15



Source: IHS (2016)

A majority (63%) of the world's commercial shipping fleet, including oil tankers and bulk carriers, is under 10 years of age, 26% is between 10-19 years old, with the balance (11%) 20 years or older (IHS, 2016). The average in-service life for commercial vessels is 23 years, with few ships remaining in-service after 25 years (OECD, 2015a). World disposals peaked in 2012, with 38.4 million GT being scrapped. Bangladesh, India, China, Turkey and Pakistan are the leading countries for shipbreaking and disposal.

Global ship exports

Global exports of ships were US$117 billion in 2015.[18] The effect of the economic recession was noticed and disruptive to both trade in ships and new orders, although many shipbuilders are still completing orders made prior to the global financial crisis.[19]

Table 4-4. Top 10 Ship Exporters by Value & Year, 2007-2015

Exporter	Exports (US$, Billions)					Share of World Ship Exports (%)				
	2007	2010	2012	2014	2015	2007	2010	2012	2014	2015
Total	**88**	**156**	**140**	**123**	**117**					
Korea	27	47	38	38	38	30%	30%	27%	31%	33%
China	12	40	39	25	28	14%	26%	28%	20%	24%
Japan	15	26	22	13	11	17%	17%	16%	10%	10%
Poland	3	3	4	5	5	4%	2%	3%	4%	4%
Germany	3	5	3	4	4	4%	3%	2%	3%	4%
India	1	4	4	5	4	1%	3%	3%	4%	3%
Saudi Arabia	1	1	2	2	2	1%	0%	1%	2%	2%
Brazil	1	0	2	2	2	1%	0%	1%	2%	2%
Netherlands	1	1	1	2	2	2%	1%	1%	1%	2%
US	1	1	2	1	2	1%	0%	1%	1%	1%
Top 10 (in 2015)	**80**	**140**	**124**	**104**	**107**	**75%**	**81%**	**83%**	**79%**	**85%**

Source: UNComtrade (2016)

Korea is the top ship exporter whereas China is the top producer (based on GT); at least one-third of China's production is for national buyers.

Figure 4-9 shows the world's ship exports by vessel type. As with production, containerships/bulkers and tankers are two of the leading categories in exports. However, offshore ships account for a much larger share of the market based on value than by GT as these are smaller, higher value vessels (IBIS, 2016). They also account for a larger share because more are produced for foreign customers than domestic buyers.

[18] These and following export figures were compiled from UNComtrade, unless otherwise stated.
[19] The typical production time varies by the type of ship; a bulk cargo ship takes 6-9 months to build while a cruise or LNG ship takes up to 2 years or more for construction (European Commission, 2003, p. 11).

Figure 4-9. World Ship Exports, by Type & Value, (US$ billions), 2007-2015

Source: UNComtrade (2016)

Table 4-6 lists the leading exporting countries in the major traded ship categories: (1) containerships, bulkers, cargo, (2) offshore, (3) tankers, (4) passenger ships. Collectively these categories accounted for 89% of exports in 2015. Korea, China and Japan are driving global exports in containerships, bulkers, and general cargo. Korea dominates the offshore category and in tankers. Passenger ships are primary from European countries.

Table 4-5. Top World Ship Exporters by Type & Value, 2015

	Overall	Container, Bulkers, Cargo	Offshore	Tankers	Passenger
Total Exports (US$)	$117 billion	$44 billion	$36 billion	$22 billion	$5 billion
Top 5 (by	Korea (33%)	China (37%)	Korea (47%)	Korea (58%)	Germany (38%)

type)	China (24%)	Japan (21%)	China (18%)	China (18%)	Italy (23%)
	Japan (10%)	Korea (20%)	India (8%)	Japan (8%)	Finland (10%)
	Poland (4%)	Poland (6%)	Brazil (5%)	Poland (7%)	Philippines (7%)
	Germany (4%)	Germany (3%)	Netherlands (4%)	Germany (3%)	Poland (4%)
Korea	33%, 1st	20%, 3rd	47%, 1st	58%, 1st	1%, 14th
HS02		890190, 890130	8905, 890790	890120	890110

Source: UNComtrade (2016); See Appendix table for codes and world values. Other not shown (8902, 8904, 890690), but included in overall total.

Demand for large commercial shipbuilding is driven by trends in seaborne trade and vessel age (except offshore vessels and passenger vessels). Trade, measured in tons, has steadily increased since the 1990s reaching 10.5 billion tons in 2014.

Table 4-6. World Exports of Ship Subassemblies/Components, 2015

System/VC Stage	Specific to Ships	Item	Main Exporters	World Exports 2015 (US$, B)
Platform: Propulsion	Ship-Specific	Turbines for marine propulsion	Japan (42%), India (15%)	< $1
		-Spark-ignition reciprocating or rotary internal combustion piston engines -Outboard motors/Other	Japan (58%), US (16%)	$3
		Compression-ignition internal combustion piston engines (diesel or semi-diesel engines)	Korea (23%) Germany (21%)	$4
	Not Ship-Specific	Nuclear reactors, boilers, machinery and mechanical appliances/Other engines and motors/Hydraulic power/Other	Germany (16%) US (16%) UK (8%)	$3
		Parts for use with engines of heading 84.07 or 84.08 /Other/for use with spark-ignition internal combustion piston engines	Germany (19%) Japan (15%), US (12%), Mexico (10%)	$30
		Parts/applies to ships and auto for engines other than internal combustion	Germany (24%) China (7%), US (7%)	$33
Mechanical	Ship-Specific	Propeller & blades	Japan (21%), Germany (14%) China (12%)	$1
	Not S.-Specific	"Other machinery self-propelled, other", 4D code lists ship derricks (crane)	Germany (24%) Japan (19%)	$3
Navigation & Comm-unication	Not Ship-Specific	Radar apparatus, radio navigational aid apparatus and radio remote control	China (16%) Germany (14%)	$18
		Surveying, hydrographic, oceanographic, hydrological, meteorological or geophysical instruments and appliances	US (22%) UK/Germany (17%)	$9
		Navigation-related	US (20%), France/ UK/Germany (30%)	$3
Hull/ Raw Materials	Not Ship-Specific	Steel	China (10%) Japan (9%) Korea (9%) Germany (7%)	$160
		Tubes & pipes & fitting (steel products)	China (19%) Germany/Italy (18%)	$71

Source: see Table A-4-1. Shipbuilding HS Codes.

4.1.5. Lead Firms and Governance Structure of the Shipbuilding GVC

Assembly and integration activities are organized as a tiered production system. The shipbuilder holds the contractual relationship with the ship owner. In commercial shipbuilding, the shipbuilder generally is responsible for hull fabrication, outfitting, and a range of service activities related to ship production, including procurement, sub-contracting, risk management, and scheduling, collectively known as Engineering, Procurement and Construction (EPC). The shipbuilder may also have design capabilities in-house. As an EPC, the shipbuilder typically develops a list of system and subsystem suppliers appropriate to the vessel specifications. Although the ship owner may add additional suppliers, the final procurement decision is made by the EPC to optimize cost and performance. Thus, the shipbuilder and ship owner collaborate in selecting the system and subsystem suppliers.

Depending on the capability of the shipbuilder and the complexity of the ship, major systems may be supplied either internally by the shipbuilding firm or by external firms. Some large shipbuilders are vertically integrated enough to use internally sourced propulsion systems; Hyundai Heavy Industries in Korea is a notable example. However, as the complexity of the ship increases, the more likely it is that systems are sourced externally from specialized firms. Below the shipbuilder are tier 1 companies, providing major systems for the ship. Additional tiers to this system supply subassemblies, components, and raw materials to the shipbuilder and tier 1 suppliers.

Table 4-7. Global Lead System Suppliers

System	Global Lead Firms
Propulsion/ Electric Power Generation	MAN Diesel (Germany), Wartsila (Finland) *Licensees of one or both of above companies:* HHI (Korea), Doosan (HSD) (Korea), Mitsui (Japan), Mitsubishi (Japan), Hitachi Zosen (Japan), Diesel United (Japan) *Others:* Caterpillar Marine Power Systems (US), GE (US), Rolls Royce (UK/US), TECO Westinghouse (US), ABB (Switz), Sulzer (Switz), Stadt (Norway), Schottel (Germany), Volvo Penta (Sweden)
Navigation & Electronics	Kongsberg Maritime (Norway); Siemens (Germany); ABB (Finland/Norway/Switz.); Wartsila/SAM Electronics (Netherlands); Imtech Marine (Netherlands); SperryMarine/Northrup Grumman (UK)
Communication	L-3 Communications (US); Inmarsat (UK); EADS/Astrium (France); Telenor Satellite Broadcasting (Norway); Cobham SATCOM (UK)
Cargo Handling	Cargotec (Finland); Liebherr (Switz); TTS Group (Norway); Scana Industrier (Norway)
Auxiliary Systems & Outfitting	HVAC: Bronswerk Marine (Canada); Ballast water treatment/emission control: Alpha Laval (Denmark), Wartsila Hamworthy (UK); Autronica Fire & Security (Norway); Winches: Bosch Rexroth (Germany) Electrical systems: Schneider Electric (France) Life-saving equipment: Survitec Group (UK)
Coatings/Paint	AkzoNobel (Brand: International Paint) (Netherlands), Hempel (Denmark) Chogoku Marine Paints (Japan), Jotun Paints (Norway), PPG Coatings (Belgium), Sigma Samsung Coatings (Korea), Subsea Industries (Belgium)
Other	Offshore Engineering & Construction: Saipem (Italy), Tyco Marine (UK); Technip (France); Aker Solutions (Norway)

Source: Authors; see also (EC, 2014)

At the components level, the degree of coordination and information exchange between buyer and supplier (i.e., value chain governance) depends on the level of product value and supply chain risk to the shipbuilder (EC, 2014). Components suppliers typically have multiple clients, both in terms of geography (i.e. domestic versus international) and industry (e.g. aerospace, infrastructure, mining and oil and gas).

- *General product*s, defined as off-the-shelf standardized products, are characterized by low product value and low supply chain risk. For example, pumps required for shipbuilding have general specifications, are readily available in large quantities, and are manufactured by several suppliers. The critical factors in general products are the acquisition costs and ease of ordering for the buyer, and quick response and delivery by the supplier.

- *Strategic products* -- those that provide product differentiation competitive advantages to the shipbuilder, are characterized by high product values and high supply chain risk. The critical factors for strategic products are long-term sourcing, long-delivery lead times, and long-term contractual agreements between the supplier and shipbuilder. Engines and complex integrated bridge systems are examples of strategic products in the shipbuilding sector because they have special-to-type specifications, are developed cooperatively with the shipbuilder, and few manufacturers exist to provide the systems.

- *Price critical products* are high value (i.e., relatively expensive to produce and purchase) but with low supply chain risk due to their general availability in the market. These are standard catalog products such as diesel generators and deck cranes, that are available from several suppliers. Differentiation among suppliers is based on price and consistent product quality; suppliers are managed by the shipbuilder through supplier audits and individual price negotiations.

