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Ming Dynasty Shipbuilding Technology From the *Chronicle of Longjiang Shipyard*: Based on the Theoretical System of Traditional Designology in China

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ABSTRACT

Taking the Ming Dynasty classic *Chronicle of Longjiang Shipyard* as the research object, this study analyzes the shipbuilding techniques of gongjiang, the types of ships, and the materials, labor, and management systems used in their production, in order to clarify the institutional factors that influenced the development of shipbuilding technology in the Ming Dynasty in China. Research Perspective: This study examines the shipbuilding technology and management systems of the Ming Dynasty in China from the perspective of traditional Chinese design theory. This study uses hermeneutics as the core method, combined with interdisciplinary research. Research Conclusion: "Longjiang Shipyard Records" provides a comprehensive perspective for studying the shipbuilding industry in the Ming Dynasty. Among them, the theoreticalization of shipbuilding technology and the systematization of the shipbuilding industry management system are the internal driving forces that promote the development of shipbuilding technology in the Ming Dynasty in China, and are the most intuitive manifestation of the technological development characteristics of gongjiang in the Ming Dynasty under the core ideas of Zhou Yi and Zhou Li.

Keywords: *Chronicle of Longjiang Shipyard*, Theoreticalization of technology, Systematization of management

INTRODUCTION

The Longjiang Shipyard in Nanjing, China, was an important official shipyard during the Ming Dynasty, built in the early years of Emperor Hongwu's reign (approximately the end of the 14th century). It is located near Longjiang Pass in the Gulou District of Nanjing City and is vast in scale, divided into two parts: the southern part is called the front yard and the northern part is called the back yard. The Longjiang Shipyard played an important role in the shipbuilding industry during the Ming Dynasty, especially during Zheng He's voyages to the Western Seas, where most of Zheng He's treasure ships were built at the Longjiang Shipyard. These ships were large in scale, well-equipped, and had a strict navigation organization. In the mid-Ming Dynasty, the Longjiang Shipyard began to decline, with a

decrease in the number of gongjiang and the gradual loss of shipbuilding technology. Despite this, the ruins of the Longjiang Shipyard still provide valuable information for studying ancient Chinese shipbuilding technology.

Chronicle of Longjiang Shipyard is an important classic written by Li Zhaoxiang in the Ming Dynasty, completed in the thirty-second year of the Jiajing era (1553). This book meticulously records the history, scale, and shipbuilding conditions of the Nanjing Longjiang Shipyard. The term "Chronicle" refers to "narratives" or "records," representing a systematic documentation of various aspects of the Nanjing Longjiang Shipyard. Li Zhaoxiang, who once oversaw the Longjiang Shipyard, included numerous materials about the shipyard in his book, which is divided into eight volumes: Training Code, Boat and Canoe, Government Affairs, Establishment, Finance,Reform,Assessment and Literature.

The fundamental form of the traditional Chinese design theory system is the Kaogongology design philosophy centered around the systems of *Zhou Yi* and *Zhou Li*. The *Zhou Yi* system primarily emphasizes the natural concept of Yin and Yang, while the *Zhou Li* system highlights the artificial concept of the Five Elements, which pertains to social order. These are the most fundamental and essential ideas in Chinese culture, both of which are indispensable and collectively referred to as Yin-Yang and Five Elements philosophy. This paper uses this as the fundamental logic to explore the institutional factors influencing the development of shipbuilding technology in the *Chronicle of Longjiang Shipyard*, focusing on the theoreticalization of shipbuilding technology and the systematization of the shipbuilding industry management. Of course, there are many other aspects that are not discussed in detail here.

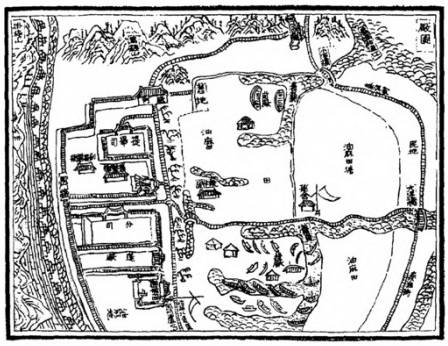


Figure 1: The map of the site of Longjiang Shipyard (Li, 2019).

THEORETICALIZATION OF SHIPBUILDING TECHNOLOGY

This chapter will thoroughly discuss the theoretical underpinnings of shipbuilding technology from three perspectives: production quota, equipment quantity, and graphical representation. The main content encompasses two aspects: the types and specifications of ships, and the internal and external structural design of ships.

