A Study on the Shipping Accessibility between Yangpu Port and Haikou Port in China

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Abstract: *Yangpu Port and Haikou Port, as important components of the Hainan Free Trade Port, play a critical role in the regional economic development through their port layout and shipping network. This paper systematically analyzes and studies the shipping accessibility between Yangpu Port and Haikou Port, focusing on the ports' geographical locations, port conditions, spatial distribution patterns, and the factors influencing shipping accessibility. The study reveals the characteristics of Hainan's port layout and the current state of its shipping network. In the context of the construction of the Hainan Free Trade Port, researching the shipping accessibility between Yangpu Port and Haikou Port is crucial for promoting the high-quality development of the free trade port. This research is beneficial for optimizing port layout, enhancing port competitiveness, and accelerating the upgrading of international shipping hub construction. In the future, as the policies of the Hainan Free Trade Port are further implemented and economic and social development continues, the findings of this study will provide important reference and support for the sustainable development of ports in Hainan Province.*

Keywords: *Shipping Accessibility; Yangpu Port; Haikou Port; Hainan Free Trade Port*

1. Introduction

With the continuous innovation and development of the shipping policies and institutional integration of the Hainan Free Trade Port (FTP), the level of foreign trade services and its radiating capacity have been significantly enhanced, further driving the construction and development of an international shipping hub. The shipping industry shows a clear positive development trend[1] (Li, 2023). According to industry experts, the growth rate of effective capacity in the domestic container transport market is expected to reach 20% in 2024. In conclusion, Hainan's shipping industry has achieved remarkable development outcomes under the dual impetus of policy support and market opportunities. In the future, as the construction of the Hainan Free Trade Port continues to progress, the shipping industry is expected to maintain a positive growth trajectory.

Improving shipping accessibility promotes international trade development (Wei, 2022)[2]. It strengthens economic ties between countries and regions and enhances the ability to open up to the outside world. More importantly, it serves as a backbone for safeguarding national maritime security (Álvarez et al., 2021)[6] and plays a key role in the security of the dual circulation economic system (Wu, 2024)[3].

As a key pilot zone and demonstration area of the Hainan Free Trade Port, Yangpu Port benefits from its status as a national-level development zone and enjoys preferential policies for bonded areas. Haikou Port, one of the major ports in Hainan Province, serves as a critical node in Hainan's participation in the new development pattern of dual circulation and integration into regional economic cooperation. In summary, both Yangpu Port and Haikou Port play vital roles in promoting trade and logistics development, driving economic growth, enhancing regional cooperation, and improving overall competitiveness.

In summary, Yangpu Port and Haikou Port play important roles in promoting development, driving economic growth, strengthening regional cooperation, and enhancing comprehensive competitiveness. This study aims to evaluate the convenience and efficiency of shipping between two ports using accessibility and provide recommendations based on the evaluation results.

2. Review

The study of composite ports requires the establishment of a regional model chain for analysis (Santos et al., 2020)[4]. Li's (2020) study selected 41 container ports from 11 provincial-level administrative units along the coast of China as research objects[5]. By collecting port throughput and liner route data, using market concentration and complex network analysis methods, five key indicators, including market share, Hirschman Herfindahl index, Gini coefficient, accessibility efficiency, and betweenness centrality, were selected to systematically analyze the spatial distribution characteristics and shipping accessibility of China's coastal provincial combined ports under the background of policy support (Li, 2023)[2]. Wei (2022) used the gravity model of maritime accessibility measurement to analyze how the maritime accessibility of countries along the route affects the development of industrial clusters in the context of the "Maritime Silk Road"[3]. The importance of this study lies not only in providing a quantitative framework to evaluate the connectivity of maritime networks but also in exploring how this connectivity affects regional economic integration and the global competitiveness of industrial clusters. Wu (2024) focuses on China's major port shipping networks along the Maritime Silk Road[4]. She comprehensively considered the frequency of liner services and the impact of geographical location and, based on the theoretical basis of land accessibility, proposed a port sea accessibility model that incorporates weighted path factors.