- Finally, *bottleneck products* have relatively low value but are critical for the final product. Suppliers are differentiated by their ability to deliver on time with consistent product quality; they closely coordinate their activities with the shipyards to ensure timely delivery at a reasonable price. Examples are ship propellers and fire doors (EC, 2014).

Shipbuilding is becoming increasingly concentrated; in 2015, only 240 shipyards received an order (although 730 were active), with 47% of orders going to 20 large shipyards (annual max capacity above 500,000 CGT) and another 47% to medium shipyards. Small shipyards only accounted for 6% of orders (annual maximum capacity of less than 80,000 CGT). Typical shipyard size also varies by country, although all large shipyards are in China, Korea, and Japan (DSF, 2016). Korea's orders are dominated by large shipyards (91% of new orders in 2015) whereas medium yards dominate in Japan (large was only 20% of new orders). China is composed of a fairly even split between large and medium firms (DSF, 2016). The number of large yards has remained constant, from 20 to 24, on average attracting 46% of annual contracting over the five-year period; 20 of the large yards have existed since at least 2011 (i.e., new large yards are uncommon).

Table 4-8. Geographical Distribution of Active Shipyards, 2015

Country	2011 (Active)	2015 (Active)	2015 w/new orders
China	191	200	75
Korea	22	30	13
Japan	48	70	55
Philippines	4		
Other		430	97
World		730	240

Source: 2011, Clarksons (2013); 2015, (DSF, 2016), p. 29-33. DSF data based on CGT, an international unit of measure that facilitates a comparison of different shipyards' production regardless of the types of vessel produced.

Offshoring production is uncommon in shipbuilding. Lead firms (with a few exceptions) primarily only own shipyards in their home country. This is at least partially tied to naval shipbuilding as countries want to keep the skills/technology to produce ships close to home for national defense reasons.

Table 4-9. Top Global Shipbuilders

Orderbook Value US$*	Name	Revenue $US, B*	Emp. ('000)	Year Est.	Ownership	Segments/Types (CGT, 2016)	Linkages/ Locations/	Yards
$24.4	Hyundai Heavy Industries (HHI)	$40.9 $16.4	27	1972	Korea, Ulsan KSE: 009540		Engines; steel; shipping HSHI: Mokpo, 2002 (acq.); $3.3B	3
$19.9	Daewoo (DSME)[20]	$13.3 $12.6	13	1973	Korea, Seoul KSE: 042660	Container (32%), LNG/LPG (32%), Oil Tankers (29%) Offshore (7%)		1-2
$10.5	Samsung Heavy Industries (SHI)	$8.6 $3.9	14	1974	Korea, Seoul KSE: 010140	Container (52%), LNG (36%), Offshore (13%)	China	2
	Hyundai Mipo Dockyard (HMD)[21]	$3.3		1975	Korea, Ulsan	Chemical tankers, containerships	Vietnam	2
	Tsuneishi				Japan	Bulkers (100%)	Philippines, China	3
	Yangzijiang Shipbuilding (Holding Co.)	$2.6	.9	2005	China Singapore SE: BS6	Bulkers, containerships	China (Jiangsu New YZJ), Singapore, US	3
$9.9	Imabari Shipbuilding			1942	Japan Private	Bulkers, containerships, tankers, others		9
$15.1	China State Shipbuilding Corp. (CSSC)			1999	China, Beijing SOE		Shanghai Waigaoqiao SB (SWS)	3?
	China COSCO		150	1999	China, Beijing	Dalian Shipyard largest. CSSC		7

[20] Recently had a yard in Romania, but sold: www.reuters.com/article/us-daewoo-restructuring-idUSKBN17K0KX
[21] HMD claims to have the largest global ship repair facility.

Orderbook Value US$*	Name	Revenue $US, B*	Emp. ('000)	Year Est.	Ownership	Segments/Types (CGT, 2016)	Linkages/ Locations/	Yards
	Shipping (COSCOCS)[22]				SOE SSE: 601989	spin-off.		
	Hanjin Heavy Industries & Construction (HHIC)	$2.8 $1.5?	2.6	1937	Korea, Busan KSE: 097230	Container, bulkers, gas	Philippines	2
	Fujian Shipbuilding				China			4+
	Oshima Shipbuilding				Japan Private	Bulkers (100%)		1

Sources: Generally based on Clarkson's 2016 rank by CGT, GT, DWT and number of ships completed. Other sources: WMN (2016) (Orderbook value in $US billions as of March 2016; same data provided in Statista), IBIS (2016), Clarksons (2011), Worldyard Statistics (2011). For Korean companies: MarketLine Company Reports; KOSHIPA members; OneSource. Notes: Revenue column (*): first number is total revenue and second is shipbuilding-specific revenue for most recent year available. KSE designates stock exchange number.

4.1.6. Standards and Institutions

The shipbuilding industry has several classification and certifications relevant to the design, production, and post-production phases of shipbuilding. "Classification" establishes that a ship or offshore structure conforms to class rules developed by national classification societies during construction and time in-service, which are verified through periodic inspections called "surveys". Ship class rules are standards for the structural strength, integrity, and functioning of various parts of a ship, including the hull, propulsion, steering, power and essential service-related auxiliary systems (IACS, 2016). "Certifications" establish conformity with safety, health, and environmental statutory requirements found in international conventions or national legislation (Table 4-10). Certifications in the marine industry are applicable to ships, offshore units and installations, marine equipment, training and management systems and thus are relevant to marine products and their components, services, people and systems (BV, 2017). We discuss classifications and certifications in turn below.

Table 4-10. Standard Setting Organizations and Agreements in the Shipbuilding GVC

Organization	Description	Reference
International Association of Classification Societies (**IACS**)	Umbrella organization for the major twelve national classification societies, which comprise more than 90% of in-service cargo ships. The twelve members are listed below.	www.iacs.org.uk/default.aspx
National classification societies	Classification societies set technical rules, confirm that designs and calculations meet these rules, inspect ("survey") ships and structures during construction and commissioning, and survey vessels to	US: American Bureau of Shipping (ABS) UK: Lloyd's Register (LR) Russia: Russian Maritime Register of Shipping Poland: Polish Register of Shipping (PRS) Korea: Korean Register of Shipping (KRS)

[22] Formed by Government of China in July 1999 from companies spun-off from CSSC, and is 100% owned by SASAC. CSIC handles shipbuilding activities in the north and west of China, while CSSC deals with those in the east and the south of the country (Wikipedia). Think is the same as China Shipbuilding Industry Corp (CSIC).

Organization	Description	Reference
	ensure that they continue to meet the rules during in-service.	Japan: ClassNK Italy: Registro Italiano Navale (RINA) India: Indian Register of Shipping (IRS) Germany/Norway: Det Norske Veritas (DNV) Germanischer Lloyd (GL) (DNV-GL) France: Bureau Veritas (BV) Croatia: Croatian Register of Shipping (CRS) China: China Classification Society (CCS)
International Maritime Organization: (**IMO**)	United Nations agency founded in 1948; establishes standards on maritime safety, health and environmental protection.	www.imo.org/en/About/Pages/Default.aspx List of IMO conventions: www.imo.org/en/About/Conventions/ListOfConventions/Pages/Default.aspx
International Convention for the Safety of Life at Sea (**SOLAS**)	(1974): IMO convention that governs safety regulations for ships.	www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-%28SOLAS%29%2c-1974.aspx
International Convention for the Prevention of Pollution from Ships (**MARPOL**)	International Convention for the Prevention of Pollution from Ships (1973, modified 1978, 1997): IMO convention that governs air and water pollution released from marine sources. **Annex VI,** limits sulphur oxide and nitrogen oxide emissions from ship exhausts and mandatory technical and operational energy efficiency measures aimed at reducing greenhouse gas emissions from ships.	www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-%28MARPOL%29.aspx

Sources: references in table.

Classification: IACS is the umbrella organization for 12 of the world's major classification societies, including those of the US, Korea, China, and Japan. More than 90% of the world's cargo carrying ships' tonnage is covered by the classification standards set by the 12 member societies of IACS (IACS, 2016). The IACS holds special status with IMO regarding the development and application of rules in the shipbuilding industry, including those related to the International Convention for the Safety of Life at Sea (SOLAS) and MARPOL (marine pollution). While classification represents the level of compliance of a ship or offshore structure to these rules, they are not a warranty of the ship's safety, seaworthiness, or that the ship is being operated in a manner consistent with its purpose. Classification societies have no control over how a vessel is manned, operated, and maintained between the periodic surveys (IACS, 2016). Classification societies set technical rules, confirm that designs and calculations comply, survey ships and structures during construction and commissioning, and inspect vessels while in-service to ensure that they continue to meet class rules. Table 4-12 details the key inspections undertaken by these classification societies.

Table 4-11. IACS Required Inspections ("Surveys")

Survey Name	Description	Frequency
Assignment of Class	Class is assigned to a vessel following review of the design and compliance surveys during construction.	**on completion of the new build**, **ship transfer** between IACS members **on completion of a satisfactory specific class survey** of an existing

Survey Name	Description	Frequency
		ship not classed with an IACS society, or not classed at all.
Annual survey	The ship is generally examined. The survey includes an inspection of the hull, equipment and machinery.	Annually (three months before to three months after anniversary date)
Intermediate survey	Includes examinations and checks on the ship's structure for compliance. Rule criteria become more stringent with age. According to the type and age of the ship the examinations of the hull may be supplemented by thickness measurements.	Every three years (three months before second to three months after third anniversary date)
Class renewal or "special" survey	Includes extensive examinations to verify that the structure, main and essential auxiliary machinery, systems and equipment are in satisfactory condition. Examinations of the hull are supplemented by thickness measurements to assess that the structural condition remains effective and to help identify substantial corrosion, significant deformation, fractures, damages or other structural deterioration.	Five-year intervals
Bottom or "Docking" survey	A bottom/docking survey is the examination of the outside of the ship's hull and related items. This examination may be carried out with the ship either in dry dock (dry-docking survey) or afloat (in-water survey). The conditions for acceptance of an in-water survey in lieu of dry-docking depend on the type, age and history of the ship.	Twice in five-year period. One of the two bottom surveys to be performed in the five-year period is to be concurrent with the class renewal survey.
Tailshaft survey	A tailshaft survey is the survey of screwshafts and tube shafts (hereafter referred to as tailshafts) and the stern bearing. Three different types of tailshaft surveys exist: **partial, modified, and complete**. "Complete" means that the shaft is drawn up for examination or that other equivalent means of examination are provided. Partial and modified are more limited examinations.	**Partial**: Permits the postponement of the complete survey, having a periodicity of 5 years, for 2.5 years. **Modified**: Alternate five-yearly surveys for tailshafts. **Complete:** Based on the type of shaft and its design.
Boiler survey	Steam boilers, superheaters and economizers are examined. Boilers are drained and prepared for the examination of the water-steam side and the fire side.	Boilers and thermal oil heaters must be surveyed twice in every five-year period. The periodicity of the boiler survey is normally 2.5 years.
Non-periodical survey	• To update classification documents (e.g. change of owner, ship name, change of flag); • To deal with damage or suspected damage, repair or renewal work, alterations or conversion, postponement of surveys or outstanding conditions of class; • At the time of port State control inspections.	Earliest opportunity and without delay

Source: IACS (2016)

Certifications: Certifications, on the other hand, establish compliance with international and national statutory (legal) requirements regarding the safe and sustainable operation of ships. Certifications cover ships, marine equipment, people and management processes.

