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Scope economy analysis of container shipping network

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SCOPE ECONOMY ANALYSIS OF CONTAINER SHIPPING NETWORK

by

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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.

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Supervisor's affiliation: …………………………..

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ABSTRACT

Firstly, this dissertation studies the theory of container shipping network and concludes that the total amount of container allocation for two routes with the same port of call is less than the sum of the total amount of container allocation for two routes running independently, which proves that there is scope economy in the container shipping network. Through research on control variables, concludes that with the increase of routes in the network, the scope economy saving rate will not increase indefinitely, but tends to an extreme value of about 20%. Also, with the increase of non-productive containers in the route, the scope economy saving rate is decreasing.

Secondly, through the collection and analysis of the actual data and the research of the actual situation, the sum of the annual operation cost of three routes operating separately is greater than that of the integrated operation, so there is scope economy in the actual container shipping network. By fitting the number of ships and the annual operating cost data of the container shipping company, the conclusion is drawn that with the increase of the number of ships allocated to the route, the diseconomies of scope appear.

Finally, analyze the historical data of China-America and China-Africa routes, by using investment portfolio theory, it is concluded that the scope economy can increase the risks resist ability of shipping companies.

KEYWORDS: Scope economy analysis; Container shipping network; Container liner shipping;

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1.Introduction

1.1 Research background

Since the container was invented in 1921, container transportation has become an indispensable part of the global integration process after nearly a hundred years of evolution. With its advantages of high efficiency, high automation, low cost, and low complexity, container accelerates the transportation of global goods, promote the adjustment of global industrial structure, shortens the time of goods turnover, and greatly reduces the cost of goods inventory and transportation. From the beginning, container transportation was only used for railway transportation and developed into a mode of transportation for both sea transportation and air transportation. Based on standardized containers, freight stations, fully automated container terminals, vessels, vehicles, trains, airplanes, etc., Zheng ting (2009), are built to form a self-contained sea, land and air container shipping network system

With the proposal of "21st Century Maritime Silk Road", China has also put forward new requirements for maritime logistics system, Wang Haiyan (2019). To cope with the complex international situation in the new international environment, a new round of development of China's shipping economy is inevitable. The construction of the maritime silk road is inseparable from the container shipping network as its carrier. The stability, efficiency, and reliability of the container liner transportation provide strong support for the trade environment of the maritime Silk Road, reduce the instability of the shipping network, and ensure the stable development of the economic and trade transportation of the "21st Century Maritime Silk Road". "The 21st Century Maritime Silk Road" links the market chain of South Asia, West Asia, North Africa, Europe, and other major economic sectors, and develops the strategic cooperative economic belt facing the South China Sea, the Pacific Ocean, and the Indian Ocean. Promoted liner companies to design more liner routes linking the 21st century Maritime Silk Road. In the process of designing new routes, the scope economy of the container shipping network is inevitably brought into the discussion. Ship companies design many different routes at the same time. In different routes, many operating costs have the same production factors, resulting in their total costs lower than the sum of the total costs of designing and operating different routes respectively, thus reducing the cost shared by a single route and forming a scope economy.

Besides, due to the impact of the epidemic, domestic and foreign container transportation are in a depressing atmosphere. As a result of the sudden outbreak of COVID-19, the global commodity trade has been hit hard. As a result, most of the shipping companies have been forced to cancel their scheduled flights and idle most of the ships in operation. According to the data and forecast released by the World Trade Organization in April this year, the global GDP will drop by 2.5% this year, and the global trade will decrease by 13% - 24%. The situation of the shipping industry is not optimistic. The profits of the world's top 15 container companies will drop by 6 billion US dollars. Alphaliner, a shipping consulting website, pointed out in a report at the beginning of February that the outbreak of the new crown epidemic will reduce the container freight volume of Chinese ports (including Hong Kong) by 6 million TEU in the first quarter of 2020, and predicted that the growth rate of global container throughput will drop by at least 0.7% this year. On the whole, the container ship market will face difficulties this year based on the reduction in the growth rate of traffic volume and excess capacity. The overall volume and profit of the container shipping network will be greatly reduced under the influence of the epidemic.