Vessel Type and Specification

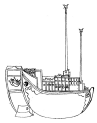
According to the *Chronicle of Longjiang Shipyard*, the scale of shipbuilding during the Ming Dynasty reached the zenith of ancient Chinese shipbuilding history. This was exceedingly rare in traditional Chinese society, where handicraft workshops and material warehouses complementing the shipyards were also fully equipped.Many large-scale ships were constructed under these conditions, and correspondingly, the larger the ship, the higher the demand for skilled gongjiang. Specifically, this book categorizes the ship types built during the Ming Dynasty in China into three major groups and twenty-seven types, including the preparatory large yellow ship, large yellow ship (flat and shallow), small yellow ship, four-hundred-ton warship, two-hundred-ton warship, one-hundred-and-fifty-ton warship, one-hundred-ton warship, three-plank ship (rowing boat), floating bridge ship, four-hundred-ton patrol ship, two-hundred-ton single-stamp patrol ship, two-hundred-ton sand patrol ship, Jiujiang-style sentry ship, Anqing-style sentry ship (Dashengguan sentry ship), light and shallow convenient ship, Jinshuihe fishing boat, Houhu No. 1 floor ship, Houhu No. 2 floor ship, Houhu flat ship, pumping seat ship, fast ship, centipede ship, sea ship, and two-ended ship. These ship types demonstrate the diversity and advancement of shipbuilding technology during the Ming Dynasty. Ship parameters are recorded using the measurement system of the Ming Dynasty in China. In designing ship types, various scales and parameters are determined according to the ship's functions, including ship length, beam, and depth, among others. Specific details are as follows:

Table 1. Types, specifications, and diagrams of ships. (Li, 2019).

Serial Number	Ship Type	Captain (cun)	Ship Width (cun)	Ship Depth (cun)	Ship Diagram
1	Prepare Dahuang Ship	793	150	62	
2	Dahuang Ship	840	144	53	
3	Small Dahuang Ship	795	150	52	
4	400-ton Warship	895	65	60	

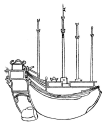
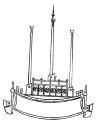
(Continued)

Table 1. Continued

Serial Number	Ship Type	Captain (cun)	Ship Width (cun)	Ship Depth (cun)	Ship Diagram
5	200-ton Warship	608	126	45	
6	150-ton Warship	550	101	36	
7	100-ton Warship	492	81	37	
8	Three-board Ship	395	84	31.5	
9	Floating-bridge Ship	602	105	46	
10	400-ton Patrol Ship	680	156	52	
11	200-ton Patrol Ship	587	120	40	
12	200-ton Sand Patrol Ship	610	123	42	
13	Jiujiang-style Sentinel Ship	370	67	27	
14	Anqing-style Sentinel Ship	341	64	24	
15	Light and Shallow-draft Boat	560	100	34	

(Continued)

Table 1. Continued

Serial Number	Ship Type	Captain (cun)	Ship Width (cun)	Ship Depth (cun)	Ship Diagram
16	Jinshuihe Fishing Boat	223	40	1.5	
17	Houhu No.1 Building Boat	505	110	206	
18	Houhu No.2 Building Boat	428	84	202	
19	Houhu Boat	392	71	203	
20	Split Seat Ship	757	156	47	
21	Clippers	——	——	——	
22	Centipede Boat	800	160	——	
23	Sea Vessel	——	——	——	
24	Two-headed Ship	——	——	——	

Ancient Chinese ships were primarily constructed from wood, with the type of wood used differing according to the ship's design and construction, predominantly including nanmu, fir, and pine. Besides the hull, ships also necessitated decoration and caulking, utilizing other materials like jute, hardware, and pigments. The following provides a brief analysis of the shipbuilding material system, centered on the *Chronicle of Longjiang Shipyard* regarding the wood requirements and standards for warships. These

three trades account for the largest timber consumption in shipbuilding, encompassing nearly all the wood utilized in the process.

Table 2. Standards for the use of wood materials in different ship types. (Li, 2019).

Ship Type Wood Usage Department		400-ton Warship	200-ton Warship	105-ton Warship	100-ton Warship
Carpenter's Workshop	Parallel-board Fang (Nanmu, veneer)	1083.64620 zhang	263.87740 zhang	267.89780 zhang	250.03680 zhang
	Parallel-board Fang (China fir,veneer)	278.16600 zhang	92.72600 zhang	57.33560 zhang	36.39500 zhang
	pine (veneer)	150.20089 zhang	178.64560 zhang	——	——
	Main Mast (China fir)	2 pieces	2 pieces	2 pieces	1 piece
	Oar (China fir)	8 pieces	6 pieces	4 pieces	2 pieces
	Pengcheng Gang (China fir)	4 pieces	2 pieces	7 pieces	4 pieces
	Zhao Gan(China fir)	1 piece	3 pieces	——	——
	Shui Qiang (mixed wood)	2 pieces	2 pieces	2 pieces	2 pieces
	Cheng Gao (Chinese fir)	16 pieces	10 pieces	6 pieces	10 pieces
	Five-sided Flagpole (Chinese fir)	16 pieces	——	——	——
	Rudder (elm)	1 piece	1 piece	1 piece	1 piece
	rudder tooth, closing rod (sandalwood)	2 pieces	2 pieces	2 pieces	2 pieces
Decoration Work Department	Fang (Chinese fir)	275.07340 zhang	123.60400 zhang	75.14780 zhang	22.51760 zhang
	Nanmu (veneer)	13.23000 zhang			

Structural Design of Ships

The structural design of ships encompasses both the external and internal structural designs. The design of a ship's structure and dimensions is a crucial determinant of its hull form.