Statutory certification of ships: The IMO[23] sets out uniform safety, security, pollution mitigation, and sustainability requirements to promote trade by ensuring that a ship registered in one country is accepted by the waters and ports of another (IACS, 2016). Statutory certifications cover four

[23] Established under the United Nations Convention on the Law of the Sea (UNCLOS) in 1948.

broad areas: (1) design and structural integrity; (2) pollution control during normal operation (see below); (3) accident prevention; and (4) accident mitigation, including containment and escape.[24]

Pollution control during normal operation must comply with several statutory and treaty obligations. Most notable among these are the ballast water convention (2004 International Convention for the Control and Management of Ships' Ballast Water and Sediments) requiring the bilge to be free from fouling organisms by September 2017, and the IMO's adoption of enhanced environmental regulations, including reductions in the emission of marine air pollutants from ships. First adopted in 1997, MARPOL limits the main air pollutants contained in ships exhaust gas, including sulphur oxides (SOx) and nitrous oxides (NOx); prohibits the deliberate emission of ozone depleting substances (ODS) and; regulates shipboard incineration, and the emissions of volatile organic compounds (VOC) from tankers. These conventions also regulate emission caps and special emissions control areas (ECAs) for SOx and NOx emissions in specific geographic areas, and stepwise reductions in CO_2 emissions (IMO, 2017a) (IMO, 2017b).

Marine equipment certification: Classification societies also establish procedures to approve marine equipment suppliers. For example, since 1999, EU's Marine Equipment Directive (MED) requires certain categories of marine equipment placed on European ships to have an EU marine equipment "conformity mark." The categories of equipment include lifesaving appliances (i.e., lifeboats and lifejackets), marine pollution prevention equipment, fire protection equipment, navigation and radio communication equipment (BV, 2017). Korea's Classification Society (KRS) identifies radio equipment, fire extinguishing equipment, lifesaving equipment, voyage recorders and low location lighting (LLL) systems as among the marine equipment requiring certification to be compliant with KRS rules and national legislation (KRS, 2017a).

Management processes: Various standard management system process standards are relevant to the shipbuilding industry. Among the most common are ISO 9001, 14001, 28000, 28007, 50001 and OHSAS 18001. ISO certifications are typically valid for three years (see table below for description).

Table 4-12. Management System Certifications in Shipbuilding

Standard	Description	Source
ISO 9001	Quality management certification	https://www.iso.org/obp/ui/#iso:std:iso:9001:ed-5:v1:en
ISO 14001	Environmental management system certification	https://www.iso.org/obp/ui/#iso:std:iso:14001:ed-3:v1:en
ISO 28000	Supply chain security management certification	https://www.iso.org/obp/ui/#iso:std:iso:28000:ed-1:v1:en
ISO 28007	Guidelines for Private Maritime Security Companies (PMSC) providing privately contracted armed security personnel (PCASP) on board ships	https://www.iso.org/obp/ui/#iso:std:iso:28007:-1:ed-1:v1:en
ISO 50001	Energy efficiency management system certification	https://www.iso.org/obp/ui/#iso:std:iso:50001:ed-1:v1:en

[24] The statutory certification of the design and structural integrity may be fulfilled by the classification survey; in other words, the classification survey may be given the status of the required statutory survey if the classification society is designated as the recognized organization to perform this function (IACS, 2016)

OHSAS 18001	Occupation health and safety management system certification	http://www.osha-bs8800-ohsas-18001-health-and-safety.com/ohsas-18001.htm

National legislation on inland and nearshore commercial vessels: Many countries designate coastal and inland waterways as closed to international vessels. The limitations are variously defended as required on national security and national capability grounds. Known as "cabotage" restrictions, these laws generally require vessels operating in coastal and inland waters to be flagged by the country and manned by sailors with citizenship or permanent residence in the country. In the U.S., the Jones Act (Merchant Marine Act of 1920) requires all goods transported by water between U.S. ports to be carried on U.S.-flag ships, which must be constructed and owned by U.S citizens, and crewed by either U.S. citizens or permanent residents.[25] Other countries with cabotage laws include Argentina, Japan, India, and Malaysia (UNCTAD, 2016b).[26]

4.1.7. Human Capital and Workforce Development

Shipbuilding is highly labor intensive, with the largest shipyard employing tens of thousands of workers. Workers tend to be skilled labor, ranging from welders to marine engineers. In countries with low labor costs, labor intensity tends to be higher as operators take advantage of lower wages. There were approximately 1 million employed by the ship and boat building industry globally in 2016 (IBIS, 2016). A report by the OECD estimated global employment in 2010 to be 1.875 million (OECD, 2016).

Given the project-based nature of shipbuilding, subcontracting is common. Subcontracting occurs in two ways. The primary shipbuilder hires subcontracted laborers (instead of regular workers) for shipyard workers (i.e., welders, fitters, operators, etc.). Although they receive temporary contracts, given the time to build a ship, they are often for a year and tend to be renewed if work at the shipyard is steady. Alternatively, primary shipbuilders will outsource a portion of the assembly process to a nearby shipyard. In many cases, subcontracted firms also co-locate in the same facility as the primary shipyard and operate as if they were a part of the main company.

Like materials and equipment purchases, the relative share of labor costs varies based on ship type and country, but typically falls in the range of 15-30% (IBIS, 2016; Korean Shipbuilding Stakeholders, 2017; Philippines Shipbuilding Stakeholders, 2016). Generally, ships with a higher share of material versus equipment costs will require more labor (i.e., bulkers, containerships).

Table 4-13. Employee Profile for the Shipbuilding Assembly

Position	Share	Median Hourly Wage (US$)	Education	Job Characteristics
Production/ Assembly	71%	$22	High school and technical college	Production, Construction, and Maintenance, including Welders, Crane Operators, Steel

[25] http://www.maritimelawcenter.com/html/the_jones_act.html

[26] For example, in Japan the limitations on foreign vessels in these waters is defended as protecting the domestic shipping industry from foreign competition, preserving domestically owned shipping infrastructure for national security purposes, and ensuring safety in congested territorial waters (JFCSA, 2011). The restrictions also may guarantee work for domestic shipyards if ships built in the country are required (UNCTAD, 2016b).

Position	Share	Median Hourly Wage (US$)	Education	Job Characteristics
				Cutters, Outfitters, Painters
Engineers	11%	$34	Technical, college, and/or post-graduate education	Engineers (electrical, mechanical, marine, naval architects; design (CAD))
Administrative	13%	$25	Technical, college, and/or post-graduate education	Business and financial operations, office and administrative support, sales & marketing
Managerial	4%	$53	Post-graduate	Management occupations
Subcontractors	*46%*			Approx. share of employment; primarily from production workers

Source: wage and share data based on BLS (2015). Occupational breakdown is similar for Korea based on data from KOSHIPA (2001-2015). Subcontractor share based on Japanese data from IHS (2009-2016).

Shipyard workers are needed to perform a variety of different tasks including welding (blocks and pipes), fitting (pipe fitting/ship outfitting), painting, masonry/carpentry, electrical work, and plumbing. The types of workers needed to build a ship are like those in the construction industry, and to a lesser extent other transportation equipment such as automobiles, airplanes, or trains and skills are thus relatively transferable across industries. Given the importance of regulations and safety in shipbuilding and all transportation industries, workers must demonstrate their ability to perform to standard operating procedures for specific tasks (i.e., welding) and employers are required to maintain documents proving their capabilities. For example, welds must be certified as being completed by a certified welder and following approved welding procedure specifications (WPS).[27] The specific qualifications of certified welders are determined by the classification society, but generally, certification requires the welder to produce test welds of acceptable quality, which are then subjected to visual examination, non-destructive testing (NDT), and mechanical testing. IACS and DNV require that welders are qualified to society recognized standards[28] Welders qualified for more difficult welds are also approved for easier welds. As such, training and workforce development are important for shipyards building and repairing IACS vessels. However, specific workforce qualification requirements are changing along with the introduction of new technologies; for example, as welding becomes more automated and mechanized, welding operators of mechanized or automated processes do not need to pass approval testing as long as they maintain records exhibiting their proficiency in programming and operating the equipment (Moore, 2009).

Box 4-2. Workforce Development in Singapore's Shipbuilding Sector

In Singapore, the shipbuilding sector is hallmarked by a strong training culture with multi-stakeholder support. Major shipyards and marine companies have invested in training infrastructure and resources in-house to ensure that workers are trained and reskilled

[27] WPS is a document providing in detail the required variables for specific application to assure repeatability by properly trained welders

[28] EN 287 (standard for welding steel) has been replaced with ISO 9606 covering a variety of metals as of October 2015 and is now more similar to ASME Section IX. (www.twi-global.com/technical-knowledge/job-knowledge/a-comparison-of-bs-en-287-part-12011-with-bs-en-iso-9606-part-1-130/) ASME IX (arc welds) and AWS D1.1 (laser welds) cover different types of welds. A good description of Section IX and ANSI/DWS D1.1 is offered by www.thefabricator.com/article/shopmanagement/asme-and-aws-welding-codes-similarities-and-differences

continuously to keep up with changing requirements to execute work safely. Key industry players worked with the Association of Singapore Marine Industries (ASMI) to set competency standards, develop generic curriculum for training marine workers and supervisors as well as certify workers' skill competency.

In recent years, academic courses on marine and offshore technology have been introduced at the technical, diploma and degree levels to ensure a continuous pipeline of trained manpower to support the sector's specialized manpower needs. ASMI continues to partner with key industry players to offer scholarships to students enrolled in relevant courses at the technical institutes, polytechnics and universities. This collective offering of scholarships is aimed at attracting more talents to join the industry as well as to groom competent leaders for the future (ASMI, 2014).

4.1.8. Upgrading Trajectories in the Shipbuilding GVC

Upgrading in the shipbuilding GVC can be analyzed in two ways. The first approach is to define the level of sophistication and capability of a company, or portfolio of firms in a country, within a segment of the value chain as low, medium, or high, and to find pathways to increase the level of sophistication of the firm, or portfolio of firms in a country, within a value chain segment. The second is to look across the entire value chain of a product and identify ways to achieve product, process, functional, and inter-sectoral upgrading of the value chain by a firm or portfolio of firms in a country.

Increased Sophistication within a Value Chain Segment
In pre-production segments, upgrading requires improvements in research, design and purchasing capabilities. Within **design**, the challenge is moving from the design of relatively simple components, to the design of systems with multiple components, to the design of ships with multiple systems, and from there to the design of increasingly more sophisticated vessels. For example, upgrading in design would move from the design of bulkers – considered relatively simple commercial vessels -- to passenger vessels and icebreakers, which are some of the most sophisticated. In the **research** segment, firms with low levels of capability engage in incremental innovation, adding simple customization to existing products, such as redesigning existing ships for conversion and refitting. Firms with a medium level of sophistication in research could design a new hull with increased efficiency or sturdiness; for example, STX Canada Marine's (now Vard Marine) design of Canada's Icebreaker. Firms with high levels of research capabilities create new products. For example, Akzo Nobel/International Paints (NL) developed new, biocide-free antifouling paints with extremely slippery surfaces, thus limiting the ability of fouling organisms to grow on the hull and increasing fuel efficiency.[29] The **purchasing** capabilities of companies can also be tracked along a continuum of less to more sophisticated supply chain management practices. Companies with a high level of sophistication search for global component suppliers and evaluate them using balanced scorecards to determine ongoing suitability for inclusion in their supply chain.