Although the overall development trend of container shipping networks is getting better, in recent years, due to the influence of the epidemic situation and trade ban of different countries, the current situation of China's foreign trade is severe, and container transportation may also be stagnant in the future. In this context, through the analysis of the scope economy of the container shipping network, we can find the inherent laws, which is helpful to reduce the logistics cost of the shipping enterprises, increase the competitiveness of the enterprises, improve the service level of the container shipping network, promote the smooth development and construction of the economic and trade of the "21st Century Maritime Silk Road", and improve the efficiency of the management of the shipping network. Therefore, the scope economy analysis of the container shipping network is a necessary and urgent research problem.

1.2 Literature review

1.2.1 Research on container network

Christiansen, M., Hellsten, E. et, al (2020) present an in-depth literature overview of existing models and solution methods for liner shipping network design and discuss the four main families of solution methods: integrated mixed-integer programming models; two-stage algorithms designing services in the first step and flowing containers in the second step; two-stage algorithms first flowing containers and then designing services; and finally algorithms for selecting a subset of proposed candidate services. We end the presentation by comparing the performance of leading algorithms using the public LINER-LIB instances. This article Liner shipping network design is concluded by discussing future trends in liner shipping, indicating directions for future research.

Agarwal, R.; Ergun, O. (2008) present an integrated model, a mixed-integer linear program, to solve the ship-scheduling and the cargo-routing problems, simultaneously in the article *Ship scheduling and network design for cargo routing in liner shipping*. The proposed model incorporates relevant constraints, such as the weekly frequency constraint on the operated routes, and emerging trends, such as the transshipment of cargo between two or more service routes. Computational experiments are performed on randomly generated instances simulating real-life with up to 20 ports and 100 ships. Our results indicate a high percentage utilization of ships' capacities and a significant number of transshipments in the final solution.

In the article *Joint routing and deployment of a fleet of container vessels,* Jose Fernando Alvarez (2009) presents a model and an algorithm to address the two problems jointly. The model captures the revenues and operating expenses of a global liner company, and allows for the representation of vessel types with different cost and operating properties, transshipment hubs and associated costs, port delays, regional trade imbalances and the possibility of rejecting transportation demand selectively. Benchmark tests demonstrate that the proposed algorithm achieves good solutions quickly. The proposed algorithm is applied in a case study with 120 ports of call distributed throughout the globe. The case study explores the sensitivity of optimal fleet deployment and routing to varying bunker costs.

In the article *The worldwide maritime network of container shipping: Spatial structure and regional dynamics*, Ducruet César and Notteboom Theo (2012) present an analysis of the global liner shipping network in 1996 and 2006, a period of rapid change in port hierarchies and liner service configurations. While transshipment hub flows and gateway flows might slightly shift among nodes in the network, the network properties remain rather stable in terms of the main nodes polarizing the network and the overall structure of the system. In addition, mapping the changing centrality of ports confirms the impacts of global trade and logistics shifts on the port hierarchy and indicates that changes are predominantly geographic.

Chen Chao, Zeng Qingcheng (2010) focuses on the optimization of the container shipping network and its operations under changing cargo demand and freight rates. In the article *Designing container shipping network under changing demand and freight rates,* the problem is formulated as a mixed-integer non-linear programming problem (MINP) to maximize the average unit ship-slot profit at three stages using the analytical methodology. The issues such as empty container repositioning, ship-slot allocating, ship sizing, and container configuration are simultaneously considered based on a series of matrices of demand for a year. To solve the model, a bi-level genetic algorithm-based method is proposed. Finally, numerical experiments are provided to illustrate the validity of the proposed model and algorithms. The obtained results show that the suggested model can provide a more realistic solution to the issues based on changing demand and freight rates and arrange a more effective approach to the optimization of container shipping network structures and operations than does the model based on the average demand.

