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Study on development of port service network along the maritime silk road via capacity sharing

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STUDY ON DEVELOPMENT OF PORT SERVICE NETWORK ALONG THE MARITIME SILK ROAD VIA CAPACITY SHARING

by

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In

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

(Signature): ……

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Supervisor's affiliation: ……

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ABSTRACT

Title of Dissertation: **Study on development of Port Service Network along the Maritime Silk Road via Capacity Sharing**

Degree: **Master of Science in International Transport and Logistics**

The dissertation is a study of developing the Port Service Network via Capacity Sharing along the 21st Century Maritime Silk Road.

A brief look is taken at the present methods of Capacity Sharing of Port Service Network and the pros and cons behind them. The definition of Port Service Network and types of Capacity Sharing are examined, taking into account information flow and capital flow, and cargo flow that has taken place. The growth and development of Infrastructure Construction and its inherent limitations as the basis for capacity sharing in port service networks. The Port-Park-City port construction model developed by some participating countries of the 21st Century Maritime Silk Road Initiative is explored to determine the current status where only some countries can participate in capacity sharing. Particular mention was made of the Greek port of Piraeus and the German port of Hamburg.

The design of the port structure is analyzed and assessed on different types of capacity sharing, as well as the existing or potential deficiencies. The Performance Evaluation System is developed based on the Overall Goal of the 21st Century Maritime Silk Road. The effectiveness of the Capacity Sharing of Port Service Network in the Pearl River Delta Region was evaluated under the system and the results were recorded.

In addition, optimization analysis took a model as an example. Results and choices of optimization directions are collated and evaluated.

The final chapter reviews the results of the optimization analysis and discusses the main contribution of Capacity Sharing in Port Service Networks. Several potential future developments outlooks were made regarding this topic.

KEYWORDS: Port Service Network, 21st Century Maritime Silk Road, Capacity Sharing

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
B&R	The Belt and Road
BOT	Build-Operate-Transfer
COSCO	China Ocean Shipping(Group) Company
EPC	Engineering Procurement Construction
ETA	Estimated Time of Arrival
IoT	Internet of Things
KPI	Key Performance Indicator
M&A	Mergers and Acquisitions
PPC	Port-Park-City
PSN	Port Service Network
RFID	Radio Frequency Identification

Chapter 1 Introduction

1.1 Research background and significance

1.1.1 Research background

After nearly 30-40 years of rapid development in China, China has now become an important and non-negligible link in the world's manufacturing and supply chains. However, after gradually shortening the distance with developed countries, some unfavorable factors brought about by China's national conditions are gradually revealed.

In the course of development, the problem of insufficient driving force has gradually emerged: First, the safety of raw materials, especially energy materials and rare minerals, are highly dependent on imports. Second, the bargaining power, which is reflected in the products produced. Low irreplaceable, due to lack of control over key materials and technologies, it can only play the role of "international foundry". The competitiveness of high-premium and high-end brands is insufficient. Third, the technological innovation environment is insufficient. Capital and the Internet, two powerful engines, have made enormous contributions to China's development. But capital is usually profit-seeking and risk-avoiding. The uncertainty of technological innovation also reveals the nature of capital seeking advantages and avoiding disadvantages and less participation in technological innovation.

Under the combined influence of various factors, China proposed the Belt and Road Initiative, and the Maritime Silk Road is a key part of it.

China hopes to develop comprehensive regional and even international economic cooperation by connecting the market chains of major economic regions around the world with the participating countries of the 21st Century Maritime Silk Road. Maritime security is an important part of it because China's energy resources and food resources are highly dependent on foreign trade. China's resources, including oil and gas resources, food resources, and mineral resources, still depend on the way of sea transportation. For shipping, the impact of geopolitics is huge. Once an emergency public event occurs, China's energy supply and raw material supply will be greatly threatened.

According to the main direction of the 21st Century Silk Road, the purpose of building the 21st Century Maritime Silk Road is to support China's coastal economic belt and strengthen cooperation with neighboring countries in the maritime field. Actively promote the construction and development of three main blue economic channels:

(1) China-Indian Ocean-Africa-Mediterranean Blue Economic Corridor

The China-Indian Ocean-Africa-Mediterranean Blue Economic Corridor is the one with the longest history among the three economic corridors, and it is also the one with the most complicated and important actual situation. There are four economic sectors: Indochina, China-Pakistan, Bangladesh-China-India-Myanmar Economic Corridor, Arab and Mediterranean. The countries along the route are mainly developing countries, and infrastructure construction and economic development along the route should be given priority.

(2) China-Oceania South Pacific Blue Economic Corridor

The China-Oceania-South Pacific Blue Economic Corridor mainly

passes through Southeast Asia and Oceania. This blue economic channel includes many co-operations with island countries. This blue economic corridor focuses on win-win cooperation between China and the South Pacific region. Except for Australia and New Zealand, the economies of other island countries in the South Pacific region are relatively weak, and local economic development is more dependent on international materials.

(3) Arctic Ocean Blue Economic Channel

The Arctic Ocean Blue Economic Corridor is mainly related to the development of Arctic shipping routes and the environmental protection of the Arctic region. Countries involved in the Arctic route have a common interest in this regard. Among them, Russia attaches great importance to the blue economic channel of the Arctic Ocean. In addition to participating in the Belt and Road Initiative, Russia has also invested a lot of resources to improve the waterway conditions of the Arctic route.

In addition to economic development, new cooperation models are also the focus of the 21st Practical Maritime Silk Road. The new cooperation model has new requirements for relevant partners in terms of green development, coastal prosperity, coastal security, smart innovation and cooperative governance. The following four aspects will be elaborated:

a. Eco-friendly development of the sea

Maintaining the marine environment is the well-being of all mankind. The 21st Century Maritime Silk Road proposes that countries along the route should jointly carry out marine ecological protection activities. Protect the health and biodiversity of marine ecosystems through the efforts of all countries. Implement cooperation in the protection and restoration of marine

ecosystems and the protection of marine endangered species. In addition to advancing regional marine environmental protection, reducing ocean-related carbon emissions is also an important cooperative goal. To this end, the 21st Century Maritime Silk Road Initiative launched the "21st Century Maritime Silk Road Blue Carbon Plan". Countries along the route are also strengthening research and conducting regular academic exchanges in the detection of marine and coastal blue carbon ecosystems, marine pollution prevention and control standards, and carbon sink trading. The 21st Century Maritime Silk Road Carbon Report promotes the establishment of an international blue carbon forum and cooperation mechanism.

b. Ocean drives economic prosperity

The ocean also plays an important role in strengthening the economic development level of neighboring countries. The ocean is rich in natural resources. Participating countries also need to cooperate in the development and utilization of resources. Countries along the coastline have reached consensus on planning the development and utilization of marine resources by conducting resource surveys, establishing resource lists and resource banks. And can provide necessary assistance to each other on related technical equipment. At the same time, maritime trade can also enhance the level of regional industrial cooperation. Countries along the 21st Century Maritime Silk Road Initiative cooperate to build marine industrial zones and economic and trade cooperation zones. Through government or private investment, strengthen the participation of regional enterprises in the construction of the park. Through one blue economic cooperation project after another, the regional development of countries along the Maritime Silk Road will be driven. The initiative has improved the living standards of the

people in the region and reduced poverty. Planning and developing marine tourism routes and creating high-quality marine tourism products are also important forms of expression. The establishment of a tourism information exchange and sharing mechanism is also the focus of the 21st Century Maritime Silk Road.

c. Maritime Security Cooperation

Maintaining maritime security is an important guarantee for the development of the marine economy. The 21st Century Maritime Silk Road advocates the maritime security concept of mutual benefit and win-win cooperation. Initiatives can strengthen marine public service cooperation. This is manifested in the increased willingness to cooperate in bilateral and multilateral maritime navigation safety and crisis management. Countries along the 21st Century Maritime Silk Road jointly ensure the safety of maritime navigation in the fight against maritime crimes and other non-traditional security aspects. The cooperating countries have strengthened information sharing with each other, and also strengthened information communication in joint search and rescue and exchange and training with relevant personnel. The ability to respond to maritime security incidents and emergencies has been effectively improved. On the early warning and rescue of marine disasters in key sea passages, the dialogue with countries along the route will be strengthened. By establishing a joint law enforcement cooperation mechanism, jointly establish emergency plans to prepare for emergencies.

d. Scientific and technological innovation

Innovation is an important way to improve productivity. The

development and cooperation of marine-related science and technology is also the focus of the initiative. The 21st Century Maritime Silk Road enables scientific research institutions and enterprises to have a more international perspective in marine scientific research and technical cooperation. And through the joint construction of marine science and technology cooperation and smart marine application platform, the sharing of information and data between countries has been promoted, laying the foundation for further deepening cooperation. Marine education and cultural exchanges are also an important part of the initiative, through the establishment of sister cities, friendly ports and other means to strengthen marine knowledge and non-governmental friendly exchanges. This also makes the 21st Century Maritime Silk Road more influential internationally.

This paper will focus on several key element ports of the 21st Century Maritime Silk Road, conduct a comprehensive analysis of the existing port technologies, theories and practical operations, and discuss some directions that can be pursued and aspects that need to be vigilant in development.

1.1.2 The significance of study

Port is the gathering point and a hub for marine and land transportation, a distribution center for industrial and agricultural products and foreign trade import and export materials, and a place for ships to berth, load and unload goods, get on and off passengers, and replenish supplies.

By browsing, collecting and summarizing the resources and throughput capacity of an important port in the port service network of the "Maritime Silk Road" in the 21st century, the study will discuss about whether it can

meet the needs of participant country's economic development under the existing conditions, and whether it can use lower cost to maximizes the range of economic effects that the port can bring. Study the specific methods of port resources and capacity sharing, and discuss how to balance the conflict of interest in capacity sharing to maximize the benefits of the overall region. The article also mentions the speed and reliability of different capabilities sharing models in the face of emergencies and emergencies.

Internationally, supply chain reliability has been revisited in the wake of the Covid-19 pandemic. This is the most widespread and influential plague in the world after high globalization. The way people work and live has changed dramatically. In this paper, supply chain reliability will receive more attention. Because of the bucket effect, we know that the reliability of a supply chain is primarily determined by the weakest link in it. For example, congestion in Los Angeles/Long Beach in February 2021 could spread to the entire West Coast of the United States. It's not because ports can't keep up with the speed at which cargo is being processed. The real root cause is the lack of capacity of the trucks to carry the cargo out of the port. This article will not only consider the port's own ability to handle cargo, but will also discuss the port's ability to handle the flow of logistics, capital, and information as a resource dispatch center.

Previous research has established that the promotion of international trade is an important component of the proposed 21st Century Maritime Silk Road. The countries along the 21st Century Maritime Silk Road are distributed in different regions of the world, and the political, economic, cultural and social environments of each region are different. This creates different investment and business environments and foreign cooperation habits, which can all lead to a series of investment risks at the national level.