[29] http://www.international-marine.com/foulrelease/foul-release-home.aspx

Within **production**, firms can be evaluated based on the type of commercial vessel they produce. Fincanteiri (IT), a well-known cruise ship designer and shipbuilder, is constructing some of the newest and most sophisticated passenger vessels around the world for Carnival and Norwegian Cruise Lines. Each ship requires sophisticated design and engineering with very high levels of customization. In contrast, China's Yangzhou Guoyu Shipbuilding Company produces relatively simple cargo vessels and bulk carriers that contain few modifications from ship to ship. These vessels are much simpler to produce, requiring little innovative production techniques or sophisticated integration. A third category of vessels, offshore vessels, can range from very simple (supply vessels) to highly complex (drill ships). Due to their broad range of sophistication, shipbuilders of a variety of capabilities can participate in this segment of the market, eventually increasing the range of products provided by increasing their capability in the market segment.

In **post-production**, companies provide a range of maintenance, repair and overhaul (MRO) services to in-service vessels to ensure that they remain compliant with regulations. Shipyards and service providers within this segment can be distinguished by the types of vessels and systems they are qualified to work on. Highly capable companies work on complex systems and vessels, while less capable companies work on less sophisticated ones. As noted in the standards and institutions section, shipyards specializing in ISS and MRO must be capable of meeting classification society requirements for the ship class, which generally requires the ability to meet new construction welding processes. Interestingly, in the final stage, shipbreaking, many of the South Asian countries with extensive experience in shipbreaking are now starting to develop their own shipbuilding industries (Johari, 2011). Thus, shipbreaking can be a pathway into shipbuilding. Table 4-14 summarizes how companies can upgrade capabilities within each segment of the shipbuilding value chain.

Table 4-14. Capability Upgrading in the Shipbuilding GVC

Stage	Value Chain Segment	Capability Level	Activity	Example
Pre-production	Research & Design	Low	Product design modification and customization	Re-designing ships for conversion and refitting
		Medium	Applied research and new product design	Developing a new hull design with advanced capability or efficiency
		High	Basic nautical research	Conducting scientific research to develop new anti-fouling coatings
	Purchasing	Low	Local search for supply chain partners	Shipbuilder identifies outfitting contractors within 20 km of plant
		Medium	Local and regional search for supply chain partners + practice of simple supply chain management practices	Shipbuilder scans for regional outfitting contractors and maintains informal quality assessments of suppliers
		High	Regional and/or global search for supply chain partners + sophisticated supply chain management practices	Shipbuilder seeks "best in class" component producers and evaluates suppliers with balanced scorecards
Production	Production	Low	Construction + assembly of simple vessels	Cargo vessels and bulk carriers
		Medium	Block construction + assembly for moderately complex vessels	Producing moderately sophisticated ships (oil tankers; RoRos)
		High	Fully integrated block construction + assembly for	Producing sophisticated passenger ships (cruise ships) or military vessels (frigates; aircraft

Stage	Value Chain Segment	Capability Level	Activity	Example
			complex vessels	carriers)
Post-production	Marketing, distribution and post-production services	Low	Domestic distribution + MRO	Domestic distribution and MRO repair network for locally owned and operated commercial vessels
		Medium	Domestic + regional distribution and MRO	Regional distribution of assembled vessels and providing MRO for regionally-owned and operated commercial + passenger vessels
		High	Domestic + regional + international distribution and MRO activities + advanced post-production services, such as consulting & training	Global export of assembled vessels; providing MRO for globally-owned and operated commercial/passenger or sophisticated military vessels; providing post-production services for commercial/passenger + military vessels

Source: Authors; adapted from Brun et al. (2012)

Value Chain Upgrading

A second path to upgrading is to distinguish between product, process, functional, and intersectoral upgrading of the value chain.

- **Entry** into the value chain is a necessary precondition to upgrading and exemplified by a firm entering the shipbuilding segment and offering a simple product or service within the shipbuilding industry. Examples could include companies producing a simple boat placed on a larger seagoing vessel, or offering welding subcontractor services. In either case, the focus of the firm is narrow to provide a product or service to a specific customer or end market in the sector.
- In **process upgrading**, a firm produces a product or service more efficiently. For example, some shipbuilders adopted robotic plasma steel plate-cutting to improve cutting quality, speed, and waste reduction. In-sourcing and outsourcing decisions are also examples of process upgrading practices.
- The purpose of **product upgrading** is to increase the value of the good or service produced by a firm. For example, a firm could produce a more durable product or provide a service requiring advanced engineering capabilities more valued in the marketplace.
- Upgrading can also be achieved by establishing additional **backward linkages** in the production-related segments of the chain. An example would be if a ship assembly facility or country establishes a local engine, steel or propeller manufacturing operation (typically via FDI).
- In **functional upgrading**, a firm enters new segments of the value chain. Examples include adding maintenance services to existing product offerings. For example, a company may start in ship repair or as a contract manufacturer, but over time takes on additional responsibilities such as input purchasing, logistics, NPD, or marketing.
- Finally, **intersectoral upgrading** occurs when a firm enters a new GVC based on the skills learned in the shipbuilding industry (i.e., entering the energy production GVC).

Figure 4-10. Types of Upgrading in the Shipbuilding Value Chain

	Value Chain Segments	Description	Example

	Value Chain Segments	Description	Example
Entry	Production, Services	• Firm offers basic shipbuilding services. • Focus of the company may be relatively narrow to focus on a specific customer, product, service or end-market.	• Company provides welding services for block construction. • Company provides design services for simple commercial ships.
Increasing productivity (Process Upgrading)	Purchasing, Production, Marketing, Distribution	• Company focuses on increasing the productivity of value chain segments. • Reconfigures production processes, pre- and post-production activities to become more efficient. • Outsourcing and in-sourcing are considered options for increasing productivity.	• Company reconfigures production line to improve efficiency. • Company streamlines distribution network to increase speed to market • Company outsources product design to specialized firm,
Better products or services (Product Upgrading)	Production, Services	• Company offers better, higher quality products and/or services. • Focus of the company is to increase unit value of products or services offered.	• Company produces more durable or better-designed products. • Company offers services requiring advanced engineering capabilities.
Expansion across value chain segments (Functional Upgrading)	R&D, Design, Production, Services	• Firm adds services to existing product manufacturing or adds product manufacturing to services. • Focus of the company expands to an increasing number of value chain segments, products, or services. • Company may carry out pre-production processes, such as design or product development with a major customer or research partner.	• Shipbuilder offers design or MRO services

Source: Authors; modified from Brun et al. (2012); Not pictured: intersectoral upgrading.

While listed separately above, the various types of upgrading often occur in combination. For example, Hawboldt Industries (CAN) traditionally only produced winches for shipboard use; however, due to the interest of one of its customers, International Submarine Engineering (ISE), it now designs and builds the Launch and Recovery System (LARS) for ISE's autonomous underwater vehicle (AUV).[30] In this case, Hawboldt engaged both product upgrading (making a more sophisticated product) and functional upgrading (participating in design with manufacturing).

4.2. The Asian Regional Value Chain (RVC)

Having discussed the global shipbuilding value chain, we now turn to the Asian regional value chain within the commercial shipbuilding industry. For most regions and industries, the global

[30] http://hawboldtind.com/project/launch-recovery-system-for-autonomous-underwater-vehicle-auv/

and regional value chains differ with regards to lead firms and position within the value chains. However, in the case of commercial shipbuilding, Japan, Korea, and China are both global and regional leaders and the analysis of the global industry also covers the region. As a result, much of the analysis and discussion provided in the global section is also relevant to the analysis of the region. In order to not duplicate the narrative in the global section, we more closely examine the shifting geography of commercial shipbuilding from Japan to Korea and China, paying particular attention to the relative productivity and production costs within product segments leading to the market shifts.

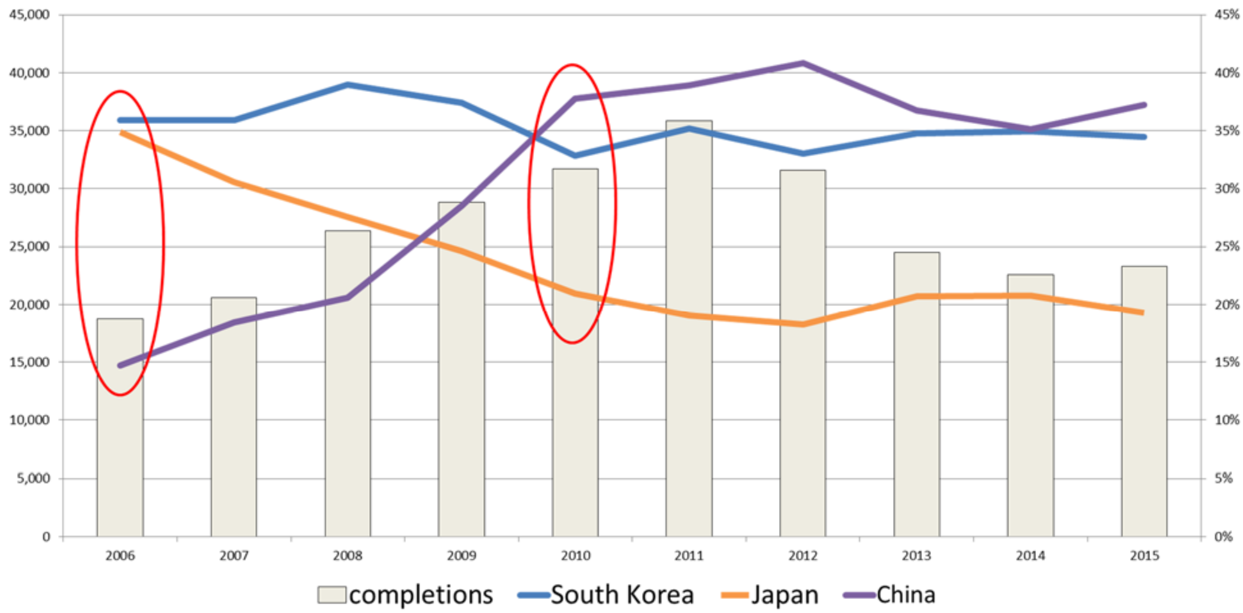
4.2.1. The Shifting Geography of the Regional Value Chain: The Rise of China

Since the advent of modern commercial shipbuilding era, the industry has been characterized by globalized sales, highly concentrated final assembly, and significant levels of state intervention. The production shifts from Western leaders to Asia, and the subsequent rise of China, occurred as high cost yards were supplanted by low cost ones, leading to intermittent periods of trade conflicts and accusations of protectionism and subsidies. During periods of crisis, in which the industry is characterized by low demand, low prices, and overcapacity, emerging shipbuilding nations have historically captured and consolidated market share as low-cost shipbuilders are better able to survive these periodic crises than higher cost builders. Korea's own industry began in a period of massive overcapacity resulting from the oil crises and aggressive price based competition during the 1970s. Likewise, China's market share growth during the 2000s is currently being consolidated during the current crisis period, and could signal another inflection point in the global shipbuilding market.