To explore the current trend of the global container shipping network vulnerability, the analytical approach and quantitative methods were put forward for researching the change rate of the network vulnerability. Wang Nuo, Dong Lingling, Wu Nuan (2016) chose the routes distribution data from the world's main container liner companies in

2004 and 2014 as the study foundation. The result shows that the vulnerability of the global container shipping network has the trend of becoming weaker in recent 10 years under intentional attack. When the scale of the attack is less than 10% of the whole network, the vulnerability of the container shipping network has weakened by about 6.1%. The research conclusion in this article *The change of global container shipping network vulnerability under intentional attack* has an important significance for deepening the research of port geography, and the analytical approach and method also provide a reference to network characteristics analysis in other fields.

1.2.2 Theoretical basis

In the article *Economic analysis for container shipping route,* Lu Bo, Hua Guowei, Zhang Xiaoxu (2015) has developed an economy evaluation model corresponding to change in transshipment cargo volume of neighbor ports in North-East Asia classifying to Route 1 and Route 2 with Busan Port as a starting point and carried out an economic evaluation of the sea route, an important data for deciding sea routes and calling ports of the shipping companies by applying this model. As a result of analyzing such 2 routes, the shipping company can develop a more profitable route and the port-related government authority or operational institution of each country can figure out the threshold of feeder cargo volume in economic viewpoint.

The historical data of containerization and national economic growth for 10 high-income states and 10 middle-income states are selected by Ma Yu, Luan Weixin (2018) in this article *Research on the relationship between container accumulation and national economic development*, and then after deductive analysis and inductive reasoning, the container accumulation pattern is summarized. Results show the container transportation is experiencing sustained growth in different countries; container generating density shows different growth trend in different income stages, and the density level is relatively low and stays stable for high-income states, while it shows the relatively high level and fast increase for middle-income states; the relationship between the container generating density and per capita income is found to be an inverse U-shape curve, while systematic differences are also noticed between different types of states; the turning point for China's container generating density has already appeared, and with the slower economic growth rate and economic restructuring in the near future, China's container accumulation density will experience a medium-low growth.

Portfolio theory and capital asset pricing models are important tools for financial market investment analysis and an important means for market participants to participate in market activities. In order to further understand the practical application and effect of these two models, Wang Lijie (2015) deeply analyzes the theoretical knowledge of portfolio theory and capital asset pricing model by briefly describing the application of portfolio theory and capital asset pricing model and its calculation method in the article *Investment portfolio theory and capital asset pricing model.*