This study brings together the focus of upgrading port service networks with the perspective of addressing risks and enhancing the resilience of regional ports. In terms of risk classification, this dissertation will follow the classification of previous scholars and classify the risks that port service networks may face into Geo-risk, market risk, unexpected accident risk, and natural disaster risk. The overall improvement strategy of the port service network based on capacity sharing is also given according to the specific types of risks.

1.2 Overview of related research

1.2.1 The theoretical research status of port service network Capacity Sharing

The literature related to this study focuses on two main directions. One of the direction is to evaluate the operation of a single port. The other focus their attention on inter-port cooperation and competition and port supply chain integration.

Expanding port capacity is one way to address port congestion. Do Ngoc and Moon (2011) argue that the key to port capacity is the storage capacity of container ports, which can be increased by increasing leasing. gaur, Pundir, and Sharma (2011) study of Indian ports also confirms the important impact of port capacity on port performance. Roll and Hayuth first introduced the DEA approach to port performance measurement, a method that quantifies port performance, and Li, Hu, and Yu further refined this approach and applied it to ports along the important Chinese Maritime Silk Road.

Another part of the single-port reliability study focuses on the impact of disruptions in operations on the overall supply chain. A subset of researchers identified port resilience as an important influencing factor. in their study, Paul and Maloni (2010) simulated optimizing shipping routes in the presence of port disruptions. Omer et al. (2012) further investigated the disruptions to port capacity due to different disruptive factors. and the resulting port operations, including outbound and inbound services.In the studies by Nair et al. (2010), Omer et al. (2012), and Yang et al. (2015), the use of a quantitative framework is proposed to assess port resilience. All of these works consider the role of conservation or restoration strategies, in improving the resilience of a single port.

Port cooperation and information sharing can improve the overall reliability of ports in the region. Lam and van de Voorde (2011) studied the integration of shipping supply chains in which ports are considered service providers. Zhang, Lam, and Huang (2014) analyzed the competition between Hong Kong port and Shenzhen port from the perspective of supply chain management and proposed a strategy for Hong Kong port. Song et al. (2016a) developed a cost model from the transport chain comparatively analyze the relative competitiveness of the two ports. Hoshino (2010) proposes a series of port cooperation measures, including joint facility investments, interconnection of information systems, joint promotion and marketing activities, and empty container scheduling in regional alliances formed between neighboring ports can also balance port capacity.

Asadabadi and Miller-Hooks (2018) propose a competition-plus-collaboration scenario that replaces the centralized decision to protect the port network through cross-port investments. Asadabadi and Miller-Hooks (2020) further extend their concept and

approach to analyze potential threats in port service networks and calculate the reliability in the face of these threats.

Python and Wakeman (2016) state that information sharing has an important role for both ports and supply chains during disruptions in normal shipping services. Zhao, Wang, and Zhou (2016) argue that the stability of port alliances is important and that alliances should carefully consider entry and exit mechanisms for effective unified and coordinated management.

Capacity sharing as a form of cooperation was earlier applied to liner shipping, intermodal transportation, and aviation. Kuo et al. (2008) proposed three cooperative strategies between multiple carriers for rail-based inter-modal freight services. Godfrey et al. (2004) simulated flight scheduling between military and commercial airlines using a distributed optimization approach to balance military missions with commercial airline workload. Ruan et al. (2018) identify all beneficiaries in a port network, and the amount of capacity they share, by proposing a nonlinear mixed-integer model. The study allowed capacity sharing between ports and designed a "hub and spoke" port service network. However, the study does not take into account the possible disadvantages of competition.

In general, the development path of PSNs and further development of their capabilities have rarely been studied. Existing studies on port cooperation also mostly focus on cooperation and competition between ports in the same region. Many cooperation models are also not related to PSN development and capacity sharing. Studies on the construction of integrated service networks for PSNs have also mostly focused on cooperation in the middle of different links of the port supply chain.

1.2.2 Practical development status of port service network Capacity Sharing

The initiative of the 21st Century Maritime Silk Road puts forward the main development idea of "leading from the point to the surface, from the line to the area, gradually forming a regional cooperation". B&R promotes international cooperation and transforms ports into international logistics centers, strengthening close cooperation in all aspects of the supply chain.

The existing 21st Century Maritime Silk Road port cooperation programs are listed in the table below. As can be seen from the table, there are different ways of cooperation between different regions. The difference in the way of cooperation is attributed to the uneven development between regions. In areas with weaker infrastructure, cooperation focuses on building infrastructure. In areas with better infrastructure, cooperation is based on capital, academic exchanges and friendly cooperation agreements.

The Southeast Asian region is dominated by island countries, and the national economy has relied on import and export trade since ancient times. Therefore, the overall port operation system in the region is well developed, and cooperation is more often based on existing ports, establishing friendly port relations, establishing port alliances and other ways.

The south Asia region is located at a key node in the energy import and export of the 21st Century Maritime Silk Road. The low level of port development poses a great threat to China's energy imports. The port cooperation of the 21st Century Maritime Silk Road is mainly realized by investing in the construction of port infrastructure.

The Middle East is located at the intersection of the three continents of Europe, Asia and Africa, where the Mediterranean Sea, the Red Sea, the Arabian Sea, the Caspian Sea and the Black Sea meet. The Middle East has an excellent geographical location connecting the Atlantic and Indian Oceans,

and is a transportation hub between the East and the West on the ancient Silk Road. The Middle East is rich in energy resources, with oil and natural gas reserves accounting for 55% and 42% of the world's proven total, respectively. As an important energy supply area in China, the cooperation also focuses on the construction of port infrastructure, but energy security deserves more attention. In the international context of "carbon neutrality", the Middle East has released and updated renewable energy development goals to reduce dependence on traditional energy, accelerate energy transition, and promote economic diversification and sustainable development.

African countries have limited natural conditions and insufficient natural resources. In recent decades, Africa has lagged other regions in industrialization. The reasons for the lag in Africa's industrialization process are not only institutional and policy factors, but also backward infrastructure, insufficient funds and technologies, and insufficient human resource reserves. A series of factors limited the development of industrialization. For investors, much of Africa is a developing country with a sluggish economy and a weak industrial base. The prevention of investment risks should be placed in an objectively important position. Faced with political instability, social instability, security and financial risks, investors must have a precautionary awareness and coping strategies. Due to lack of resources, most of Africa's daily necessities are imported, and the prices are 50% to 80% higher than China's. At the same time, the cost of training local workers is high, so the development of Africa's local and surrounding markets is a major issue for Africa's 21st Century Maritime Silk Road. In addition to the construction of African port infrastructure, all related facilities of the port service network, such as warehouses, railways, industrial zones, etc., require investment and

construction.

European region port has early development time, advanced management concept and other characteristics, and the main form of cooperation with the European port is investment in equity, with the weakening of the European economy, the layout of the port network can reduce trade costs and improve trade efficiency.

Table 1-1 Existing port cooperation

Region	**Country**	**Cooperation Projects**	**Type of cooperation**
Southeast Asia	Myanmar	In 2015, Qingdao Port and Kyaukpyu Port Signed Friendship Port Agreement.	Inter-port Cooperation
		In 2015, Commissioning of the China-invested Kyaukpyu deep-water port.	Invest in Port Construction
	Vietnam	In 2010, China Merchants International invested in Vung Tau Container Terminal.	Invest in shares
	Thailand	In 2015, Guangzhou Port and Laem Chabang Port signed a letter of intent on the conclusion of a friendly port.	Inter-port Cooperation
	Cambodia	In 2015, Qingdao Port and Sihanoukville Port signed a friendly port agreement.	Inter-port Cooperation
	Malaysia	Guangxi Beibu Gulf Port and Port Klang signed a friendly port agreement.	Inter-port Cooperation
		In 2015, Shenzhen Port and Port Klang signed a friendly port agreement.	Inter-port Cooperation
	Indonesia	In 2015, Shenzhen Port and Indonesia National Port Group	Inter-port Cooperation

		signed a friendship port.	
		In 2019, Zhejiang Haigang Group and Indonesia PT Pelindo I Port Company signed a memorandum of understanding on cooperation and development.	Inter-port Cooperation, Investment in the construction of ports
		In 2019, Ningbo Zhoushan Port Group and Indonesia PT Pelindo II Port Company signed a memorandum of understanding on cooperation and development.	Inter-port Cooperation
	Singapore	In 2019, Shanghai Zhenhua Heavy Industry signed a cooperation agreement with PSA	Invest in Port Construction
South Asia	Sri Lanka	In 2014, China Harbour Co., Ltd. adopted the BOT model to build Colombo Port City.	Invest in Port Construction (BOT)
		In 2011, China Merchants International invested in the construction and operation of the Colombo South Port Container Terminal.	Invest in Port Construction (BOT)
		In 2008, China aided the construction of Hambantota Port, which was constructed by China Harbour Engineering Co., Ltd. in the EPC mode.	Invest in Port Construction
	Pakistan	In 2001, China was invited to invest in the construction of Gwadar Port.	Invest in Port Construction
		In 2013, China Overseas Port Holding Company, China Merchants International Co., Ltd. and China Ocean Shipping Group officially took over the operation right of Gwadar Port.	Invest in Port Construction
		In 2015, Gwadar Port was officially opened, and Chinese companies were granted the right to operate for 40 years.	Capital injection holding

	Bangladesh	In 2010, China funded the construction of Chittagong Port.	Invest in Port Construction
Middle East	Israel	In 2015, Shanghai Port won the bid for the 25-year operation right of the Haifa New Port	Invest in shares
		In 2019, Shanghai Zhenhua Heavy Industry Signs TIL Port Construction Agreement.	Invest in Port Construction
	Qatar	In 2011, China Harbour Construction Co., Ltd. undertook the construction of the first phase of Doha New Port.	Invest in Port Construction
Africa	Egypt	In 2006, China Shipping Terminals jointly operated the Damietta Container Terminal.	Joint venture
		In 2007, COSCO Pacific acquired a 20% stake in Suez Canal Terminal.	M&A
		In 2008, China State Construction undertook the construction of Port Said in the EPC mode.	Invest in Port Construction
	Djibouti	In 2013, China Merchants International acquired a 23.1% stake in Djibouti Container Terminal.	M&A
		In 2014, China State Construction won the bid for the Djibouti port terminal construction project.	Invest in Port Construction
		In 2019, China Merchants Port Group and Djibouti Great Horn Investment Holdings SAS signed a framework agreement for the reconstruction of the old port of Djibouti.	Invest in Port Construction
	Tanzania	In 2013, China invested in the construction of the new Bagamoyo port and upgraded the old port equipment.	Invest in Port Construction
	Nigeria	In 2011, China Merchants International Co., Ltd. acquired Star	M&A

		Shipping's shares in Tincan Island Container Terminal.	
Europe	Greece	In 2009, China Ocean Shipping Group obtained the right to operate the Port of Piraeus for 35 years.	Invest in shares
	Belgium	In 2004, COSCO Pacific acquired a 25% stake in the Belgian port of Antwerp.	Invest in shares
		In 2010, Shanghai Port Group acquired a 25% stake in the Port of Zeebrugge.	Invest in shares
		Shanghai Port, Shenzhen Port, Ningbo Port, Tianjin Port, Qingdao Port and Dalian Port have successively signed a friendship port agreement or a memorandum of understanding with Antwerp Port.	Inter-port Cooperation
	Germany	In 2019, Chongqing Liangjiang New Area signed a memorandum of strategic cooperation with the Port of Duisburg	Inter-port Cooperation
	France	In 2015, Shanghai Port signed friendship port agreements with Marseille, Le Havre and Dunkirk successively.	Inter-port Cooperation
	Netherlands	In 2005, Shanghai Port and Rotterdam Port signed a friendly port agreement.	Inter-port Cooperation
		In 2007, the Port of Rotterdam became the first foreign friendly port of Shenzhen Port.	Inter-port Cooperation

Due to the long and uncertain payback period of the investment in the port service network as a partnership. The actual results are more presented in the areas with better infrastructure development. This paper briefly introduces what impact the 21st Century Maritime Silk Road initiative has brought to the region, taking the Greek port of Piraeus as an example.