The design of a ship's external structure encompasses dimensioning its bottom, sides, and upper surface. According to historical records, ship bottoms consist of the main bottom and the side bottoms. The main bottom is the section that keeps the ship afloat on the water surface. The side bottoms, located at the very bottom of the ship's sides, connect the bottom planks of the ship to the side planks, consisting of two plates joined together. The ship's sides are primarily constructed from rectangular planks, also referred to as "stack". The hull comprises various parts including the mud-pulling stack, water-exiting stack, middle stack, finishing stack, and foot-exiting stack, arranged from bottom to top, culminating at the beam near the ship's side. The primary upper surface of the ship is the deck, which is not a regular rectangular shape but extends from the bow to the stern on both sides. For instance, in a 400-ton warship, the deck features components such as the dare hall, lo frame, flat plate, head plate, tail plate, and lion head, according to Ming Dynasty shipbuilding terminology.

The sizing of the ship's bottom is derived from its classification. The tallest is composed of 13 wooden boards, with the number dropping by 2 for each lower category. The lowest category has a floor made of 7 boards. The sizing of the ship's bottom is an odd number, influenced by the traditional Chinese philosophy of Yin and Yang and the Five Elements centered on "Yi". Odd numbers represent "Yang", while even numbers are associated with "Yin". In traditional Chinese thought, water is considered Yin, and to support a ship, it must be balanced by "Yang". Hence, the ship's bottom is designed with only odd numbers, ensuring the vessel's safety as it sails on water.

Table 3. Quantity of wooden boards used at the bottom of different ship types. (Li, 2019).

Ship Type	Number of Main Bottom Planks (pcs)
400-ton warship	13
200-ton warship	11
150-ton warship	9
100-ton warships	7
Three-board boat	7

The internal structure of ships primarily consists of watertight compartments, which partition the ship into various-sized cabins, using bulkheads as the primary support and isolation structure. It is widely acknowledged in the academic community that China was among the earliest nations in the world to utilize watertight compartments, with designs tracing back to the Tang Dynasty. The cross-section of a watertight compartment primarily consists of the bulkhead, base beam, and surface beams beneath the bulkhead. Some ships also feature two side frame plates to bolster their robustness. Watertight compartments serve two functions: firstly, to enhance the ship's anti-sinking capabilities, and secondly, to maintain the hull's lateral strength. Significant differences exist in the approaches taken by Chinese and Western ship structures to enhance lateral pressure resistance. The lateral strength of ancient Chinese ships primarily depended on extensive bulkheads and surface beams beneath the deck, whereas ancient Western ships relied on numerous ribs to fortify the hull's interior. According to the internal structure of ships during the Ming Dynasty, the "crossbeam" was the central component. In the Ming Dynasty's ship internal structure, the "crossbeam" served as the primary component. Crossbeams were constructed to enhance the hull's lateral strength and came in many varieties. For warships, crossbeams typically comprised the following sections: the stem, the dragon mouth, the first masthead, the second masthead, the third masthead, the masthead's port, the masthead's face, the sturdy foot, the primary storage, the secondary storage, the tertiary storage, the superstructure, the main storage compartment, the secondary storage compartment, the tertiary storage compartment, the waterproof barrier, the galley, the foot brace, the bracing beam, the cantilever beam,

the tiered beam, the curved beam, the straight beam, and the compartment beam.

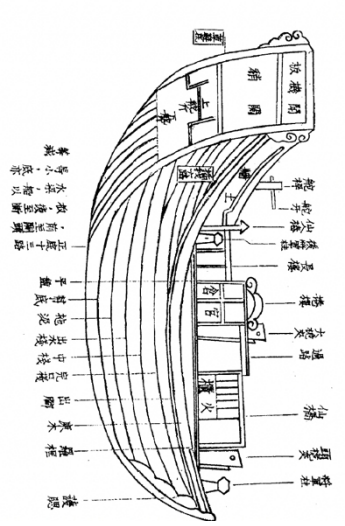


Figure 2: Schematic diagram of hull structure (Li, 2019).

SYETEMATIZATION OF SHIPBUILDING MANAGEMENT

Shipbuilding in China originated during the Qin and Han dynasties, with early explorations into standardized management. Following significant developments during the Sui and Tang, and Song and Yuan dynasties, a comprehensive standardized shipbuilding management system was established during the Ming dynasty.