China rapidly emerged since 2000 to become the largest shipbuilding nation in the world. By 2006, it was the third largest commercial shipbuilder, producing about 15,000 thousand GT per year (circle 1 in Figure 4-11). Over the next four years, China doubled its shipbuilding activities (circle 2), surpassing both Korea and Japan to become the largest shipbuilder by volume. This remarkable growth followed the designation of shipbuilding as a strategic sector. The sector is dominated by two large state-owned shipbuilders, the China State Shipbuilding Corporation (CSSC) and the China Shipbuilding Industry Corporation (CSIC) which own approximately 26 shipyards across China, and report, as do other heavy industries in China, to the State Council through the State-owned Assets Supervision and Administration Commission (SASAC). CSSC and CSIC originated from the China State Shipbuilding Corporation in 1982, and received increased access to financing to develop and expand shipyards from a variety of sources, including state subsidies, tax exemptions, reinvested profits, and private-sector financing. Many of these supports are still in place today.[31]

[31] For an accessible history of the development of China's shipbuilding sector, please see G. Collins and M. C. Grubb (2008).

Figure 4-11. Ship Completions (in thousand GT) and Market Share, by Country 2006-2015



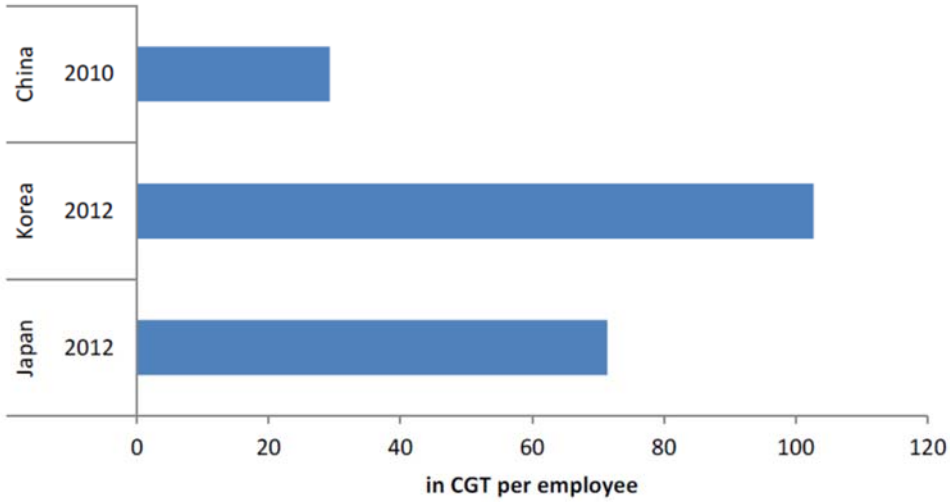
Note: Circle 1 illustrates the situation in 2006 in which China was in third place, after Japan and Korea. Circle 2 illustrates the situation in 2010 when China became the leading shipbuilding country in the world.
Source: calculated from IHS (2009-2016)

During China's tremendous growth in shipbuilding production, Korea kept pace with China as a result of its focus on higher value vessels. In contrast, Japan's output remained static and the country has lost market share. Korea continues to capture more than 30% of the total value in global shipbuilding market. From 2006-2013, Korea generally led the sector by total value captured of vessels delivered (OECD, 2015b).[32] In contrast, Japan's share in total value declined from 23% in 2007 to 14% in 2013, due largely to China's rise in the shipbuilding market. Measured on a per-vessel basis, Korea's average value per ship was US$92 million in 2013, compared to a world average value of approximately US$ 50 million. China's average per-vessel value was lowest among major shipbuilding nations (~US$45 million), while Japan averaged US$48 million. Korea was surpassed in unit values of vessels delivered only by smaller scale, specialty shipbuilders in Germany and Italy, which averaged US$175 million and US$105 million, respectively (OECD, 2015b).

China currently leads the region in building lower cost, less sophisticated ships. Although the productivity of China's shipbuilding sector is half that of Japan's and a third of Korea's (see Figure 4-12), it has significant cost advantages over Japan and Korea in building in this segment, resulting in greater profits. Calculations by Jiang et al. (2013) indicate that China has profit rates in bulk carriers and tankers around 30% greater than Korea, and between 44% (tankers) and 54% (bulkers) greater than Japan. These profit differentials become significantly greater during periods of crisis. China's profit rates relative to Korea during crises periods increase to 33% for bulkers and 39% for tankers, while for Japan they rise to 69% for tankers and 76% for bulkers. Thus, market troughs further strengthen China's shipbuilding competitiveness due to its lower shipbuilding costs in the tanker and bulker product markets.

[32] With the exception of 2012 when China narrowly received more total value than all other shipbuilding countries.

Figure 4-12. Shipbuilding Industry Productivity, China, Korea, and Japan

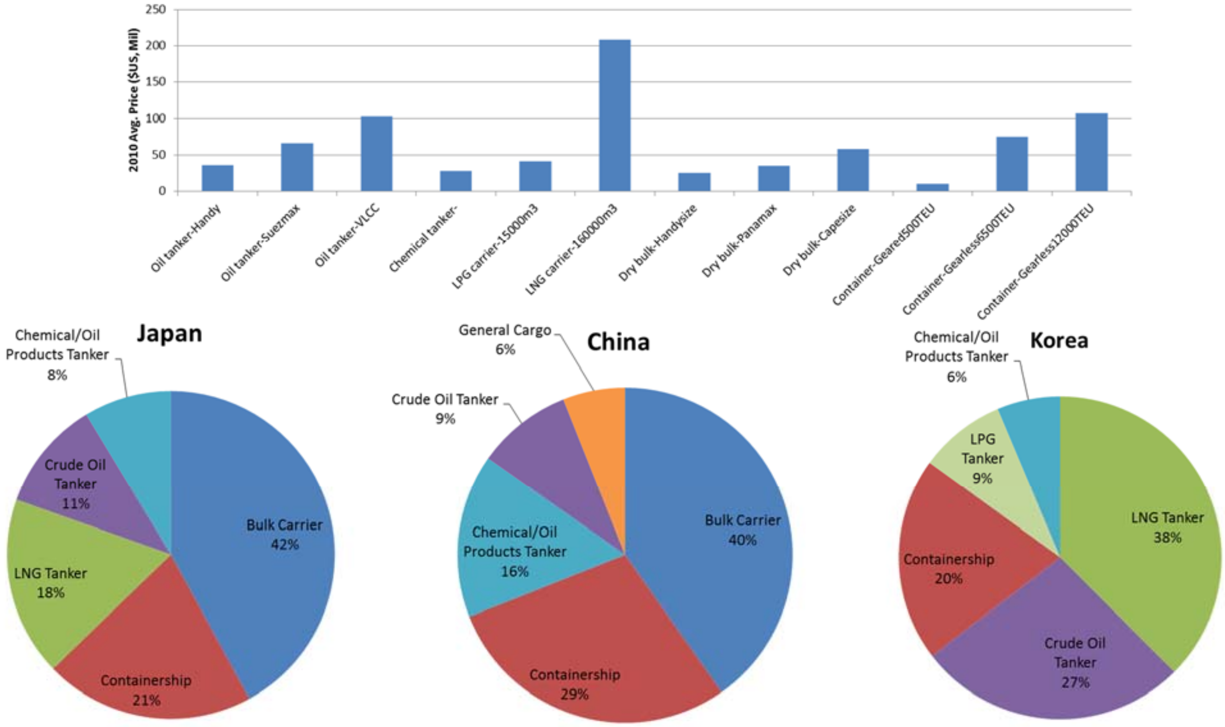


Source: OECD (2015a)

China's strategy has focused on exceling in the construction of general cargo ships and dry bulk carriers. While these are less complex vessels than those produced by Korea (see discussion on ship types in global section), they have been a traditional strength of Japan's shipbuilders. The cost differential between low costs producers in China and higher cost operations in Japan is accentuated in crises like the current period. These crises serve to make low cost producers stronger relative to higher cost producers and capture market share in product categories.

The point is underscored by the product portfolio and the value of ships produced by Japan, China, and Korea illustrated in Figure 4-13. Both China and Japan produce bulk carriers and containerships which are more commoditized, lower value ships than Korea's dominant footprint in gas carriers (LNG/LPG tankers) and crude oil tankers. Because price is a dominant competitive factor for lower value ships, China will continue to erode Japan's position in these product markets. In contrast, Korea's position in the gas carrier and tanker product markets is both a higher value category and less susceptible to price based competition due to the higher technological requirements and the "very large" nature of these ships, which China has, up to now, been unable to match. How long the dominant position of the Korean shipbuilders in these product markets will remain is uncertain, however. During our interviews with Korean shipbuilders, they noted that China has completed construction of a VLCC and has orders for both LPG and LNG tankers.

Figure 4-13. Product Portfolio and Value of Ships: Japan, China and Korea, 2010-2015



Source: Bottom calculated from IHS (2009-2016); top UNCTAD (2016b)

In the next section we more closely examine Korea's position in the shipbuilding value chain, recounting its historical development, current status, workforce profile, and examples of upgrading in the sector. In the final section, we provide our recommendations for maintaining and improving the competitiveness of the commercial shipbuilding sector in Korea.

4.3. Korea and the Shipbuilding Global Value Chain

Leading technological development in both shipbuilding and component production have allowed Korea to remain globally competitive in terms of productivity, exports, and improving the types of ships it produces. Prior to the 1970's, Korean shipbuilding was primarily concentrated in wooden ship and small fishing vessel construction; today it is a global leader in VLCCS, LNG/LPG ships, FPSOs and drillships and entering into higher cost and technologically sophisticated ice-classed and passenger vessels. It achieved this level of success by continually investing in its production facilities to make them more efficient, able to meet global demand, and be at the forefront of technology development and adoption (Sung-hyuk, 2010). Interestingly, while Brazil, Taiwan, and Korea all tried to enter the shipbuilding market during the 1970s using similar state-led development approaches and a focus on price competitiveness, only Korea was able to flourish due to its ability to maintain shipbuilding activity that was not only based on low wages but improved productivity and backward linkages (Bruno & Tenold, 2011).

Policies of the Korean government have revolved around three aspects: upgrading and maintenance of facilities, technology development, and "localization" of equipment and machineries (Mendoza, 1994). Korea created a well-developed 'cluster-type' strategy that focused on developing backward linkages to key inputs, investment in R&D and public-private research and training institutions, as well as developing horizontal linkage to similar industries in the country at the same time, notably heavy industries including automotive and construction. Today, the Korean shipyards' market share is driven by its traditional focus on producing "very large" ships combined with 1) efficient yard management, 2) access to the newest technologies through either indigenous development or licensing agreements, and 3) ability to develop and retain skilled manpower, particularly for welding work. Korean yards have robust R&D and integrated business structures that enhance the quality of the vessels built in terms of ship operating performance, fuel efficiency and technically-strong designs to meet the customized requirements of different ship owners.