In 2010, the European debt crisis put the port of Piraeus in a dire situation. Under this circumstance, Chinese company COSCO have boldly invested in the Greek port service network infrastructure sector. With the dual development of funding and infrastructure development, the port of Piraeus has gradually regained its vitality. The port has turned losses into profits, and its capacity has increased, making it the largest port in the Mediterranean Sea, and its container capacity has risen sharply from 93rd in 2010 to 26th in the world in 2020. The Greek port of Piraeus became one of the fastest growing container port in the world.

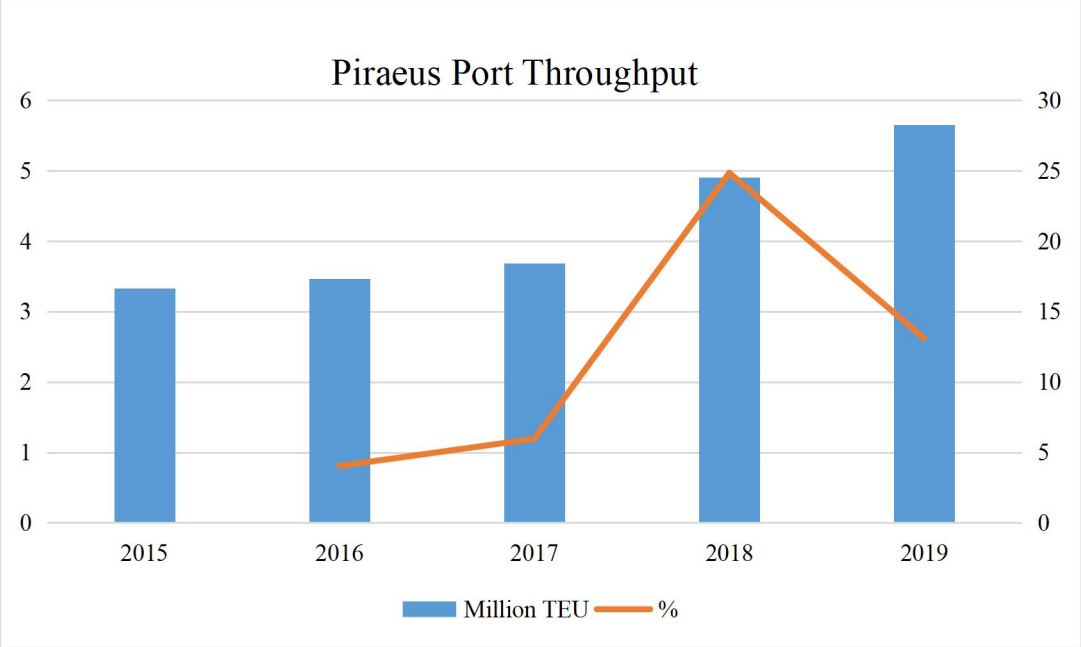

Figure 1-1 Piraeus Port Throughput (2015-2019)

COSCO's cooperation with Piraeus Port of Greece started earlier. In terms of results, the project has boosted the trade between Greece and China. and even more so in 2019, allowing China to overtake Italy as the second

largest importer to Greece.

This cooperation project is characterized by integration and diversification. The integration is mainly reflected in the investment in the port itself (mainly in the expansion of the port) and the further construction of port facilities and land-sea expressways. The connection of the Greek railroad to the port will shorten the transit time between China and the EU by 8-12 days. Diversification is reflected in the diversification of port cooperation. The success of the port of Piraeus has attracted companies such as HP, Hyundai and Sony to set up logistics centers in the region.

Table 1-2 Greece Trade Value of Imports and Exports (China)

Greece Trade Value of imports and exports (China)				
	Import Billion USD	Import Ratio %	Export Billion USD	Export Ratio %
2015	3.48	7.35	0.319	1.09
2016	3.92	7.94	0.426	1.5
2017	3.96	7.26	0.325	1
2018	5.31	8.31	0.813	2.07
2019	6.26	9.87	0.814	2.16
2020	5.56	9.83	0.997	2.78

1.3 Research content and ideas

1.3.1 Research content

The main research question of this paper is how to develop a maritime

Silk Road port service network through capacity sharing.

Practical cases about this issue, theoretical background and research context (21st Century Maritime Silk Road) will be considered. From the existing studies and practical cases, possible problems of capacity sharing in port service networks are identified. From the starting point of the PSN motivation, combined with the decision strategies of the participants in the PSN network and the external influences on the PSN, I divide the problem into three main areas: revenue sharing of participants, port capacity elasticity, and efficiency improvement.

The article proposes solutions according to the different problems and discusses the methodological choices for these methods. Based on the analysis conclusions are drawn for the main research problem and future perspectives on the issue are provided.

1.3.2 Research technology route

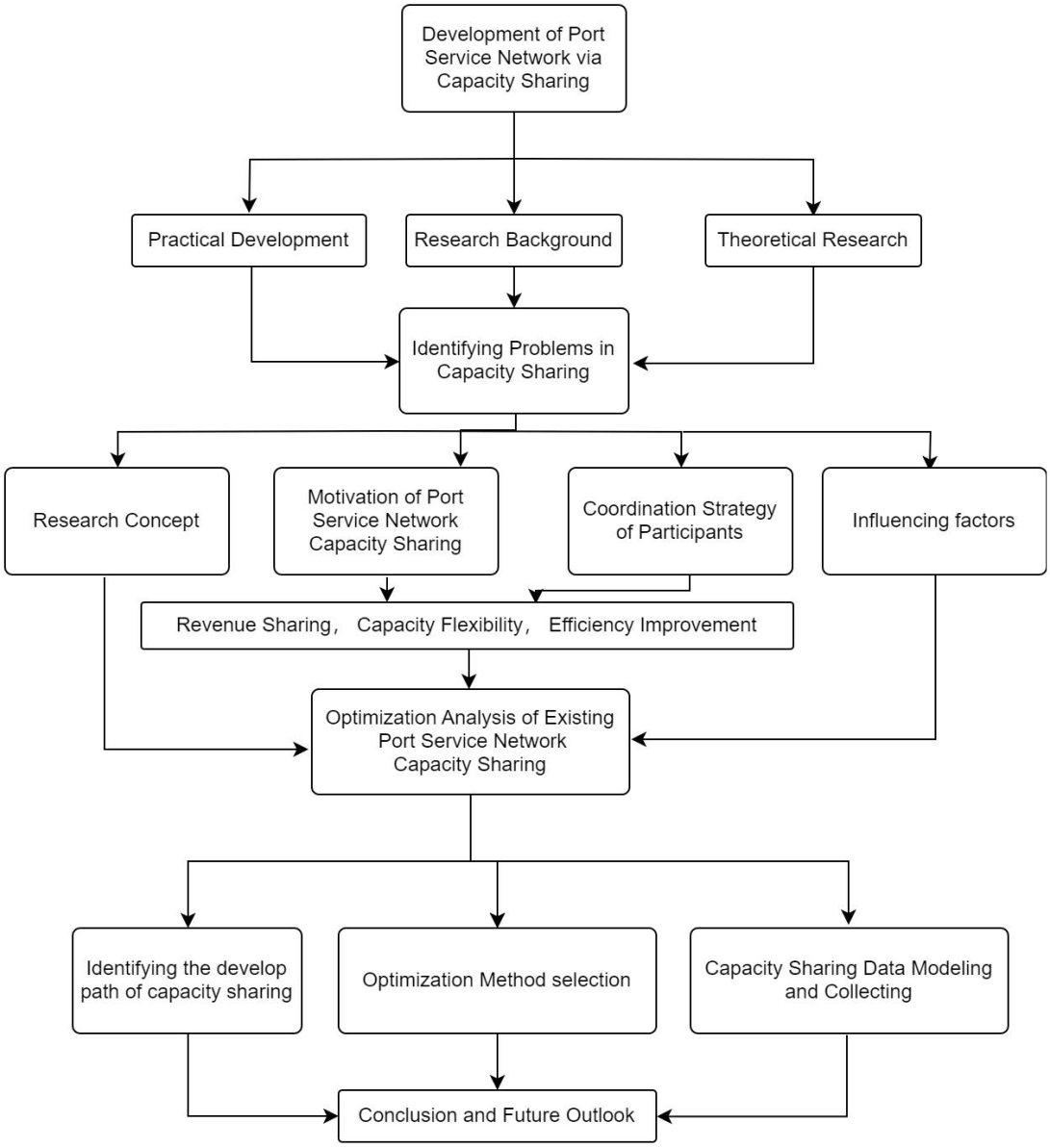

Figure 1-2 Research Technology Route

Chapter 2 Analysis of the Construction and Coordination of Port Service Network

2.1 Port Service Network

Traditionally, the main functions of a port include transportation and transshipment of goods, loading of goods, storage functions and yard functions. With the development of ports and business needs, many ports also have distribution functions, distribution and processing functions, information processing functions, bonded port functions and other service functions (such as supply of ship's necessities, food supply for crew, container washing and maritime disaster relief, etc.).

The port service network widens the content and direction of port services and furthers the linkage of strategic cooperation supporting services between ports and related industries. Port service networks are usually centered on ports and logistics-related industries. Geographically, the port service network extends from the port to the hinterland region. The related industries within the port service network are usually comprehensive, international, and cross-industry.

To form a port service network, it is necessary to clarify the positioning of members in it. Hub members need to coordinate the distribution of interests and conflicts of other stakeholders in the port service network. This requires hub members to have strong trust endorsements. Hub members can decide which capabilities should be shared and how to price among members and externally. Balancing the supply and distribution of port service network users and port service network stakeholders is also critical to the success of capacity sharing.