However, there is a lack of comprehensive evaluation: Currently, research on the accessibility of Yangpu Port to Haikou Port mainly focuses on certain aspects, such as transportation infrastructure and modes, and lacks a comprehensive evaluation of multiple factors.:

A. Natural resources and environmental conditions: including coastline features, beach conditions, water quality, and hydrodynamic characteristics, which directly affect the accessibility of ports.

B. Port facilities and operational status: It involves factors such as port size, facility completeness, throughput, and service quality, which determine the convenience and efficiency of shipping.

C. Development level around the port: including the local economic development level, the richness of tourism resources, and the completeness of surrounding supporting facilities, these factors also affect the accessibility of shipping.

Through these specific research questions, the study of shipping accessibility from Yangpu Port to Haikou Port in Hainan Province will provide scientific basis and practical guidance for enhancing the regional and international shipping hub functions of the two ports, releasing policy dividends, reducing logistics costs, and improving logistics efficiency.

3. Shipping Accessibility Analysis

3.1 Evaluation of Shipping Accessibility of Hainan's Composite Ports

3.1.1 Natural Resources and Environmental Conditions

Yangpu Port is located northwest of Hainan Island, with a winding coastline and natural harbors that provide excellent conditions for ship docking. The geological features of the northern shores of Yangpu Bay and Xinying Bay offer natural barriers, reducing the impact of wind and waves. The harbor basin and shipping channels have a depth of over 10 meters, making it suitable for constructing deep-water berths, and it is a natural harbor of Hainan Island. The port has good protective conditions, favorable wave conditions, and, as a regular tidal port, stable tidal and current conditions, allowing for extended working hours.

Haikou Port faces the sea to the north, with a gentle 136.23 km coastline of fine white sandy beaches and clear water, making it suitable for swimming. Haikou Port's shipping channels include Xiuying Port, New Haikou Port, and Macheng Port, with comprehensive navigation facilities for day-and-night operations. The channel's seabed is composed of silt, and the design accommodates vessels of various tonnages. These favorable conditions provide Haikou Port and Yangpu Port with strong shipping accessibility, making them important maritime hubs for Hainan and southern China.

3.1.2 Port Facilities and Operational Status

Yangpu Port has enhanced its competitiveness and service level through infrastructure improvement, expanded shipping networks, and strengthened international cooperation, attracting more shipping businesses. It currently operates 48 container liner routes, including 25 foreign trade and 23 domestic

trade routes, with 3 new routes added in 2024. These improvements have bolstered the competitiveness and influence of the regional shipping hub and increased its accessibility. The port's cargo and container throughput has steadily grown, supporting the development of the shipping industry. Yangpu Port is also advancing the construction of a digital and smart port, improving operational efficiency and service quality, further boosting its shipping accessibility.

Haikou Port's shipping channels are fully equipped, ensuring day-and-night operation. Advanced loading and unloading equipment has enhanced efficiency and reduced vessel waiting times. The availability of warehouses and stacking yards ensures smooth cargo flow. Haikou Port's extensive shipping routes connect to various domestic and international locations, strengthening its accessibility. The growth of cargo and container throughput reflects the successful operation of the port, which has attracted increasing business. Through resource optimization and the "One Port, Three Areas" service model, Haikou Port has enhanced port connectivity, constructed efficient logistics corridors, and supported Hainan's open economy. These measures improve port efficiency and service quality, increasing shipping accessibility.

3.1.3 Port Surrounding Development

Yangpu Port has invested over 10 billion yuan in expanding its international container hub, entering the peak construction phase and greatly enhancing its transport and logistics capabilities. The port has launched 47 container routes, including 23 domestic and 24 international routes, covering major ports, strengthening its position as an international shipping hub. As Hainan's first national logistics hub, Yangpu Port enjoys preferential policies in the Free Trade Port, attracting shipping enterprises and facilitating the aggregation of maritime elements. The growth in cargo and foreign trade container throughput forms a positive route and cargo volume development cycle.