Highly Refined Organizational Structure

In ancient China, gongjiang constituted the primary technical force in creation. The Ming Dynasty featured a distinct gongjiang system: gongjiang were categorized as rotating or resident, distinguished by their service models. The primary distinction between the two concerned their service duration and conditions. Rotating gongjiang served a three-year cycle, including a three-month stint in the capital (1386), which was later adjusted to a one-to-five-year rotation based on their craft type (1393). Resident gongjiang, however, were required to serve for a significantly longer period, ten days a month.

According to the *Chronicle of Longjiang Shipyard*, the shipyard boasted a highly refined organizational structure. It employed key officials including those in charge and supervisory roles, alongside fifth-grade officials from the Ministry of Works, such as the deputy minister, chief, supervisor, and assistant commander. The shipyard employed nearly 100 lower-level leaders, including compartment leaders and workshop heads. Shipbuilders and gongjiang hailed from various provinces including Zhejiang, Jiangxi, Huguang, Fujian, and Jiangsu, with both resident and rotating gongjiang. The meticulous division of labor involved four compartments, with each compartment subdivided

into ten households, each led by a head who oversaw ten households. One compartment housed shipwood, shuttle, oar, and rope gongjiang; the second housed shipwood, iron, and cable gongjiang; the third was dedicated to hull gongjiang; and the fourth to palm and canopy gongjiang. Additionally, there were officials in charge of the imperial palace, the imperial horses, spice, watchmen, bridge workers, footmen, shipbuilders, tenants, and upper-level leaders.

Meticulous Division of Gongjiang

The immense task of shipbuilding necessitates the involvement of numerous gongjiang, organized into specialized roles. The division of gongjiang's roles is a fundamental prerequisite, as specialized collaboration markedly boosts the industrial economy's production efficiency. The variety of tasks required in shipbuilding demands a high level of specialization, with each trade dedicated to distinct phases of the shipbuilding process, ultimately enhancing the efficiency of the shipbuilding endeavor. There are over thirty distinct shipbuilding trades, augmented by miscellaneous assistants in actual operations. Variations in the ship types under construction result in the employment of differing numbers and types of gongjiang. For instance, the "Longjiang Shipyard Records" details the principal trades required for the construction of five major ship types produced by the Longjiang Shipyard.

The Yellow Boat, designated for royal use with significant protocol and hierarchy, demands meticulous attention during its construction, employing the most diverse workforce, totaling 36 categories including miscellaneous roles. The War Cruiser, tasked with military security including river and sea defense, employs about 21 categories of workers. The Lake Boat, used for official daily operations, employs about 10 categories. It should be noted that the employment categories for the aforementioned ship types are derived from comprehensive statistical principles based on broad ship category classifications. Even within a specific ship category, there may be various models, each requiring different types of workers.

Table 4. Meticulous division of Gongjiang. (Li, 2019).

Ship Type	Job Types
Huang ship	Woodworking, decoration, carving, hull construction, ironwork, upper ironwork, canopy construction, ropework, upper ropework, cablework, bamboo work, painting, five-color painting, makeup carving, gold plating, flag making, drum making, shell work, tassel making, spinning, dyeing, tailoring, tin decoration, double-line work, washing work, chair threading, barrel work, copper work, sounding copper work, casting work, as well as boat wood sawyers, decoration sawyers, spring ash, tearing hemp, pulling diamond, picking up boards and other miscellaneous workers.
Battle patrol ship	ship woodwork, decoration work, carving and inlay work, cabin work, iron work, upper iron work, canopy work, rope work, cable, calligraphy, painting, five-ink painting, flag making, drum making, shell craft, tassel craft, spinning craft, dyeing, tin decoration, and double-thread craft. Additionally, there are boat wood sawyers, decoration sawyers, and other miscellaneous workers.
Hu boat	Boat woodwork, decoration work, cabin work, iron work, canopy work, rope work, paint work, five ink work, boat wood sawyers, decoration sawyers, and other miscellaneous workers.

CONCLUSION

This paper primarily explores the institutional factors influencing the development of the Ming Dynasty's shipbuilding industry through the lens of traditional Chinese design theory, without delving into the specifics of ship engineering construction. This focus is evident in two key aspects. First, the theoretical development of shipbuilding technology. Historically, China has emphasized empiricism in technological advancement, with core techniques predominantly held by gongjiang who passed them on through personal instruction, thereby constraining the ancient Chinese shipbuilding industry's growth and innovation. The "Longjiang Shipyard Records" marked a shift from an empirical to a theoretical framework in shipbuilding technology. Second, the establishment of a systematic shipbuilding management. The implementation of specialized division of labor and management systems provided vital support and assurance for the Ming Dynasty's shipbuilding industry.

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