This article argues that there are three most important flows in the port service network: capital flow, cargo flow and information flow. Ensuring the efficient transmission of these flows in the overall port service network is the key to developing a port service network.

2.2 Motivation of Port Service Network Capacity Sharing

The motivation for the establishment of port service networks and capacity sharing should be viewed from two perspectives: the development of ports, and cooperation and competition between ports.

With the continuous improvement of port construction, advanced ports often do not have much difference in the construction of infrastructure. It is the level of port management that determines whether that port is prosperous or not. The level of port management is reflected in more aspects than just the efficiency of loading and unloading cargo. Such as whether to provide high-quality ship supply services, whether to provide cargo-related handling services in the vicinity, and the efficiency of cargo clearance and many other aspects.

In addition to meeting the traditional logistics requirements: bigger ships and faster cargo movement, after covid-19 and the conflict in Ukraine we are more concerned about the sustainable and reliable delivery of port services. The development of ports is now shifting to the Smart Port model, which uses cutting-edge technologies such as AI, Big Data, IoT and Block chain to assist port authorities in improving port efficiency.

Big Data is mainly manifested in the use of data from different sources and its aggregation and storage. IoT can be used by port authorities to track ship arrivals and ship cargo, and can help ports and authorities to control the

destination of cargo more flexibly. Block chain technology can enhance the trust of all parties involved in the port, and this technology can reduce the amount of repetitive paperwork for the port.These technologies have proven in practice at ports that they can help ports operate more efficiently. In the Port Services Network, Smart Port-related functions can be further extended from the port to other stakeholders.

The digital intelligence of the port itself has laid the foundation for the formation and development of the PSN, and the new technology has given the port the ability to provide more services. The development of inter-port cooperation is also an important prerequisite for PSN Capacity Sharing.

The way of port cooperation is mainly reflected in inter-port cooperation I mainly divide into two directions to explore: cooperation between ports that are geographically connected; cooperation between ports that are not geographically adjacent.

Cooperation between geographically connected ports is usually accompanied by competition. Neighboring ports generally have the same port hinterland. This means that ports are bound to compete with each other for cargo from the hinterland. The introduction of a new way of cooperation can be a good way to promote cooperation. This cooperative approach is characterized by port specialization and hinterland extension. Port specialization allows different ports in the region not to waste resources by building the same infrastructure at the same time. Hinterland extension allows for the development of different transportation modes between ports. This can not only ease the competition between ports in the hinterland region, but it can also lead ports to work together to expand other higher value-added services in the hinterland region, leading to the development of the overall region.

And there are two main ways of cooperation between ports that are not geographically connected. The first is similar to the 21st Century Maritime Silk Road initiative, which enhances the overall flow of goods on logistics routes. The other is a partnership agreement to regularly exchange port management experiences and results.

Port alliances are also an important form of cooperation, both for ports in the same region and for ports that are geographically distant from each other. Capacity sharing is also mostly generated based on port alliances. This article will be covered in detail in Chapters 3 and 4, so I will briefly introduce it here.

2.3 Coordination of port service network Capacity Sharing

The article explores the benefits of capacity sharing for PSN development from three aspects: efficiency, effectiveness and economy.

2.3.1 Capacity Sharing can improve the efficiency of PSN

In terms of efficiency, capacity sharing has proven to be a good way to alleviate container shortages in the logistics chain.

Take China's Yangtze River Delta port group and its economic hinterland as an example. The construction of a port service network allows empty containers to flow throughout the network. Thanks to the information sharing of the port service network, these empty containers can be used as a shared resource to optimally reach areas of the entire port service network with empty container demand. After converting the one-to-one correspondence between ports and railways into a many-to-many relationship.

This capacity-sharing approach can reduce empty container transportation mileage and empty container storage costs, making the overall port service network more efficient.

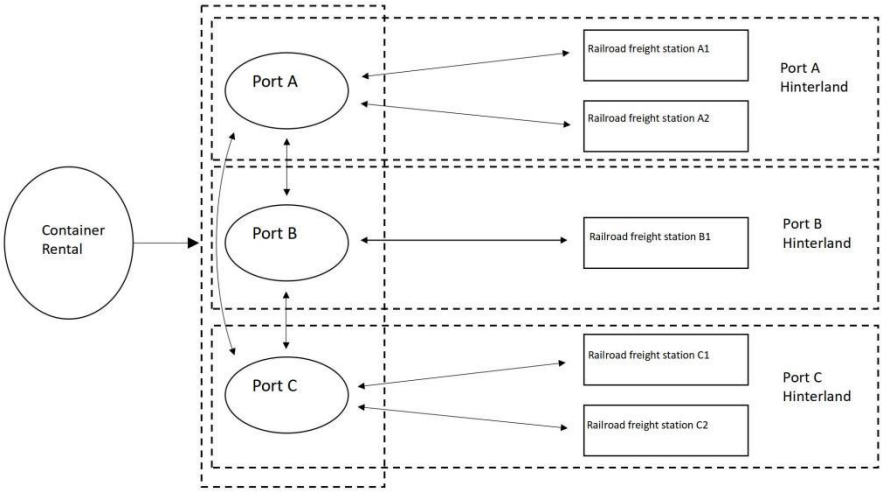

Figure 2-1 “Traditional Mode” Container Shipping Service Network

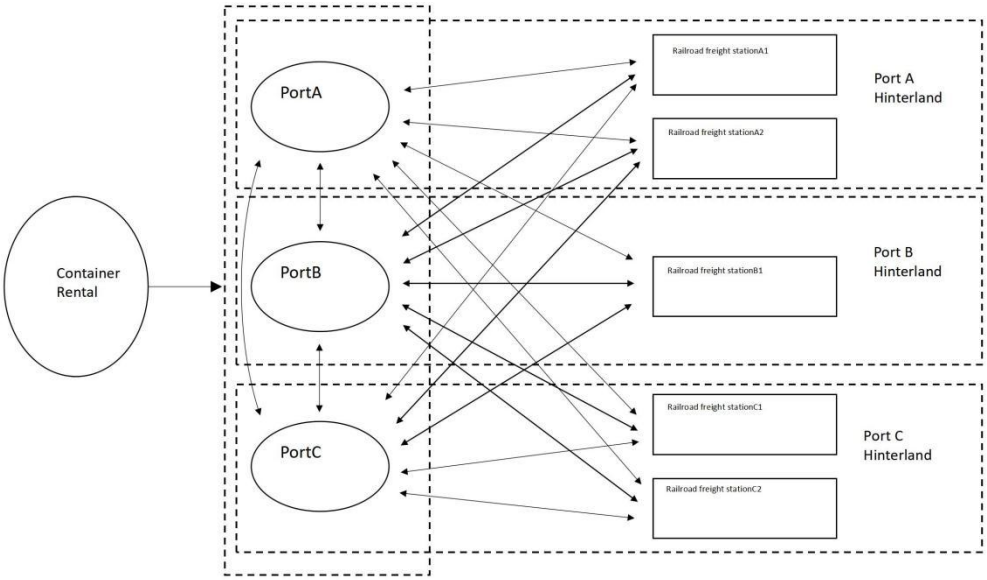

Figure 2-2 “Sharing Mode” Container Shipping Service Network

2.3.2 Capacity Sharing can make PSN more flexible

Information sharing as a way of sharing capabilities can make port operations more resilient.

As one of the key player of the 21st Century Maritime Silk Road, the Port of Hamburg is the third largest port in Europe and a pioneer in smart ports. The continuous growth of port throughput from 2000 to 2007 was achieved by the continuous expansion of the port itself and the renewal of its infrastructure. Around 2014, the Port of Hamburg could no longer rely on additional construction infrastructure to improve port efficiency. Traffic congestion in the port area was also a frequent occurrence. The Hamburg Port Authority responded to this situation by establishing the Smart Port Area System. It contains aspects such as storage management, transport management, tracking management transport planning management and enables information sharing in the port service network. We can also see

from the graph that the port service network was more stable and reliable in response to the economic crisis in 2016.

Table 2-1 The smart port model of the Port of Hamburg

Terminal Operation	Terminal Operations
	Port operations, yard management
	Communication and collaboration platform
Enterprise application	Port Infrastructure Development
	Asset/Equipment maintenance and management
	Customer billing and bill reconciliation
	External personnel management
Digital Focus	Human Resource Management
	Financial Accounting
	Sales and Distribution Network
	Goods visualization

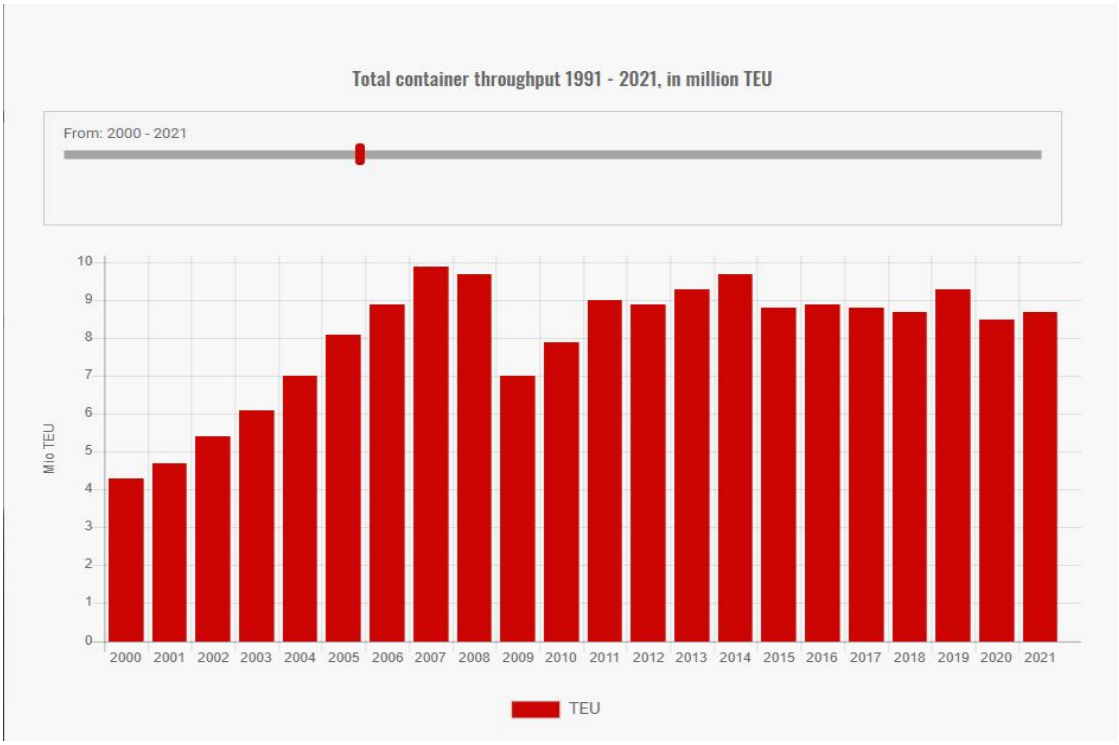

Figure 2-3 Annual throughput of the Port of Hamburg 2000-2021

2.3.3 Capacity sharing can bring greater economic benefits to the region

In terms of driving the regional economy, Djibouti's port services network development is representative. The Multipurpose New Port of Dohare and the Asia-Japan Railway are important cooperation projects of the B&R Initiative in Djibouti.