The purpose of this section is to examine Korea's position in the global shipbuilding value chain by summarizing its development, current status in the industry, workforce profile and how it has upgraded throughout the years. The survey of Korea's historical development, current position, and upgrading provides a foundation for our recommendations for the future development of the sector.

4.3.1. Development

Both international and national level factors led to Korea's rapid emergence as a commercial shipbuilding powerhouse (Bruno & Tenold, 2011). Internationally, the oil crisis of the early 1970s led to a rapid decline in demand for shipbuilding, which affected high cost shipyards in Europe more than the lower-cost shipyards in Japan and Korea. Europe's main shipbuilding nations could not keep up with productivity improvements necessary to maintain their global leadership despite infusions of public funding (Bruno & Tenold, 2011). Domestically, Korea established key national policies targeting the development of heavy industries, including shipbuilding. The Third Five Year Development Plan (1972-1976) focused on heavy and chemical industrialization (HCI), which included shipbuilding, as a key objective for economic growth in Korea. HCI development was emphasized in light of the erosion of the country's competitive advantage in light manufacturing exports as labor costs increased and international competition ramped up (Bruno & Tenold, 2011). In addition, shipbuilding was prioritized in the midst of national security concerns resulting from the1969 US announcement to reduce its presence in Asian countries (the "Nixon Doctrine"), including a reduction of US troops in Korea.

The first Shipbuilding Development Plan was launched by the Korean Ministry of Trade and Industry (MTI) in 1973. The goal was to make Korea self-sufficient in vessels by 1980 and ensure that shipbuilding exports reached US$1 billion (3.2 million GT) by 1980 and US$2 billion (6.2 million GT) by 1985. The plan designated the construction of nine shipyards by 1980 and another five by 1985. To help achieve these goals, the government provided capital incentives, infrastructure, steel industry investments, trade incentives and tax holidays. The capital incentives included low nominal rates from state-owned banks, which made real interest rates for preferred sectors negative for most of the decade, as well as government guarantees for foreign loans. Complementary investments included large infrastructure programs for new facilities in both the shipbuilding and steel industry (Bruno & Tenold, 2011).

Hyundai Heavy Industries (HHI), established in 1972, was designated by the Korean government to lead shipbuilding production (Bruno & Tenold, 2011). As a *chaebol*, HHI was supported by the government to achieve a competitive level of efficiency in production, and was managed in a hierarchical, top-down, and centralized manner in close cooperation with the national government in return for the support (Hassink & Shin, 2005). By 1983, HHI had become the largest shipbuilder in the world in 1983, a position it still holds in 2017.

Shipbuilding was once-again targeted in the Fourth Five Year Development Plan (1977–81). The Development Plan emphasized the goal of producing ship components domestically and the use of government procurement to increase demand. Additional financing came from the National Investment Fund and foreign loans. Due to overcapacity and low international shipping rates during the period, the number of planned shipyards was reduced in the Development Plan from nine to two (Bruno & Tenold, 2011). Two other *chaebols*, Daewoo and Samsung, entered the shipbuilding market under the plan. In December 1978, Daewoo purchased the former Korea Shipbuilding and Engineering Corporation (KSEC) shipyards at Okp'o and completed it in January 1981. Samsung purchased the Geoje Shipyard and began shipbuilding operations in September 1979. Daewoo and Samsung also received state support in the form of preferential access to financing and lending guarantees

During this early development phase, Korean shipbuilders used technological assistance and license agreements with foreign firms to develop shipbuilding technological capacity in the country. This is seen as a critical element for upgrading the Korean shipyards (Bruno & Tenold, 2011); European shipbuilders, unable to secure new shipbuilding orders due to the shipping crises of the 1970s and early 1980s, were willing to sell technology and services to the Korean yards. HHI received dockyard designs from A&P Appledore (UK), ship designs and shipyard operation instructions from a second UK company, Scott Lithgow, and production knowledge from Kawasaki Shipbuilding (Bruno & Tenold, 2011). Samsung, Daewoo, and smaller shipbuilders in Korea signed 159 license agreements and spent US$117 million between 1962 and 1987 to develop their productive capacity (Gomes-Casseres & Lee, 1989). The agreements included access to European engineers who worked at HHI's Ulsan Shipyard for the first three years of its operation, and overseas training in shipbuilding technology and management by Appledore and Scott Lithgow.

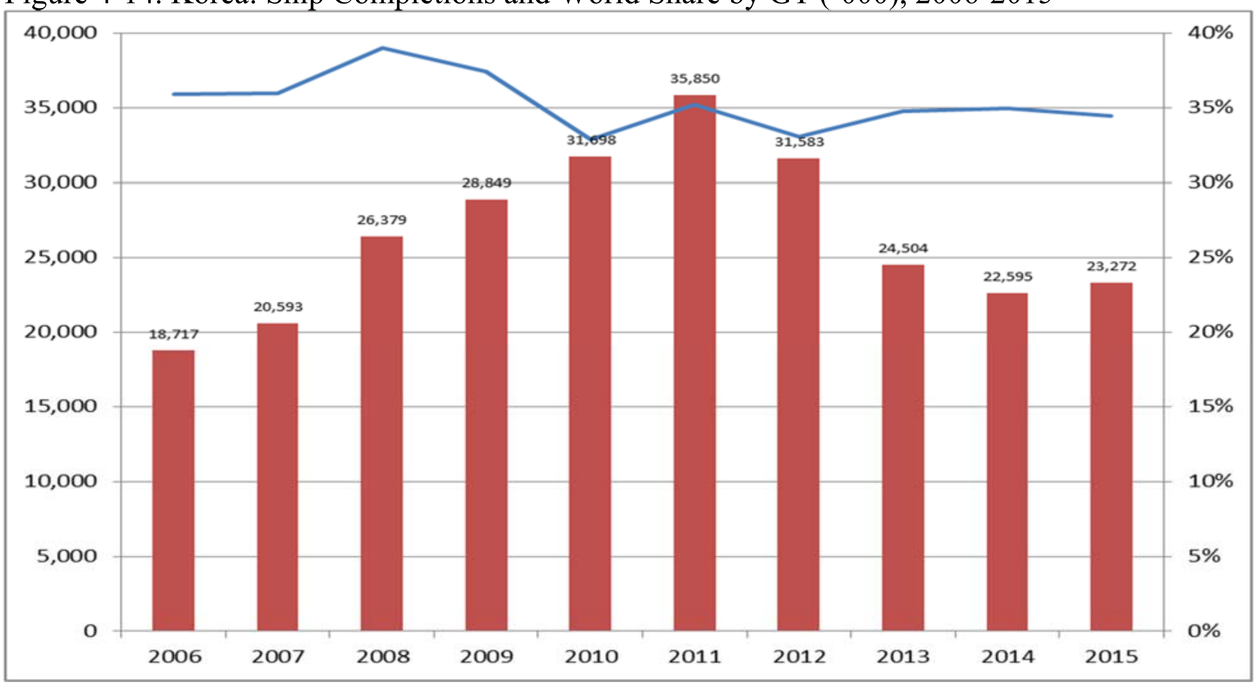
Similarly, while most shipbuilding components were imported during the 1970s and early 1980s, by the end of the 1990s, between 70-80% of components were supplied domestically (Bruno & Tenold, 2011). To achieve this level of domestic production, shipbuilders either developed in-house capabilities or used Korean component manufacturers. HHI developed, with technical assistance, licensing, and overseas training, the ability to make engines and other ship components (Amsden, 1989). Samsung used its electronics division to develop and purchase electronic component systems for its shipbuilding unit. The government also put its R&D resources behind the industry, developing components in partnership with shipbuilders and suppliers. Hyundai Mipo developed a research center in Ulsan; Samsung established a research center in Daejon, and governmental research institutes began to actively develop increased capabilities in ship component systems. The Korean Institute of Machinery and Materials (Daejon and Changwon), Pusan University's Advanced Ship Engineering Research Center, and the Korea Electronics and Telecommunications Research Institute (ETRI) have been important in developing ship systems, with ETRI leading the development of electronic devices for shipbuilding, including semiconductors, telecommunications and information technology (Shin & Hassink, 2011).

From this early stage, Korea created a shipbuilding industry that has been a cornerstone of its development and source of foreign exchange. Its cluster development approach coordinated financing, production, workforce development, and research and development to increase the Korean content of commercial vessels. In the next section we discuss the current status of the Korean shipbuilding industry before turning to it workforce and upgrading trajectories.

4.3.2. Current Status

Korea is one of the world's three major shipbuilders, competing with Japan and China for a combined 92% of 2015 global ship production (IHS, 2016). Korea consistently completes around 35% of total world ship completions (Figure 4-14). Total completions almost doubled from 2006-2011, from 18.7 million GT to 35.9 million GT when the global financial crisis affected the shipbuilding industry.

Figure 4-14. Korea: Ship Completions and World Share by GT ('000), 2006-2015



Source: IHS (2009-2016)

An important reason for Korea's continued strength in capturing value in the global shipbuilding industry is the portfolio of ships produced. Korea is particularly strong in the construction of gas carriers[33] (81% of global completions), containerships (58% of global completions), and oil tankers (53% of global completions) (Table 4-15).

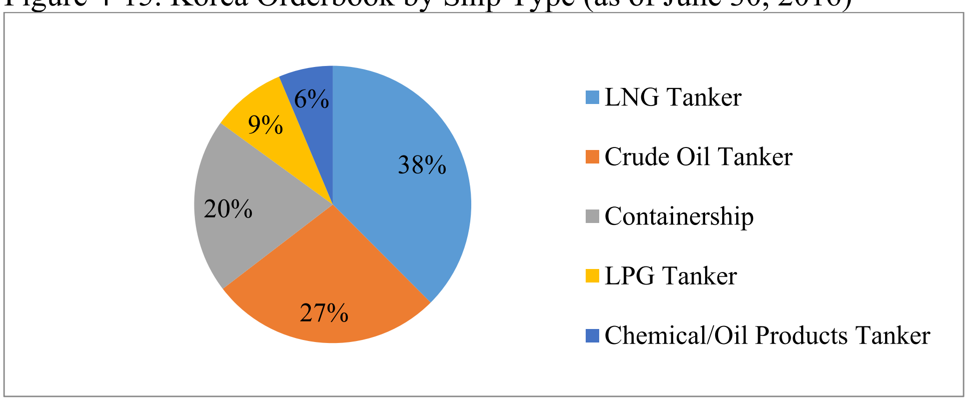
Table 4-15. Korea Ship Completions by Vessel Type, Share of World, 2015

	Korean Global Market Share
Gas carriers	81.1%
Containerships	57.8%
Oil Tankers	53.3%
Offshore	43.9%
Chemical tankers	28.7%
General cargo ships	20.4%
Bulk carriers	5.9%
Ferries and Passenger	0.6%

Source: (UNCTAD, 2016a)