Through the "One Port, Three Areas" plan, Haikou Port optimizes resource allocation and contributes to the construction of Hainan's Free Trade Port. By accelerating infrastructure development, improving port connectivity, and adding direct shipping routes to Southeast Asia, South Asia, and the Middle East, Haikou Port has strengthened its ties with the Guangdong-Hong Kong-Macao Greater Bay Area and the Beibu Gulf city cluster, establishing efficient maritime logistics corridors. The growth in cargo and container throughput has driven the development of port-side industries, enhanced service capacity, and improved shipping competitiveness. Haikou Port attracts nearly 400 shipping companies and has registered over 200 ships with a total deadweight tonnage exceeding 10 million.

3.2 Analysis of the Relationship Between Shipping Accessibility and Economic Development of Hainan Free Trade Port

In order to examine the relationship between shipping accessibility and the economic development of each port area of Hainan Free Trade Port, this study combines the indicators and information mentioned above, using the port area GDP as the economic indicator and taking "A.natural resources and environmental conditions B. Port facilities and operating conditions; C. The level of development around the port has been used as an indicator of shipping accessibility, and a shipping accessibility system for the port area has been constructed (Table 1).

Table 1: Expert Evaluation Table for Shipping Accessibility Indicators

Name	Regional economy (GDP/billion yuan)	First level indicator (blue)	Secondary indicator (orange)
Haikou Port	2358.4	A. Natural resources and environmental conditions	The morphology of the A1 coastline
			Development of A2 Beach
			A3 water quality dynamic characteristics
			A4 Hydrodynamic Characteristics
		B. Port facilities and operational status	The scale of A1 Port
			A2 facility completeness level
			A3 throughput capacity
			A4 Service Level
		C. Development level around	Economic development level of A1 port location
			The richness of A2 tourism resources

		the port	The completeness of supporting facilities around A3
		A. Natural resources and environmental conditions	The morphology of the A1 coastline
			Development of A2 Beach
			A3 water quality dynamic characteristics
			A4 Hydrodynamic Characteristics
Yangpu Port		B. Port facilities and operational status	The scale of A1 Port
			A2 facility completeness level
			A3 throughput capacity
			A4 Service Level
		C. Development level around the port	Economic development level of A1 port location
			The richness of A2 tourism resources
			The completeness of supporting facilities around A3

This study invited three port experts (two maritime experts from universities and one expert with more than 5 years of work experience from a shipping company) to score the shipping accessibility of the port based on indicators, with 1 point indicating weak shipping accessibility and 5 points indicating strong shipping accessibility. This study conducted a reliability analysis on the first and second-level indicators of shipping accessibility established and the scores of three experts at the first level. The results are shown in Table 2, with a reliability coefficient value of 0.818, which is greater than 0.7, indicating that the reliability quality of the research data is acceptable. Regarding the "alpha coefficient with deleted items," the reliability coefficient does not show a significant increase after any item is deleted, indicating that the item should not be deleted. In summary, the reliability coefficient of the research data is close to 0.7, indicating that the data has a certain level of reliability.

Table 2: Cronbach's Reliability Analysis

Name	Corrected Item-Total Correlation (CITC)	Alpha Coefficient if Item Deleted	Cronbach's α Coefficient
Primary Indicators	0.438	0.667	
Secondary Indicators	0.352	0.702	
Expert A	0.562	0.533	0.818
Expert B	0.552	0.607	
Expert C	0.529	0.520	