Table 2-2 Djibouti Basic Economic Indicators

Year	2014	2015	2016	2017	2018	2019
GDP (billion USD)	1.59	1.73	2.6	2.75	3.01	3.32
GDP per capita (USD)	1764	1919	2893	3057	3013	3319
Real GDP Growth Rate (%)	6	6.5	6.7	5.4	8.4	7.5
Inflation rate (%)	1.3	-0.8	2.7	0.6	0.1	3.3
Commodity Export (billion USD)	0.13	0.13	1.73	3.16	3.52	4
Commodity Import (billion USD)	0.66	0.87	2.33	3.58	3.6	4.14
Current Account Balance (billion USD)	-0.23	-0.3	-0.03	-0.13	0.43	0.45
Foreign exchange reserves (billion USD)	0.38	0.35	0.4	0.55	0.44	0.49
Exchange rate (quantity of 1 USD to local currency)	177.72	177.72	177.7	177.7	177.7	177.7

Data source: EIU, World Bank

In 2013, China Merchants Co., Ltd. participated in the restructuring of Djibouti Port Company and became the second largest shareholder of the port by acquiring 23.5% of its shares with USD 185 million. The multifunctional new port of Dohare was completed on April 16, 2017 after 30 months of infrastructure construction and officially opened on May 24 of that year. The port has a water depth of 153 meters, can dock 100,000-ton vessels and is designed to handle 7.08 million tons of break-bulk cargo and 200,000 TEUs of containers per year. This will expand the port's throughput

capacity to more than 1.5 times of the original one.

The Yagi railroad is also part of the infrastructure development of Djibouti port. The railroad connects the capital of Djibouti with the capital of Ethiopia, Addis Ababa, and goes straight to the mouth of the Red Sea. It provides an alternative for goods that would otherwise be transported only by road.

In addition to the construction of logistics facilities, China Merchants Group believes that corporate foreign investment is not free aid and ROI should also be paid attention to. Whether the port can drive the economic development of the surrounding areas and whether it can establish a good business model are key factors for the success of foreign investment.

The port of Djibouti adopts the integrated development approach of Port-Park-City, where the old capacity is eliminated or relocated to solve the problem of conflict between the port and the city of Djibouti and to adapt to the trend of larger ships, while Park refers to the construction of a free trade zone behind the port. In addition to creating a large number of jobs to boost the regional economy, the FTZ will serve as a distribution center for goods and attract a large number of European and African customers. City partially dismantled and relocated the old wharf that was previously eliminated, and re-planned the site to build commercial, office, hotel and tourism facilities to create a new commercial center of Djibouti.

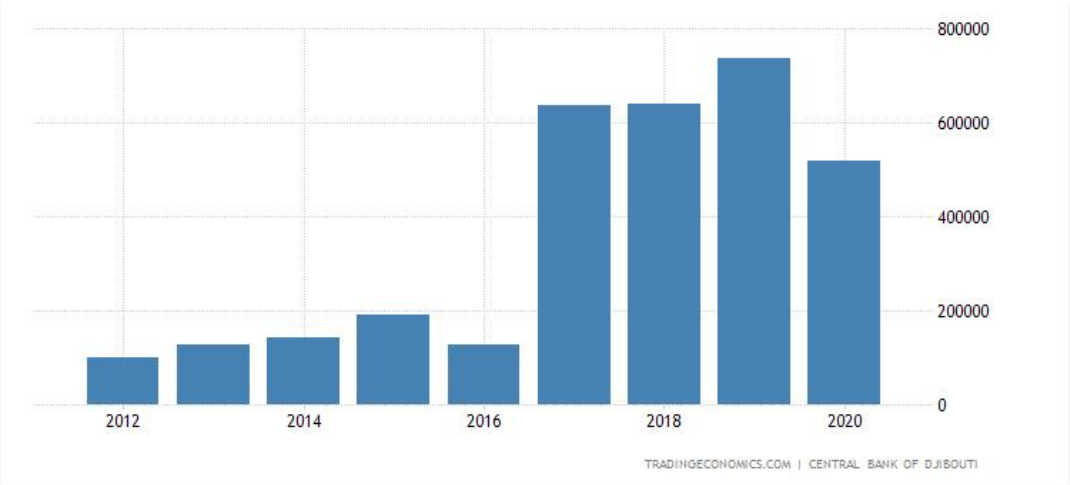

Figure 2-4 Djibouti Import Data

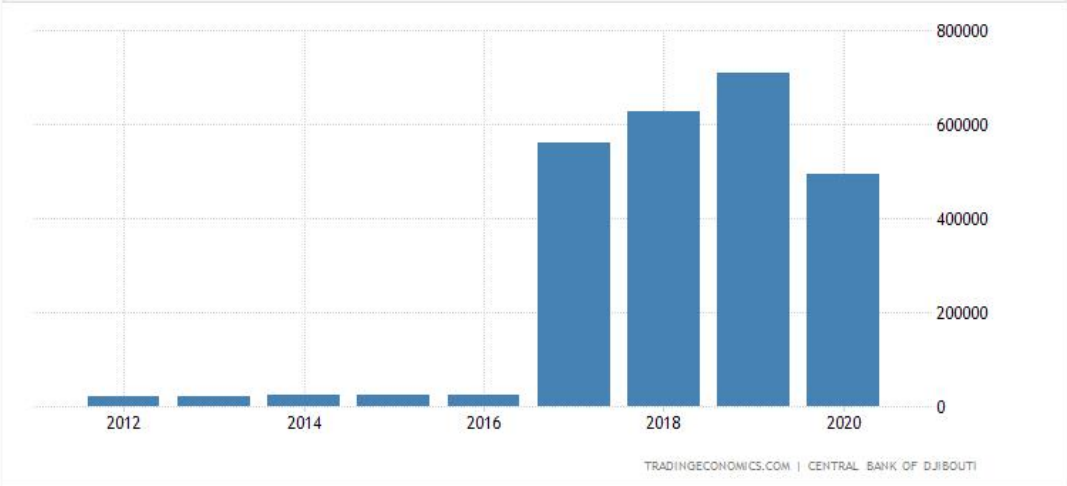

Figure 2-5 Djibouti Export Data

Chapter 3 Specific Issues in Capacity Sharing

3.1 Analysis of port structure design based on Capacity Sharing

Three kinds of capacities are defined in the paper, namely, information capacity, financial capacity, and physical capacity. The reason for using physical capacity instead of cargo capacity is that the object of the port service network is not only containers or cargo, but also port materials, transshipment vehicles, train cars, and warehouses are part of the port service network.

3.1.1 Analysis of port structure design based on Information Capacity Sharing

Information sharing can help PSN break through the barriers between different departments. At present, the mainstream information sharing method is to establish a data information center or platform to input all the information of passing ships, cargo information and port assets in the network into the data information center, and then further processing or judgment will be carried out by human or AI. Information sharing can be practically applied to cargo customs clearance, such as the "one document pass" customs declaration method implemented by Shenzhen port, which can save the manual and repetitive work of port departments and allow customs clearance and commodity inspection to be completed more efficiently. Information sharing can also be applied to the settlement of goods. International cargoes involve a lot of settlement links at the port, and the costs are complicated. Establishing a regional RMB pool allows for better

circulation of funds and facilitates settlement by all parties in the PSN.

Information sharing can also facilitate the management of port facilities by port authorities. Through information collection of equipment and comparison of maintenance data, ports can conduct more scientific maintenance and overhaul of assets and reduce safety risks in port operations. Information sharing also has many attempts in the management of ETA. By building data models, port authorities can accurately predict the ETA of ships, and notify and arrange relevant personnel and equipment in advance for ship conditions, saving the waiting time of ports and ships.

3.1.2 Analysis of port structure design based on Financial Capacity Sharing

Financial sharing is mainly carried out for port authorities and subordinate enterprises. At the beginning of many ports, the technology level at that time was not sufficient to support the financial management of the overall port group, and port enterprises usually faced problems such as financial data loss, incompatible financial data, confusing financial management authority or cumbersome financial processes. This may lead to risks in legal policy compliance and bring bad corporate reputation to the enterprise.

Financial sharing can optimize financial processes by establishing a financial sharing center, ensure the integrity and identifiable of financial data of upstream or downstream enterprises, and unify financial data interfaces. After realizing the transparency of the group's financial information, it can collect and centralize the management of idle funds for the enterprises and eliminate the occurrence of fraud and other incidents. It

can also implement risk assessment and control for receivables or debts. Under the sharing mode, the cost situation of different departments and businesses can be clearly counted, which is convenient for the group to control the cost of each business process. Financial management responsibilities can be more clearly defined. The labor waste caused by double accounting can also be reduced, which is convenient for the group to conduct internal audits.

3.1.3 Analysis of port structure design based on Physical Capacity Sharing

Physical sharing is more reflected in the cooperation between ports. In the context of the 21st Century Maritime Silk Road, the main forms of physical sharing of port service networks are:

a. Multi-modal transportation of empty container shipment

It is mainly reflected in the dispatch of empty container boxes by rail instead of water barges. The sharing of information can make the demand and redundancy of containers better respond on the unified information platform. The regional inland sea cooperative empty container dispatching strategy is to use empty containers as the shared subject and to allocate empty containers as well as the storage location selection based on the logistics network between railroads, roads, and ports.

b. Berth sharing of neighboring ports

The realization of shared berths in port clusters cannot be achieved without the joint support and changes of the local government, port side, ship

side, information technology, and other related industries in the port service network. This requires the formation of a unified policy between ports and standardized operational standards. The integration of resources in each port can realize real-time logistics resources and information resources sharing; good conditions for consolidation and distribution within the port group. The merger of port enterprises and integration of resources in a regional unit has become the starting point of port reform and has been effective. Reduce or even avoid the occurrence of large-scale berthing phenomenon between ports within the port group, and realize the more flexible and efficient loading and unloading, and transportation of goods between ports within the port group. Port shipping industry information technology is perfect. The information on waterways, berths, and shore bridges between ports can be shared in real-time. The information recorded between each other can be communicated and understood promptly.

c. Sharing of yards in neighboring ports

The shared yard agreement extends the container storage into 2 main areas: the central station yard and the terminal yard. Containers are mainly stacked in the central station loading line yard. In the non-shared mode, the imported containers are unloaded from the ship to the terminal yard and then transported to the railroad loading line after the train arrives at the station.