From 2003 to 2013, Korea increased its share in global LNG tankers completions from 60% to 90%, LPG tankers from 27% to 62%, containerships from 42% to 68%, and oil product tankers from 21% to 50%, while minimally participating in the bulk carrier market dominated by Japan and China (OECD, 2015b). Orderbook statistics through June 2016 indicate that Korea continues to specialize in LNG tankers (32% of orderbook), crude oil tankers (23% of orderbook), and containerships (17% of orderbook), while Japan and China's orderbooks are dominated by bulk carriers and containerships (IHS, 2016).[34]

Figure 4-15. Korea Orderbook by Ship Type (as of June 30, 2016)

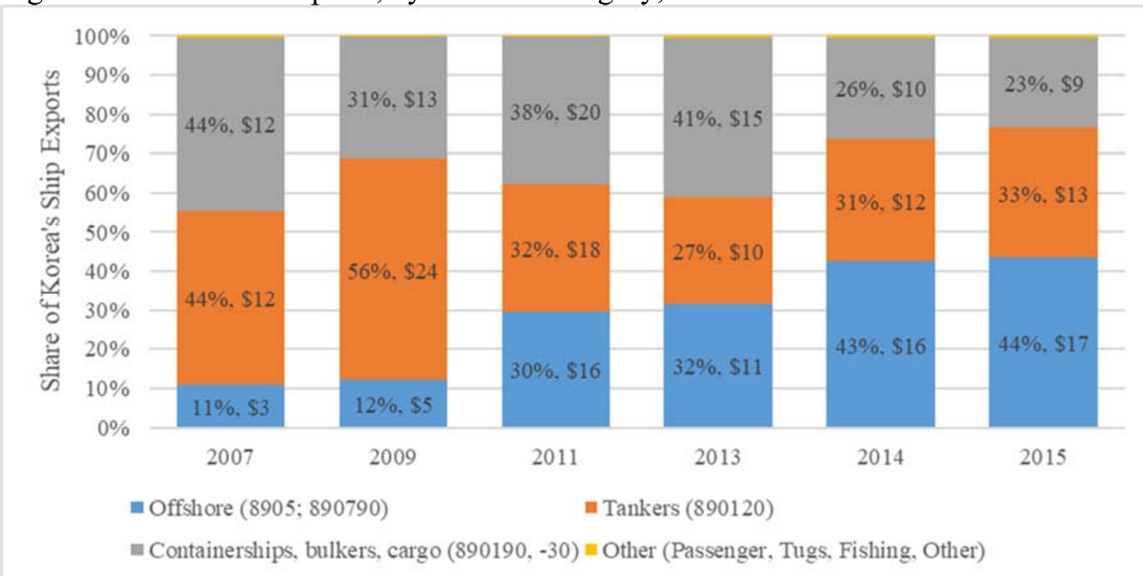


Source: IHS (2016)

Korea is primarily an exporter of offshore vessels and tankers (based on value) as well as containerships (Figure 4-15). In 2015, Korea's US$38 billion in exports accounted for 30% of world ship exports. In the same year, ships accounted for 7.3% of Korea's total exports.

[33] Especially LNG tankers. Korea regularly accounts for 90% of LNG tankers completed annually (OECD, 2015b)
[34] Top three orderbook items are Japan: 33% Bulk, 16% container, 14% LNG Tanker; China: 29% Bulk, 21% Container, 11% Chemical & Oil product tankers.

Figure 4-16. Korea's Exports, by Product Category, 2007-2015



Source: UNComtrade (2016); bars include values in billions and shares.

Firm Profile

The lead firms in Korea's shipbuilding industry are globally competitive shipbuilding conglomerates. The conglomerates own shipyards and possess networks of marine equipment manufacturers, which also include globally competitive heavy industry manufacturers. In 2012, there were 1,275 shipbuilding establishments in Korea, with output valued at US$59 billion (4% of Korea's output in 2012) (Table 4-16).

Table 4-16. Key Indicators of Shipbuilding in Korea

Variable	Year (2000-2014)															% Change	Share of Mfg.	
	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	00-12	00	12
Output (US$, Billions)	14	15	17	19	22	29	39	51	60	59	64	71	59	71	74	317%	3%	4%
Employees ('000)	77	87	86	86	90	92	104	118	128	130	132	137	131	154	154	70%	3%	5%
Establishments	761	893	900	830	808	800	1,020	1,028	1,104	1,114	--	1,286	1,275			68%	1%	1%

Source: UNIDO (1963-2014, 1985-2013, 2005-2013); Represents ISIC 351/301 (Building and repairing of ships and boat) except 2013-14 (35/30, other transport equipment). 2000-2006 based on INDSTAT4, Rev3, 2007-12 on INDSTAT4, Rev4.

Most of the shipbuilding production and output is concentrated in three shipyards. The three largest shipyards in Korea include:[35]

Hyundai Heavy Industries (HHI): HHI is the global leader in shipbuilding, routinely capturing around 10% of global orders. Although HHI can produce a variety of ship types, it mainly produces tankers, bulk carriers, and container vessels. HHI also has a specialized business

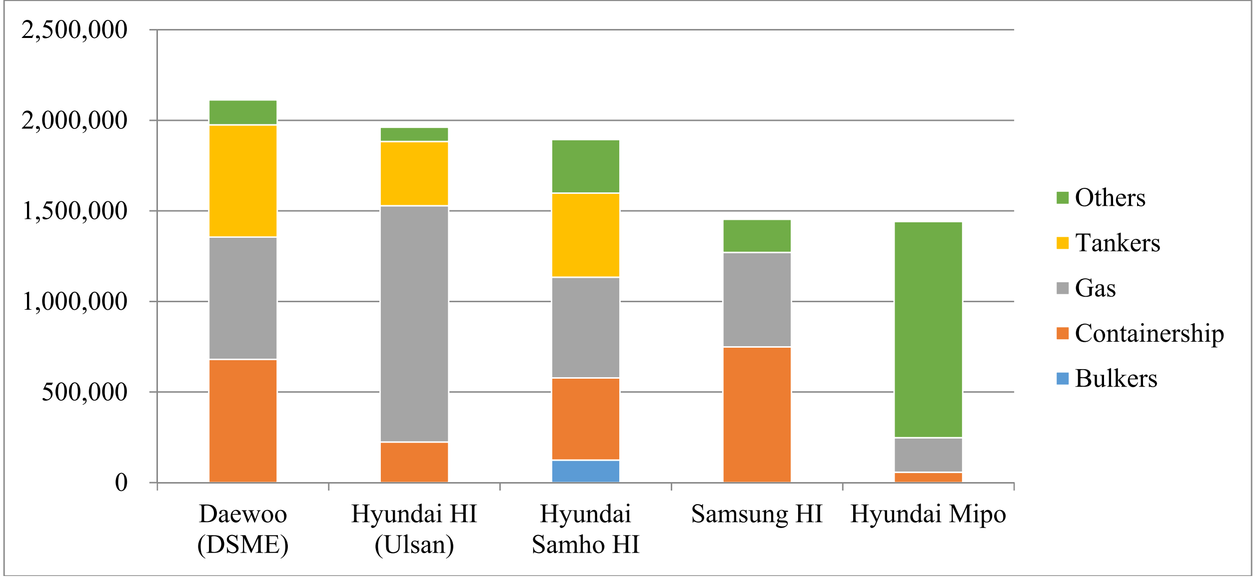
[35] Adapted from (ECORYS, 2009)

service unit for the oil extraction and production ("offshore") market. Production primarily occurs in Ulsan, with secondary yards in Samho and Gunsan, Korea. It maintains a repair yard (Vinashin) in Vietnam. HHI is largely a vertically integrated firm, with components produced internally. Engines are jointly produced by a joint venture with Wärtsilä.

Daewoo Shipbuilding & Marine Engineering (DSME): Daewoo is routinely one of the world's largest shipbuilders, capturing around 6% of total world orders. Its largest shipyard is situated in Okpo, Korea and is focused on LNG and specialized carriers. It used to own yards in China (DSME Shandong), which opened in 2005, and a facility in Europe ((Daewoo Mangalia Heavy Industries (DMHI), focused on both bulk and container carriers as well as ship repair, but which were recently sold. DSME is a vertically integrated firm, supplying most of its shipbuilding inputs internally.

Samsung Heavy Industries (SHI): SHI is one of the top three shipbuilders in the world. The company produces mostly tankers and container ships, but is also increasing production of LNG and offshore vessels. Its shipyard is in Geoje, Korea.

Figure 4-17. Vessel Completions of Major Korean Shipyards, by Type (in CGT), 2016



Note: "Others" primarily refers to the offshore market

Source: Clarkson's Shipyard Monitor, 2016

4.3.3. Workforce Profile

Employment in the industry has increased by 70% since 2000 (Table 4-16). According to the Korea Offshore & Shipbuilding Association (KOSHIPA), there were 181,239 workers in the industry in late 2015. Assuming the manufacturing profile has remained similar to 2012, this is approximately 5% of Korea's manufacturing employment (UNIDO, 2005-2013)(Table 4-17).

Table 4-17. Workforce Profile of the Shipbuilding and Offshore Industry in Korea, 2015

Position	Share	Workers
Subcontractors	70%	126,716

Technical & Skilled Workers	17%	30,060
Engineers	11%	19,401
Managerial/Administrative	3%	5,062
Total		**181,239**

Source: KOSHIPA (2001-2015)

4.3.1. Evidence of Upgrading

The traditional focus in the Korean shipbuilding industry has been on process and product upgrading, that is, improving the efficiency of the manufacturing and assembly processes and improving products. **Process upgrading** remains relevant today. Korean shipbuilders are developing and implementing shipyard improvements that optimize work flow and processes ("Smart Shipyards"), and adopting associated technologies such as welding robots to help workers assemble ever-larger ship sections more efficiently, and unmanned flatbeds and forklifts to move materials from one area of the shipyard to another. Although still progressing, the adoption of Industry 4.0 technologies in shipyards could improve shipyard efficiency by 30% (Y.Heo, 2017). To remain competitive in the face of china's low cost yards, Korea's shipbuilders are looking to optimize their use of technology to increase productivity.

Product upgrading continues to be relevant and actively pursued in three distinct senses. First, the quality of the ships continues to improve, and continues to be well-regarded in the marketplace. Korean ships are considered better built and easier to maintain than Chinese ships. Second, products are being improved through the introduction of ICT to improve ship operation and navigation efficiency, which may reduce the number of personnel needed on commercial vessels, offering significant value and cost savings to shipowners and positioning the Korean industry for continued growth. The development and adoption of "Smart Ship" technologies continue to add value to the brand and reputation of Korean shipbuilders even though full implementation of driverless ships is still in the future. Third, Korean shipbuilders continue to dominate product categories that are particularly high value, such as gas carriers and FPSOs, that are financially profitable and highly sophisticated. FSRUs used for South Asian energy production are also an important offshore product category for Korean shipbuilders.[36] Deepwater offshore oil platforms, while not pursued by all three major shipbuilders at present due to different perceptions of product market risk, are an additional area for product upgrading identified in government documents.[37]

In addition, Korean shipbuilders are developing the technical capability to enter new product markets. For example, Korean shipbuilders have active plans to modify roll-on/roll-off passenger ferries (RoPax) for the growing Chinese cruise market segment, and are active, though not dominate, in ice-classed commercial vessels led by Norway. Workforce development strategies that address shipbuilders' needs as they pursue these upgrading initiatives will be particularly important in light of Industry 4.0 trends KISTEP (2017).