This study conducted a Kappa consistency test to ensure consistency in the ratings of three experts (two in the theoretical field and one in the practical field). P-value analysis found that a p-value less than 0.05 indicates a certain degree of consistency. The specific degree of consistency can be analyzed for the Kappa coefficient values, as shown in Table 3. The range of Kappa coefficient values and the strength of consistency are as follows: Kappa<0.2 indicates poor consistency; Between 0.2 and 0.4, it indicates a moderate level of consistency; A consistency level between 0.4 and 0.6 indicates moderate consistency; Between 0.6 and 0.8, it indicates a strong degree of consistency; Between 0.8 and 1.0, it indicates a strong degree of consistency. The expert consensus KAPPA coefficient of this study is 0.478 and 0.562, ranging from 0.4-0.6 (see Table 3), indicating that there is little disagreement among the experts in this study and the degree of consistency is moderate, within an acceptable range. Therefore, the shipping accessibility results of this study have expert validity.

Table 3: Validity Analysis: Kappa Test Results

Name	Kappa Value	Standard Error (Null Hypothesis)	z-value	p-value	Standard Error	95% CI
Expert A & B	0.562	0.045	4.521	0.001**	0.044	0.057 ~ 0.328
Expert A & C	0.478	0.067	6.431	0.000**	0.034	0.326 ~ 0.621

*Note:p<0.05, ** p<0.01*

According to the Pearson correlation analysis in Table 4, it can be seen that using correlation analysis to study the correlation between the port area economy (GDP), A. natural resources and environmental conditions, B. port facilities and operation status, C. degree of development around the port, and the average value of shipping accessibility (AVG) in the port area, a total of 5 items, Pearson correlation coefficient is used to represent the strength of the correlation. Specific analysis shows that the correlation coefficient between GDP and "natural resources and environmental conditions" is 0.317, the correlation coefficient between GDP and "port facilities and operation status" is 0.436, and the correlation coefficient between GDP and "port surrounding development level" is. 582. The p-values of the above results are all less than 0.05, indicating statistical significance. Therefore, it suggests a positive correlation between GDP and the three indicators. The correlation coefficient between GDP and shipping accessibility AVG is 0.447, and the p-value is less than 0.05, indicating a positive correlation between GDP and shipping accessibility AVG. The stronger the accessibility of the port area, the stronger the economic promotion of the port area. The development level around the port has the greatest impact (0.582), followed by the port facilities and operation status (0.436), and finally, the natural resources and environmental conditions (0.317) This indicates that in the future, with limited humans, material, and financial resources, resources should be concentrated on the development and improvement of port facilities and operations in the surrounding areas.

Table 4: Correlation Analysis: Pearson's Results

	GDP	A. Natural Resources & Environmental Conditions	B. Port Facilities & Operational Status	C. Port Surrounding Development	Accessibility AVG
GDP	1				
A. Natural Resources & Environmental Conditions	0.317**	1			
B. Port Facilities & Operational Status	0.436**	0.480**	1		
C. Port Surrounding Development	0.582**	0.452**	0.457**	1	
AVG	0.447**	0.466**	0.532**	0.408**	1

*Note:p<0.05, ** p<0.01*

4. Research Recommendations

4.1 Positioning and Division of Labor: Optimize Port Layout

Haikou Port should strengthen its hub function, develop passenger, cruise, and roll-on/roll-off services, and gradually transfer its freight functions to Yangpu Port. Yangpu Port will focus on container and freight transportation, develop into an international shipping hub, and enhance its scale and hub level. Yangpu Port must strengthen infrastructure construction, improve throughput capacity, accelerate port traffic construction, and enhance service guarantee capabilities. Through intelligent transformation, loading and unloading efficiency and service quality can be improved, the integration of container and bulk cargo terminal resources can be optimized, and throughput capacity can be enhanced. Yangpu Port should increase its Southeast Asian routes, enhance the attractiveness of routes to key nodes such as Singapore, and leverage the shipping connection between Hainan and ASEAN. Accelerate the implementation of free trade port policies, attract shipping factors and enterprises to gather, and improve shipping systems and industrial policies. Establish an optimization model to avoid duplicate port construction and achieve optimal resource allocation. Promote joint inspections of ships, establish efficient regulatory policies, and provide financial services. Yangpu Port should strengthen cooperation with provinces, autonomous regions, and municipalities under the Western Land Sea New Corridor Agreement, promote cross-regional cooperation projects, and efficiently coordinate maritime transportation networks.