Under the physical sharing mode, after the imported containers arrive at the port, the coordinating department can reasonably allocate the yard according to the cargo owner's demand, taking into account various factors such as storage capacity limitation, free storage period, and changeover cost, etc. There are three storage options available.

1) Plan A: Vessel - Terminal Yard - Liner.

2) Plan B: Vessel - Central Station Yard - Liner.

3) Plan C: Vessel - Terminal Yard - Central Station Yard - Liner.

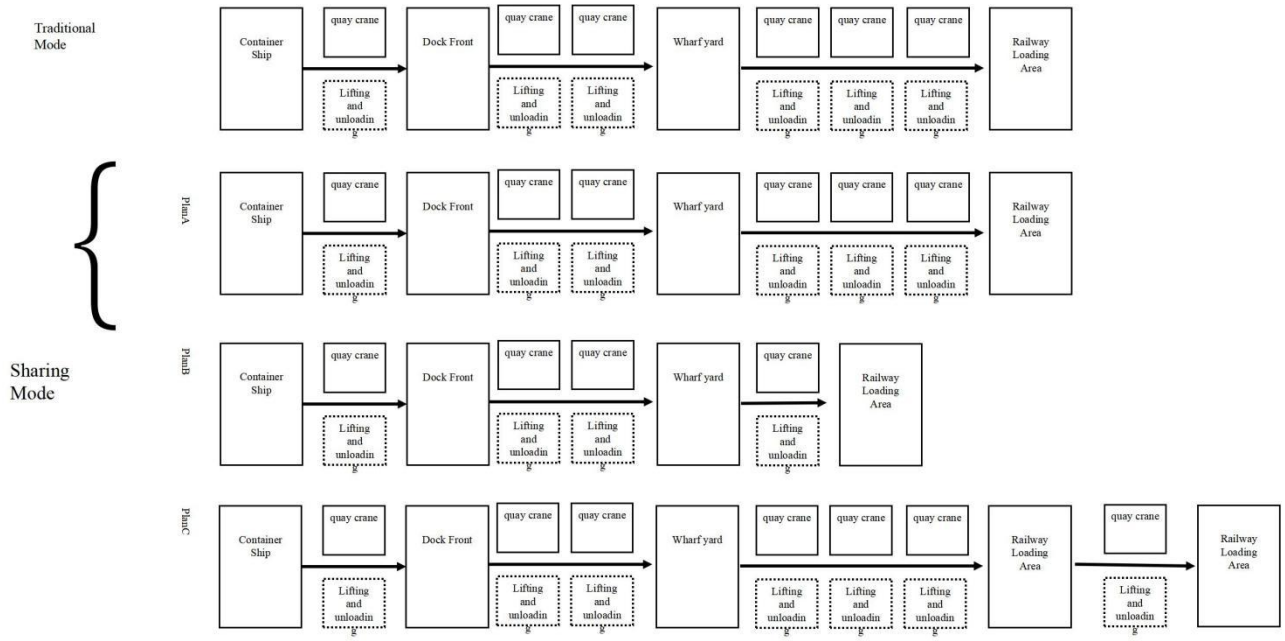

Figure 3-1 Model of yard sharing

3.2 Deficient Analysis in the port service network based on capacity sharing

All capacity sharing is based on the context of information sharing. However, for many less developed countries of the 21st Century Maritime Silk Road, the premise of information sharing is difficult to achieve. Take Djibouti as an example, before the re-planning of Djibouti ports was carried

out, the old ports were equipped with power supply facilities that could not even meet the power supply requirements of the new ports. For these countries, the need for infrastructure development resulting from the 21st Century Maritime Silk Road initiative is far more urgent than capacity sharing by port authorities. Therefore, the capacity sharing discussed below is based on ports with more developed port infrastructure between them.

3.2.1 Deficiency Analysis of Information Capacity sharing

Potential threats that may arise from information capacity sharing are mainly in the following aspects：

a. Threats to information security

Information sharing can make information in the port service network transparent, even cargo-specific information. Some countries are thinking strategically for their own countries, and they are not happy to display information about reserve cargoes, such as food, oil, gas, etc., under information systems that can be detected by other countries. Information sharing platforms also mostly need to rely on network and sensor providers to achieve this. Hacking, sensor failure, and faulty judgment of AI can create havoc for information capacity sharing.

b. Information overload

Information overload can confuse the users of information systems. The universal installation of sensors can be achieved by investment, yet understanding fluctuations in sensor numbers requires professional judgment. Failure to transform the collected information in a way that the information

user can understand can result in wasted information. The information recorded by various parties from different ports to each other, and from ports to railroads, warehouses, or ships is also not understood by each other if there is not a uniform information format. The information overload reflects the problem of information not being processed correctly.

c. Distortion of information due to language differences

The official languages of different subjects in international trade are different. We cannot require all information users to be able to use English correctly. Information may also bring misunderstanding in the conversion of different languages. In information sharing, we should pay attention to the development of multilingualism and the localization of information-sharing platforms.

d. Gaps in-laws and regulations

Information capacity sharing brings the participants of PSN into a larger information environment. It also means that the participants of PSN put themselves in a more transparent environment. Vulnerabilities in law and regulations may lead to unhealthy competition among participants and even threaten the stability of Port Service Networks.

e. Subsequent Management of Information Sharing Platforms

Information sharing systems are required to be constantly updated and iterated to meet the needs of usage. Information sharing platforms are not perfect when they are launched. International information sharing requires the cooperation of multiple information sharing centers to perfect it. The builder of the information system may not be able to take care of the

follow-up services, which may result in the information sharing platform not achieving the expected results.

3.2.2 Deficiency Analysis of Financial Capacity sharing

There are several key deficiencies for participants in financial capacity sharing.

a. Cost advantages are not obvious

Considering the actual situation of most participants, the initial construction of a financial shared service center requires a significant investment in framework construction. Tying up surplus capital can cause participants conducting financial sharing to choose to invest less or not to invest in the construction of the financial sharing platform for the sake of business performance. That is, there is a lack of incentive to participate. Establishing a financial sharing center enterprise requires a large investment of capital, and also requires coordination and matching with the participants' internal information system and internal control mechanism. The financial sharing system has a high demand for highly skilled personnel. The general technical personnel in the market are difficult to perform the related work, which makes it difficult for participants to recruit. In addition, the original branches all aggregate financial operations and funds for integrated management, which can cause the power to be taken up causing subordinate companies to lose enthusiasm for expanding business.

b. Grass-roots personnel are prone to resist

Financial sharing platforms are often constantly innovative. It

requires learning costs for both managers and grassroots personnel. The continuous learning of the shared platform will make the staff of each branch resist. When analyzed at the grassroots level, the core business of the company is uploaded to the financial shared service center for processing, resulting in the basic authority and responsibility of subordinate financial managers not being exercised. The new financial shared service model puts forward new requirements for financial personnel. In addition to the traditional accounting, bookkeeping and billing operations, the financial sharing system requires finance personnel to have high analytical skills and to understand the necessary requirements for building a financial sharing center. Understanding how to handle core operations with the help of new financial management tools.

c. Inadequate optimization of related processes

The financial sharing model can realize the integration of the core business of each subsidiary and carry out unified control. This approach can improve the efficiency of financial information dissemination in the overall information platform and enhance the level of process monitoring. In the case of practical application of the financial sharing model, supporting personnel management, material management and other operational mechanisms should also be paid attention to. Many participants, after establishing a financial sharing center, simply develop relevant processes. However, in the subsequent development stage, they do not pay attention to financial sharing, resulting in a waste of resources for the enterprise. Therefore, not all participants should engage in financial capacity sharing.

3.2.3 Deficiency Analysis of Physical Capacity sharing

Although physical capacity sharing is also based on information sharing, its disadvantages are also more obvious, mainly in the following aspects.

a. Mostly expressed as cooperation between neighboring regions

Whether it is empty container shipment, shared berth or shared yard, all operations require geographic proximity by nature. However, the 21st Century Maritime Silk Road is a global cooperation program, and we should focus more on international routes and international trade. These cooperative approaches can save costs and improve the efficiency of PSN, but they require uniform management within the region. This includes standardization of shared material handling methods, collaborative response of multiple regions to the same demand, establishment of rules for charging and storage of shared materials, and improvement of access requirements for relevant joiners.

b. Emphasis on central management

Therefore, Physical Capacity Sharing has a great need for strong supervision. This requires the sharing platform itself to have control and decision-making power over these shared entities. Whereas the entity Capacity Sharing cited earlier is often achieved under the leadership of a regional government, the port cooperation of the 21st Century Maritime Silk Road is sometimes co-managed by two or more entities. Different subjects may make choices that go against the global optimum based on their own interests.

c. Disorderly management of shared entities

The experience obtained from other industries such as shared rechargeable battery, shared bicycle, shared umbrella, etc. shows that the management of shared entities is generally less than expected.Physical Sharing initiators generally require a deposit in excess of the Physical item being shared. This means that in the process of using the service, the deposit of Physical Sharing participants may be misappropriated or even maliciously deducted by the Physical Sharing initiator, causing a sharing credit crisis. It is also extremely easy for disputes to arise between Physical Sharing initiators and participants if they encounter damage or hygiene problems of Physical Sharing items.

d. Greater public benefit attributes

The hope that Physical Capacity Sharing can reduce a large amount of cost is the only way for Physical Sharing participants to join the sharing program. Therefore, the price and the definition of rights and obligations become an important game between the sponsor of the sharing entity and the participants. If the price is set too high, Physical Sharing participants may lose their enthusiasm to join the Physical Sharing program due to risk aversion. Conversely, Physical Sharing sponsors may face financial difficulties in making ends meet. Generally speaking, Physical Sharing is a public good and hardly becomes a mature global business model.