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[36] See for example, www.lngworldnews.com/excelerate-lines-up-seven-fsrus-at-dsme/ and www.lngworldnews.com/industry-majors-join-forces-on-pakistan-fsru-project/

[37] See KMTI "Future Growth Engine Comprehensive Action Plan 2016"

Korean shipbuilders have also engaged in **backward linkages** and **functional upgrading**. Shipbuilders are aggressively working on increasing backward linkages to enhance the domestic content of commercial ships in different product categories. Notably, in component system product categories where the domestic content is low, as, for example, cryogenic pressurized systems needed for LNG ships and LNG propulsion, Korean shipbuilders are actively conducting the R&D, material testing and partnering with technology developers to either develop domestic systems or increase the domestic content and fabrication of licensed technology. Government support through business-government consortia like Union for LNG that includes shipbuilders and component manufacturers have been effective historically in developing competitive domestic component systems for Korean shipbuilders. Forward linkages are also being added. The after-service market is an area of focus for HHI as it expands service offerings both domestically (Busan) and abroad (Shandon, China; Singapore/Malaysia, Houston, and Dubai).

In addition, Korean shipbuilders are assisting the development of shipbuilding capacity abroad; HHI is transferring technology to Saudi Arabia to establish an offshore shipbuilding industry in the country (Reuters, 2017).

Intersectoral upgrading is an active area for Korean shipbuilders. Active cross-industry expansion into allied heavy industries is occurring, particularly in energy production. In addition to the increasing presence of Korean shipbuilders in the offshore market, especially for FPSO and FSRUs, some of Korea's conglomerates are active in expanding technology from shipbuilding sector to onshore electric power generation and construction.

4.4. Shipbuilding Recommendations

The advent of Industry 4.0 leads to additional considerations for upgrading that have not been part of the traditional focus on better processes or products as the source for competitive advantage in the shipbuilding industry. The introduction of Industry 4.0 technologies leads to four additional considerations, which we touch on here briefly:

- Product-as-service business model
- Ship finance
- Software and systems
- Monetizing data.

As discussed in the first chapter, Industry 4.0 technologies are introducing new business models in which capital equipment is seen as a service. Due to the rapidly changing technology and service requirements of Industry 4.0 capital equipment, pay-by-use and subscription services could become an attractive option for both shipowners and shipbuilders, turning capital expenditures into operational expenditures. In the shipbuilding industry, the implication of this trend is that a variety of new business models could emerge. In the traditional business model, the shipbuilder builds a ship to customer specifications and sells the ship outright to the shipowner with an industry-standard one-year warranty for product performance. In the product-as-service business model, the focus is not on selling a product to a customer, but rather selling a capability, in this example water-borne transportation services, to a customer on a subscription or per-use basis. The shipbuilder extends their responsibility and risk for product performance beyond one year in return for access to the revenue stream related to the maintenance and service of the ship and the data generated from shipborne systems. The maintenance and service revenue stream is not inconsequential; a third of the purchase price of the ship is used to keep the ship maintained and operating in good condition, assuming no major upgrades like ballast water management systems to keep the vessel compliant with regulations. By incorporating the maintenance costs into the subscription or pay by use price, the shipbuilder can capture downstream value currently abandoned.

Hybrid business models exist between the extremes of traditional product sales and the product-as-service or product-sharing model. Product sales can be bundled with warranties, service contracts or performance-based contracts in which the manufacturer maintains the responsibility and risk for product performance. In return, the manufacturer retains a close relationship with its customer and can monetize the data being generated from the ship to a variety of customers.

The shift from thinking of equipment as a capital cost to an operations costs is a major change in the way capital equipment (including heavy industrial and manufacturing equipment) producers and their customers relate to one another. It is rapidly changing the automotive industry and could have similar effects in the shipbuilding industry. The new business models have consequences for ship finance, but new approaches – such as those developed by Japan's Joint Ownership Shipbuilding Scheme and China's ICBC Leasing Scheme are good models to evaluate.[38]

More generally, as sensors and communication capabilities are embedded in products, they can be used to create system platforms of similar products, optimize their individual or combined use, or be sold to develop new information products to new customers. For example, data on fuel efficiency of a ship under different operating conditions could be valuable to a number of potential customers, including other shipbuilders and shipping companies. Data on how, when, and where the product is used could be valuable to shipbuilders to better segment customers, customize features and provide specialized service plans or discounts for additional products. The increasing value of data further supports the shift to a product-as-service business model as this offers the opportunity to collect longitudinal data on the ships operations.

Operating systems are becoming essential platforms in a variety of products, leading to the entrance of new suppliers that have core capabilities in software and electronic systems integration. As commercial vessels become more sophisticated, will Korean shipbuilders outsource the development of these operating systems, or develop them internally? If outsourced, operating system developers could begin to commoditize the ships as functioning and performance is less dependent on mechanical systems and more dependent on the interoperability of internal systems and coordination with external communication and control systems. If internalized, it will require enhanced capability and concomitant resource dedication to ensure that operating systems are interoperable and secure. Potential lessons could be learned from the automotive industry about how best to develop software systems that meet the performance and operating requirements.

[38] For the ICBC Leasing Scheme, please see a number of conferences held on the topic by Marine Money, including a recent presentation: https://www.marinemoney.com/sites/marinemoney.com/files/1525%20Interview.mp3).

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Appendix

Table A-4-1. Shipbuilding HS Codes by Value Chain Stage

Shipbuilding Final Products, HS02 Codes & World Export Statistics, 2015

Category	HS02 Codes	World Exports (US$, B)
Total		**$117**
Containerships, bulkers, cargo		**$44**
Other goods carriers (e.g., containerships)	890190	$44
Refrigerated vessels (reefers)	890130	$0.1
Tankers	890120	$22
Offshore		**$36**
Floating structures: rafts, tanks, coffer-dams, landing-stages, buoys, beacons	890790	$1
Construction: dredgers	890510	$1
Drilling/production platforms	890520	$11
Light-vessels, fire-floats, floating cranes; other vessels of which navigability is subsidiary to their main function; floating docks	890590	$22
Passenger ships	890110	$5
Other		**$10**
Tugs and pusher craft	8904	$5
Fishing	8902	$2
Other vessels (life boats)	890690	$4

Shipbuilding Subassemblies, Components & Raw Materials, HS02 Codes

System/VC Stage	Ship-Specific	Item	HS02 Codes
Platform: Propulsion	Yes	Turbines for marine propulsion	840610*
		Marine propulsion engines: -Spark-ignition reciprocating or rotary internal combustion piston engines -Outboard motors/Other	840721 840729
		Compression-ignition internal combustion piston engines (diesel or semi-diesel engines)/Marine propulsion engines	840810
	No	Nuclear reactors, boilers, machinery and mechanical appliances/Other engines and motors/Hydraulic power/Other Hydro-jet engines for marine propulsion code ended in .40	841229
		Parts for use with engines of heading 84.07 or 84.08 /Other/for use with spark-ignition internal combustion piston engines	840991
		Parts/applies to ships and auto for engines other than internal combustion	840999
Mechanical	Yes	Propeller & blades (Note: 848710 in HS07-12)	848510
	No	Other machinery self-propelled, other; 4D lists ship derrick (crane)	842649*
Navigation & Communication	No	Radar, radio navigational aid apparatus and radio remote control	8526
		Surveying, hydrographic, oceanographic, hydrological, meteorological or geophysical instruments and appliances	9015
		Navigation-related	901480* 901490*
Hull/ Raw Materials	No	Steel (iron & non-alloy steel)	7206-7217
		Tubes & pipes & fitting	7303-7307

Source: Authors; see Gereffi et al. (2012) for an earlier version; (*) code was not included in it, but added here.

Table A-4-2. Delivery of Newbuilds by Vessel Type and Country of Build, 2015

Type	**Gross Tons (millions)**						**Country's Share of World (%)**					**Vessel Type Share of Country's GT (%)**					
	China	**Japan**	**Korea**	**Phil**	**ROW**	**Total**	**China**	**Japan**	**Korea**	**Phil.**	**ROW**	**China**	**Japan**	**Korea**	**Phil.**	**ROW**	**Total**
Total	**23.1**	**13.4**	**22.0**	**1.9**	**3.8**	**64.1**	**36**	**21**	**34**	**3**	**6**						
Bulk carriers	13.3	10.8	1.6	0.9	0.2	26.8	50	40	6	3	1	58	81	7	47	6	42
Containerships	5.0	0.2	9.3	1.0	0.6	16.1	31	1	58	6	4	22	1	42	53	17	25
General cargo	0.7	0.2	0.3	0.0	0.4	1.6	43	12	20	0	24	3	1	1	0	10	3
Oil tankers	2.9	0.9	4.8	0.0	0.4	9.0	32	10	53	0	5	12	7	22	0	11	14
Other ships (if looking at UNCTAD vessel groupings data, all below are under "other")																	
Gas carriers	0.1	0.7	3.4	0.0	0.0	4.2	3	16	81	0	0	1	5	16	0	0	7
Chemical tankers	0.2	0.2	0.2	0.0	0.1	0.6	23	30	29	0	18	1	1	1	0	3	1
Offshore	0.9	0.0	1.5	0.0	1.0	3.4	25	1	44	0	29	4	0	7	0	26	5
Ferries and Passenger	0.1	0.0	0.0	0.0	0.8	0.9	11	3	1	0	85	0	0	0	0	21	1
Other	0.0	0.4	0.8	0.0	0.2	1.5	3	27	57	0	13	0	3	4	0	5	2
Containership, bulkers, cargo	19.0	11.2	11.2	1.9	1.3	44.5	43	25	25	4	3	82	83	51	100	33	69
Tankers	3.1	1.8	8.4	0.0	0.6	13.8	23	13	61	0	4	14	13	38	0	15	22

Source: UNCTAD (2016b); UNCTAD secretariat calculations, based on data from Clarkson. Note: covers propelled seagoing merchant vessels of 100GT+.

Table A-4-3. Supporting Shipbuilding-Specific Stakeholders in Korea by Focus Area

Name	**Abbreviation**	**Focus**	**Location (City)**
Korea Marine Equipment Association	KOMEA	Industry Association	Seoul
Korea Marine Equipment Global Service Center	KOMEC	Industry Association	Busan
Korea Offshore & Shipbuilding Association	KOSHIPA	Industry Association	Seoul
Korea Research Institute of Ships & Ocean Engineering	KRISCO	Research	Daejeon
Korea Shipbuilding Industry Cooperative	KOSIC		Seoul
Korean Register of Shipping	KRS	Classification Society	Busan
The Society of Naval Architects of Korea	SNAK	Professional Society	Seoul
Korea Marine Equipment Research Institute	KOMERI	Research	Busan
The Korea Shipowners' Association		Industry Association	Seoul