4.2 Distinct Development: Enhance Overall Competitiveness of Hainan's Yangpu Port and Haikou Port

Yangpu Port should be an international shipping hub, focusing on container and freight services,

while Haikou Port develops passenger, cruise, and roll-on/roll-off services. Yangpu Port needs to strengthen infrastructure construction and improve throughput capacity, such as expanding terminals and waterways and transforming container terminals into intelligent ones. At the same time, it will increase Southeast Asian routes, especially to key nodes such as Singapore, and strengthen the shipping links between Hainan and ASEAN. Yangpu Port should cooperate with provinces, autonomous regions, and municipalities under the Western Land Sea New Corridor Agreement to jointly build cross-regional projects, improve shipping logistics and service quality, integrate supply chain resources, and enhance transit consolidation functions by integrating resources, avoiding redundant construction, and achieving economies of scale. Improve loading and unloading capacity, renovate storage yards, introduce intelligent scheduling, and reduce logistics costs for foreign trade enterprises. Promote the opening of ocean routes and reduce reliance on Hong Kong for transit. Coordinate with port enterprises to provide preferential policies, extend the time for no transit plug-in, reduce logistics costs, revise shipping subsidy policies, and ensure the coordinated development of Hainan's port, shipping, and foreign trade industries.

4.3 Connectivity: Improve Logistics Efficiency of Yangpu Port-Haikou Port Composite Port

Yangpu Port will improve its loading and unloading capacity and operational efficiency by renovating its yard, purchasing new equipment, and introducing intelligent scheduling technology. Accelerate the construction of foreign trade supervision yards, increase the number of cold plugs, improve inspection efficiency, and meet the growing demand for foreign trade containers. According to market demand, increase barge capacity to ensure transportation efficiency. Promote the opening of ocean routes, reduce reliance on Hong Kong transit, and lower logistics costs. Port enterprises will provide more favorable business policies, extend the time for no transit plug-in, and reduce logistics costs according to the situation of the enterprise. Revise the shipping subsidy policy to reduce costs further and ensure the industry's coordinated development. Strengthen the application of new-generation technologies in transportation, promote the intelligence and digitization of transportation infrastructure, and create a "smart highway." Upgrade the logistics information platform, achieve information sharing, and improve the level of freight logistics services. Promote the construction of Yangpu Smart Port and EDI, achieve paperless logistics documents at the port, and enhance port intelligence. Pilot the "parallel port" model, share route resources, improve loading rates and customs clearance efficiency, and reduce logistics costs.

5. Conclusion

The preferential policies brought about by the construction of free trade ports have attracted more shipping companies to settle in or increase business exchanges. This has optimized the route layout from Yangpu Port to Haikou Port Combined Port, giving shipping companies greater motivation to open up new routes or increase the frequency of existing routes, directly improving shipping accessibility. Driven by the construction of free trade ports, the infrastructure of Yangpu Port and Haikou Port has been upgraded, thereby enhancing shipping accessibility. The construction of free trade ports has promoted logistics coordination between the ports and surrounding areas. A more efficient logistics information platform has been established, where relevant parties such as ports, freight forwarders, shipping agents, and shippers can share information in real-time, improving the efficiency of logistics organization.

Although the construction of free trade ports has many advantages, other ports in the surrounding areas are also constantly developing. The combination ports of Yangpu Port and Haikou Port face competition from other ports, which may lead to diversifying some routes and cargo sources. If competitiveness cannot be maintained regarding service quality, cost control, and other aspects, the improvement of shipping accessibility may be suppressed. It is necessary to integrate resources further and optimize management to fully leverage the promoting effect of free trade port construction on shipping accessibility.

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