3.3 Judging the effectiveness of Capacity Sharing based on the performance evaluation system

Capacity Sharing relies on port service networks under the 21st Century

Maritime Silk Road initiative. Port-Park-City is the most important port cooperation philosophy of the 21st Century Maritime Silk Road and the basis of Capacity Sharing. Therefore, it is very important to construct a Capacity Sharing evaluation system from the perspective of 21st Century Maritime Silk Road cooperation. The article will provide directions for the establishment of the evaluation system from the perspective of KPI. The evaluation direction is mainly set in five aspects: Policy communication, Facility connectivity, Smooth trade flow, Financial integration and Cultural communication according to the planning and construction direction of the 21st Century Maritime Silk Road Initiative. These five aspects can comprehensively evaluate the current situation of international cooperation.

a. Policy communication

The cooperation is based on mutual policy understanding. Although the 21st Century Maritime Silk Road cooperation is conducted by agreement the evaluation system still needs to take into account the mutual understanding of policies. The regime stability of the cooperating authorities, the mutual understanding of policies, the stability of the international environment and the attitude of both parties to Capacity Sharing need to be taken into account.

b. Facility connectivity

Facility connectivity is the basis for the formation of a network of port services. In areas where infrastructure development needs to be improved, it is particularly important to improve related infrastructure development. The construction of port, railroad and road networks can increase the number of jobs and reduce unemployment. More importantly, the interconnection of facilities facilitates international trade. It can facilitate the movement of

businessmen and goods from neighboring regions.

c. Smooth trade flow

Capacity Sharing can facilitate trade and reduce trade costs; Information Sharing can provide a larger platform for trade in goods, services and technologies, allowing for faster matching of supply and demand. Physical sharing can reduce the costs incurred in the trade process and improve the efficiency of trade.

d. Financial integration

The main directions of capacity sharing in finance are centralized settlement and currency internationalization. Centralized settlement can facilitate the reduction of financial settlement processes between parties in the port service network. It will break the original way of mutual settlement of buyer - forwarder - transporter - carrier - port, and realize "one payment to multiple parties" through block-chain and centralized settlement, which will reduce the duplicated work of payment collection. Currency internationalization refers to the realization of trade currency reserves in the clearing house of both sides. This reduces the need to rely on the U.S. dollar as the central currency for two exchange processes. The accelerated flow of capital between the two countries can also promote private investment activities.

e. Cultural communication

Evaluating the effectiveness of Capacity Sharing from cultural communication is to consider the cases of failed port cooperation. All the needs in the port service network are based on human needs. It is dangerous

to ignore the local people's evaluation of the cooperation and just to enhance the cooperation between governments. Failed port cooperation will not only lose a lot of investment money but also make Capacity Sharing impossible.

Table 3-1 Evaluation System Table

Directions	Objectives	Measures	Targets	Initiatives
Policy communication	Stability of authority	If the cooperation country is at risk of government change	No	Strengthen the policy communication between the two partners
	Understanding of policy	Awareness of practical actions based on cooperation in various projects	Yes	
	International Environment	Threats from the international situation	No	
	Attitude of Capacity Sharing	Supportive of Capacity Sharing	Yes	
Facility connectivity	Infrastructure Availability	Progress of infrastructure construction	100%	Investment in infrastructure to ensure the flow of goods and materials
	Logistic network availability	Availability of sufficient capacity and non-blocking logistics connectivity at major ports and logistics hubs	Yes	
	Labor Availability	Availability of labor near logistics facilities to meet demand	Yes	Train local workforce to meet facility needs

	Information Platform Availability	Whether there is an information platform or the willingness to establish an information platform	Yes	Create an information platform or find a reliable alternative solution
Smooth trade flow	Foreign trade structure	Is the ratio of import and export balanced	Yes	Join trade partnerships to enhance regional trade
	Trade Barriers	Whether there are high tariffs or trade barriers	No	
	Trade Activity	Trade Volume	As high as possible	
	Product Quality	Does the product quality evaluation system refer to international standards	Yes	Promote the linkage of national and international standards
Financial integration	Currency liquidity	Whether the currency can be easily exchanged	Yes	Enhanced financial flows can empower collaboration
	Currency Security	Is the exchange rate stable	Yes	
	Investment profitability	ROCE	As high as possible	
Cultural communication	Cultural Exchange	Degree of Civilian Friendship	As high as possible	The strengthening of civil communication can promote the implementation of civil cooperation between the two regions and
	Religious Issues	Existence of religious conflicts	No	
	Media Views	The media's attitude towards cooperation	Positive	

				regular exchange activities

3.4 Pearl River Delta port capacity sharing evaluation based on performance evaluation system

China has three major port groups: the Pearl River Delta port group in southern China, the Yangtze River Delta port group in eastern China and the Bohai Rim port group in the north. Because of the special historical reasons and geographical conditions of the Pearl River Delta port group, it is significantly different from the other two port groups.

As the region with the highest population density in China, the Pearl River Delta region has always enjoyed the development dividend brought by the large population. However, international cooperation is easier than before in the context of the 21st Century Maritime Silk Road. This also facilitates the relocation of industries in the Pearl River Delta. A large number of low-end manufacturing industries have chosen countries and regions with lower labor costs such as Vietnam as their destinations. This forces the Pearl River Delta have to face more pressing pressure than the other two port groups in terms of technological innovation, service improvement and industrial upgrading. Due to historical reasons, Hong Kong and Macao have a large room for independent decision-making in the port service network development, which also makes it difficult to carry out coordination and cooperation in the port group.

Figure 3-2 Pearl River Delta Map

The mainstream view generally holds that Guangzhou, Shenzhen and Hong Kong are the three most important ports in the Pearl River Delta port group. Guangzhou has a solid foundation for the development of the manufacturing industry, and both foreign trade and domestic trade and transportation started earlier. As the capital of Guangdong Province, Guangzhou has expanded the urban land area of Guangzhou by integrating many surrounding districts and counties through regional re-planning. Whether it is sea transportation or railway transportation, Guangzhou can be easily transferred to other provinces and cities in China, and it is the transportation hub of the entire Pearl River Delta port.

As a special economic zone in Guangdong Province, Shenzhen started the establishment and practice of a free trade zone earlier. Shenzhen has rich

and excellent coastline and port resources, and has absorbed Hong Kong's advanced port management experience in port management. It has acted as a low-cost substitute for Hong Kong port in the past period of time. After the establishment of the port information system, the embarrassing position of Shenzhen Port was reversed.

The development of Hong Kong port in recent years has shown obvious disadvantages. In terms of supply and charges, the goods of Hong Kong port are extremely easy to be diverted by other ports in the Pearl River Delta. The core competitiveness of Hong Kong Port lies in its unique free port development system. Hong Kong has excellent port facilities and service systems as well as well-trained practitioners thanks to the high-speed operation of international capital and talents in Hong Kong. Shipping finance, talent training system in line with international standards and high production efficiency make the port service network more mature and complete than the other two ports. However, the high labor cost and scarce land resources in Hong Kong have become the main reasons for restricting its development.

The development conditions and limitations of the port itself have prompted the further development of the port service network of the Pearl River Delta port group. Strengthening the cooperation of these three ports can not only provide more hinterland areas for Hong Kong's port-related industries, but also bring more international trade orders to Guangzhou and Shenzhen, and provide conditions for personnel exchanges and mutual learning of port management progress.

a. Policy Communication

The 21st Century Maritime Silk Road has further promoted cooperation

between regional governments. Although the Pearl River Delta region is different in system, there is no risk of government change in the foreseeable future. The 21st Century Maritime Silk Road has enabled the governments of the three places to have in-depth policy communication on many issues related to port operations. The adjacent regional locations make these three ports have similar geographical conditions and maintain a consensus on the international situation in the surrounding areas. In terms of capacity sharing, the management authorities of the Pearl River Delta port group are also actively exploring different cooperation models, and jointly promote the development path of capacity sharing through industrial relocation, industrial upgrading and strengthening academic exchanges.

b. Facility Connectivity

The Pearl River Delta port group has relatively complete infrastructure construction, advanced railways and internal water transportation. The Pearl River Delta port group has also had a lot of practice in the availability of port service network logistics network. In terms of positioning, a port service network pattern with Guangzhou as the hub has been formed. Hong Kong's high-end shipping personnel and other shipping personnel in the Pearl River Delta region can also form a good complement to each other. It can improve the port production efficiency of other port groups in the Pearl River Delta while reducing the high labor cost in Hong Kong. The availability of information systems is currently under development. Except for Hong Kong and Macau, other ports in the Pearl River Delta have basically completed the construction of information platforms. Based on the consideration of its own strategic development and core competitiveness, Hong Kong Port is relatively conservative in the availability of information platforms.

c. Smooth trade flow

Hong Kong is the only free trade port in the entire Pearl River Delta port group, with a higher level of international trade than other members of the port group. The Pearl River Delta port service network has become the port service network with the lowest trade barriers in China because of Hong Kong and Shenzhen. Low trade barriers bring a lot of foreign capital and trade opportunities. The high population density has also boosted the local import and export trade demand. Under the dual effects of the passage of time and the relocation of the industry, the product quality is better in line with international standards. The development of emerging industries such as cross-border e-commerce has promoted the internationalization of product quality in the region.

d. Financial integration

There are three currencies within the Pearl River Delta port service network. Currency exchange and settlement is also very important in the port service network. Hong Kong dollars and patacas are only circulated locally. RMB has become the first choice for settlement in the Pearl River Delta port service network. The high liquidity and security of RMB lays the foundation for Financial Integration. The higher ROCE is also due to the large business volume of the local port service network and the clear classification between ports.

e. Culture Communication

The culture within the Pearl River Delta port service network is of the same origin. The same language and regional customs lead to frequent and

friendly cultural exchanges between peoples. Religious issues do not appear in the port service network. Driven by the 21st Century Maritime Silk Road, the media in the overall port service network are all friendly towards the B&R initiative.

The infrastructure of the Pearl River Delta port service network is in good condition. Capability sharing can solve the development pain points of each member in the service network.

Guangzhou Port should use its status as a transportation hub for waterways and railways to further promote cooperation in service networks. Providing a hinterland to the ports of Shenzhen and Hong Kong can promote the development of the port industry in the port of Guangzhou. The scarcity of land resources in Hong Kong and Shenzhen will also be resolved.

Shenzhen Port and Hong Kong Port should strengthen negotiation and cooperation on price to avoid the occurrence of low-price competition in the preemptive supply of goods. Shenzhen Port and Hong Kong Port should formulate unified standards for port services, and conduct regular port management and personnel exchanges.

Other smaller ports in the Pearl River Delta port service network, such as Zhuhai, Dongguan, Zhongshan and Huizhou, should further develop their functional positioning. For example, Dongguan Port, as a grain import port, should further develop in the field of grain import and export and the handling of grain arrival at the port. The provision of higher value-added services and the development of food-related industries can drive regional prosperity.

Chapter 4 Optimization Analysis of Existing Port Service Network Capacity Sharing

4.1 Description of the optimization problem for Capacity Sharing

The previous section talked about the current strengths of Capacity Sharing development and the current weaknesses of Capacity Sharing. The reliability of the port service network has been challenged as never before by geopolitics, epidemic impacts and natural disasters.

There are many reasons for port or critical channel blockages, which fall into two main categories. One category is the cause of restricted natural conditions. Such as hurricanes, earthquakes, tsunamis, and other reasons that cause ships to be unable to dock, resulting in supply chain blockage. The other category is caused by human factors. Such as strikes, epidemics, war and other factors lead to supply chain blockage.

At this time, the advantages of railroad transportation appear. Compared with water transportation, railroad transportation is less affected by natural environment, and the scheduling of railroad can also ensure the flexibility of regular transportation. In the context of the 21st Century Maritime Silk Road Capacity Sharing can provide PSN with the ability to use rail transportation to transport goods to areas that need to be met when critical shipping lanes are blocked. In the case of emergency and contingency situations, capacity sharing can be used to meet the needs or defuse the crisis with ease.

4.2 Optimization direction selection of Capacity Sharing

The optimization direction of Capacity Sharing is to strengthen the

construction of port service network and guarantee the efficient transmission of information in the port service network. In case of congestion on maritime roads, real-time information transmission makes it possible to ensure the smooth flow of the supply chain by detouring or changing the mode of transportation for cargo.

The article transforms the route from the traditional water transport mode to the form of port service network. The single chain transportation mode is changed into a network transportation mode by adding point C. The dotted line in the figure indicates the rail transport mode, and the solid line indicates the maritime transport mode. In this case C is the rail hub adjacent to port B.

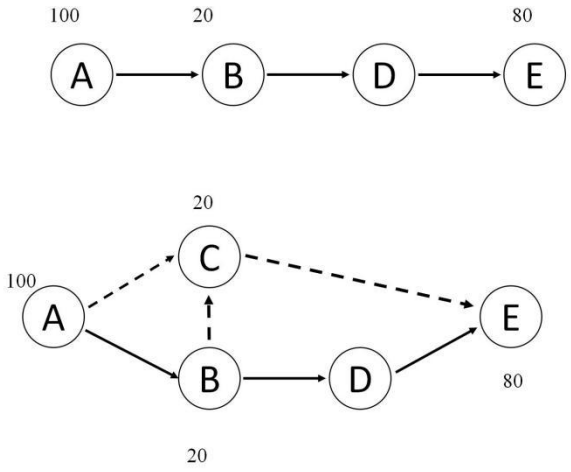

Figure 4-1 Model of Capacity Sharing

4.3 Establishment of an optimization model for Capacity Sharing

4.3.1 Parameter description

Assume that the capacity output and demand from A to E are shown in the figure.

Input : i is the starting point j is the end point denoted by A~E.

(i, j): The arc from i to j

C_j^i: Transport Cost

K_i： Capacity of Departure point

D_i： Demand of Region

Table 4-1 Transport cost assumption

Transport cost	To node				
From node	A	B	C	D	E
A		$300	$800		
B			$100	$800	
C					$4000
D					$1400
E					

Capacity Limit Node A 100

Capacity Limit Node B/C 20

Capacity Limit Node E 80

Table 4-2 Transport time assumption

Transport time	To node				
From node	A	B	C	D	E
A		6	2		

B		1	15	
C				10
D				25
E				

4.3.2 Model establishment

From the simple calculation in the figure, it can be obtained that the pure rail transportation is: A→C→E , the transportation cost is $400,000 , and the transportation time is 12 days.

Pure waterway transportation is: A→B→D→E, transportation cost is $206,000, transportation time is 46 days.

4.4 Model solution method

We assume that the blockage is known to occur at point D on the route after the ship leaves the port and that the blockage time is calculated based on the median of 6 days of disruption in the study of J. Verschuur et al. (2020). The time for purely waterborne transport would be extended to 52 days. However, if the transportation method of A→B→C→E is used, the transportation time is only 17 days and the overall cost is $358,000.

Table 4-3 Preliminary calculation results of the model

Route	Total Cost	Total transport time	Operable times a year
A→C→E	$400,000	12	30.42

A→B→D→E	$206,000	46	7.93
A→B→C→E	$358,000	17	21.47

Since B and C are set in the model as a port hub and a railroad hub in the same region, the calculation of the chain A → B → C → E can be further refined.

Table 4-4 Further calculation for A→B→C→E

Demand at point B	Demand at point C	Total Cost
0	20	$360,000
1	19	$359,900
2	18	$359,800
3	17	$359,700
4	16	$359,600
5	15	$359,500
6	14	$359,400
7	13	$359,300
8	12	$359,200
9	11	$359,100
10	10	$359,000
11	9	$358,900
12	8	$358,800
13	7	$358,700
14	6	$358,600
15	5	$358,500
16	4	$358,400
17	3	$358,300
18	2	$358,200
19	1	$358,100
20	0	$358,000

4.5 Example analysis

Based on the results of the calculations, the use of Capacity Sharing can help freight participants in the port service network to flexibly allocate capacity in the network to ensure better alignment with customer needs. The inclusion of rail transport network can significantly reduce the cargo transportation time by 35 days and give the participants in the port service network another option in terms of route allocation.

4.5.1 Analysis of result

From the results we see that the cost of water transport is very low, but the period of pure water transport is very long. Even assuming that transporters transport this route 365 days a year without interruption, the profit that can be obtained is very small. The model demonstrates a negative correlation between profit and transit time.

The transmission of information in the port service network can make port services more responsive to decision-making. Insufficient capacity caused by emergencies in a port can be achieved by ports in its vicinity through capacity sharing. This is of great significance for users of the port service network in terms of advance planning and risk warning.

Table 4-5 Fixed Margin view on profit calculation

Route	Total Cost	Total transport time	Operable times a year	Margin of transport set at 5%	Profit under 5%	Margin of transport set at	Profit under 10%	Margin of transport set at	Profit under 15%	Margin of transport set at	Profit under 20%
A→B→D→E	$206,000	46	7.93	$216,842	$86,030	$228,889	$181,618	$242,353	$288,453	$257,500	$408,641
A→B→C→E	$358,000	17	21.47	$376,842	$404,551	$397,778	$854,052	$421,176	$1,356,436	$447,500	$1,921,618
A→B→C→E	$358,100	17	21.47	$376,947	$404,664	$397,889	$854,291	$421,294	$1,356,815	$447,625	$1,922,154
A→B→C→E	$358,200	17	21.47	$377,053	$404,777	$398,000	$854,529	$421,412	$1,357,194	$447,750	$1,922,691
A→B→C→E	$358,300	17	21.47	$377,158	$404,890	$398,111	$854,768	$421,529	$1,357,573	$447,875	$1,923,228
A→B→C→E	$358,400	17	21.47	$377,263	$405,003	$398,222	$855,007	$421,647	$1,357,952	$448,000	$1,923,765
A→B→C→E	$358,500	17	21.47	$377,368	$405,116	$398,333	$855,245	$421,765	$1,358,330	$448,125	$1,924,301
A→B→C→E	$358,600	17	21.47	$377,474	$405,229	$398,444	$855,484	$421,882	$1,358,709	$448,250	$1,924,838
A→B→C→E	$358,700	17	21.47	$377,579	$405,342	$398,556	$855,722	$422,000	$1,359,088	$448,375	$1,925,375
A→B→C→E	$358,800	17	21.47	$377,684	$405,455	$398,667	$855,961	$422,118	$1,359,467	$448,500	$1,925,912
A→B→C→E	$358,900	17	21.47	$377,789	$405,568	$398,778	$856,199	$422,235	$1,359,846	$448,625	$1,926,449
A→B→C→E	$359,000	17	21.47	$377,895	$405,681	$398,889	$856,438	$422,353	$1,360,225	$448,750	$1,926,985
A→B→C→E	$359,100	17	21.47	$378,000	$405,794	$399,000	$856,676	$422,471	$1,360,604	$448,875	$1,927,522
A→B→C→E	$359,200	17	21.47	$378,105	$405,907	$399,111	$856,915	$422,588	$1,360,983	$449,000	$1,928,059
A→B→C→E	$359,300	17	21.47	$378,211	$406,020	$399,222	$857,154	$422,706	$1,361,362	$449,125	$1,928,596
A→B→C→E	$359,400	17	21.47	$378,316	$406,133	$399,333	$857,392	$422,824	$1,361,740	$449,250	$1,929,132
A→B→C→E	$359,500	17	21.47	$378,421	$406,246	$399,444	$857,631	$422,941	$1,362,119	$449,375	$1,929,669
A→B→C→E	$359,600	17	21.47	$378,526	$406,359	$399,556	$857,869	$423,059	$1,362,498	$449,500	$1,930,206
A→B→C→E	$359,700	17	21.47	$378,632	$406,472	$399,667	$858,108	$423,176	$1,362,877	$449,625	$1,930,743
A→B→C→E	$359,800	17	21.47	$378,737	$406,585	$399,778	$858,346	$423,294	$1,363,256	$449,750	$1,931,279
A→B→C→E	$359,900	17	21.47	$378,842	$406,698	$399,889	$858,585	$423,412	$1,363,635	$449,875	$1,931,816
A→B→C→E	$360,000	17	21.47	$378,947	$406,811	$400,000	$858,824	$423,529	$1,364,014	$450,000	$1,932,353
A→C→E	$400,000	12	30.42	$421,053	$640,351	$444,444	$1,351,852	$470,588	$2,147,059	$500,000	$3,041,667

4.5.2 Directions for further experiments

The experiment only considered the case of blockage at point D, and did not consider the case of maritime blockage on several other transport routes. The article considers Profit Margin without taking different ratio for ocean and rail transportation. Different Margin Ratio for ocean and rail transportation may be closer to the actual situation.

Chapter 5 Conclusion and Outlook

5.1 Main contributions

The article first analyzes researchers in related fields, relevant studies on the construction of port networks in the 21st Century Maritime Silk Road. The theoretical and practical development of the port service network is described in terms of how it is constructed, the motivation for its establishment, and how to carry out Capacity Sharing.

This dissertation also analyzes how the port, the most important part of the port service network, should be built to meet the requirements of Capacity Sharing based on the model of Capacity Sharing.

The article divides Capacity Sharing into three different forms: information sharing, financial sharing and physical sharing. The success stories and many shortcomings of Capacity Sharing in port service networks today are illustrated from both positive and negative perspectives.

The capacity sharing evaluation system is proposed from the development principle of the 21st Century Maritime Silk Road. The status of port service network and capacity sharing in the Pearl River Delta is also measured based on this. According to the existing pattern article, some feasible development suggestions are put forward.

The optimization and solution of transportation routes are discussed to show how capacity sharing is realized on a single route. And through the obstruction simulation of the route, we analyze the transportation method based on rail-waterway cooperation to improve the efficiency of cargo passage in the port service network.

5.2 Research Prospects

The 21st Century Maritime Silk Road, as part of the B&R is still in the development stage. Port-Park-City is the basic module of the port service network, which is more functional than traditional ports.

For the regional port service network, more models of Physical Capacity Sharing are worth exploring. More port service networks under the 21st Century Maritime Silk Road will also be further extended, providing a new way of thinking for future cooperation.

Capability sharing across regions is difficult to express in physical form. The sharing of information and finance is of great significance in exploring cross-regional port service network capability sharing. Capability sharing should be practiced in fields that are easy to standardize, such as international empty container transportation. Through precise calculation, the empty container level of participants in the service network should be evaluated, and it should be allocated to the areas in need in a globally optimal way.

Financial sharing can be achieved in the settlement of international goods. New technologies can form a centralized settlement center across countries and regions. Block chain can trace and track cargo documents and bills. Trust among users in the port service network is increased. Unified accounting can also reduce the settlement steps and waiting periods of funds, and speed up the flow of funds in the port service network.

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