1.3 Article structure

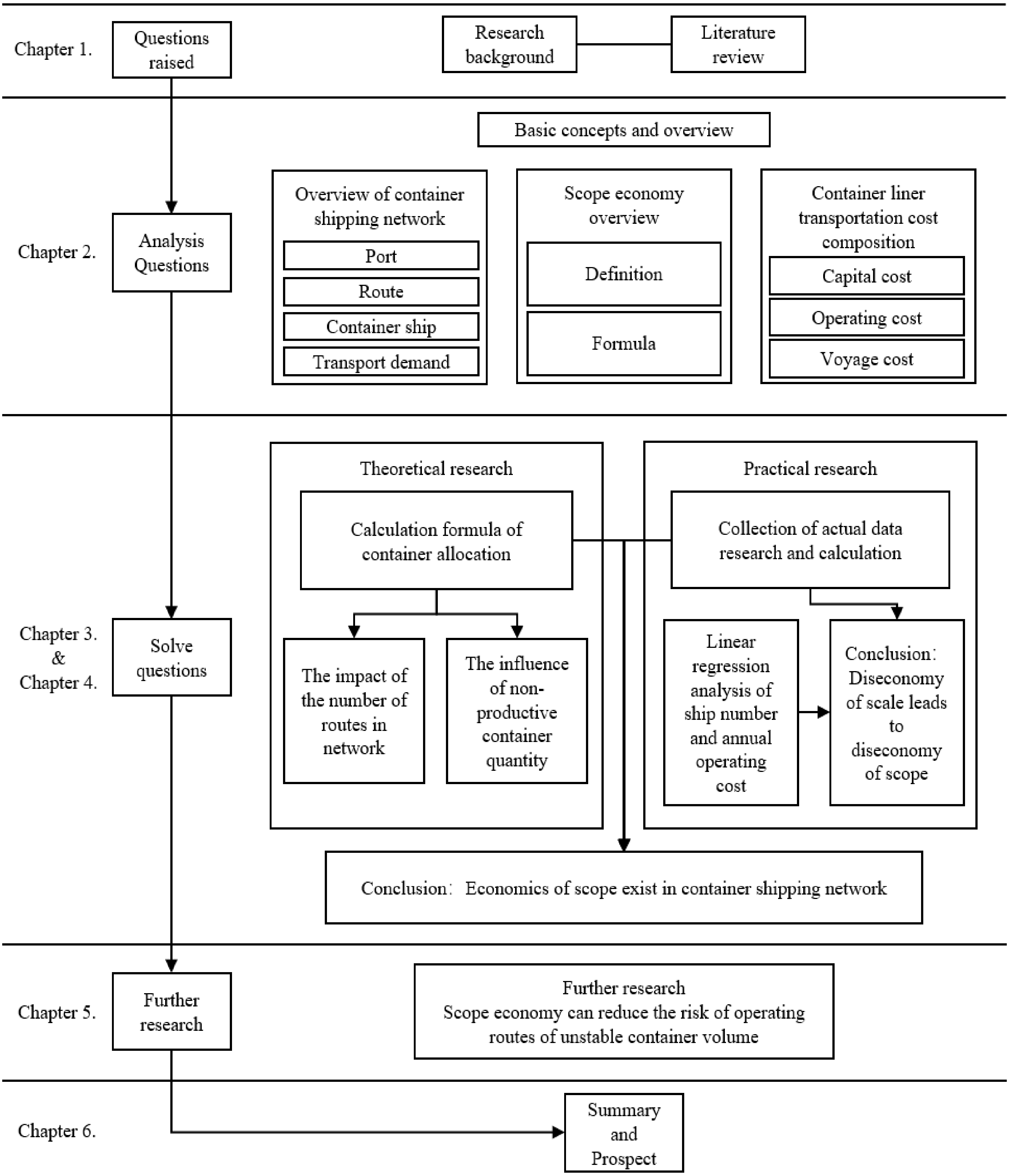

Figure 1 Technology-route Map

2. Theoretical basis and overview

2.1 Overview of container shipping network

The term "network" is usually used to describe a structure, which can be either physical or abstract. Each network includes two sets of feature points and edge sets connecting them. The spatial layout of the container liner transportation system itself forms a typical network structure.

2.1.1 Port

As a node of shipping network, ports, especially some international hub ports, are in a very important strategic position in the container liner transportation network. On the one hand, they connect with major container ports in the world through trunk flights, and on the other hand, they collect and distribute small and medium-sized containers through feeder flights, which are the channels for inland container import and export. With the rapid development of container transportation, the trend of large-scale ships, the reduction of the number of main ports, and the competition among major ports is more and more fierce, and the requirements for hub ports are also higher and higher. There may be several large ports in the same area competing to be a main hub port at the same time. In this way, once the location of the hub port changes, the layout of the whole liner transportation network will change. Therefore, as a hub node, it is the central link of the whole transportation network.

2.1.2 Route

Another important factor of the container shipping network is route. Based on the traditional liner shipping route, the container shipping route develops gradually with the containerization of liner shipping. Container shipping is a kind of capital-intensive system. To maximize the efficiency and economic benefits, it is necessary to actively promote the stability of the main container shipping routes and further expand the regional shipping network and the whole network.

At present, the world's container shipping routes have formed three main routes, namely, the Pacific route, the Mediterranean route, and the Atlantic route, forming a relatively complete and systematic route network with these three main routes as the core and supporting regional transport routes, connecting the world's major economic regions.

2.1.3 Container ship

With the development of large-scale container ships, and the renewal interval of container ships is also greatly shortened, the carrying capacity of the largest container ships under construction has exceeded 20000 TEU. This changing trend is mainly considered from the aspect of scale economic benefits.

Theoretically, the biggest benefit of Very-large container ships with a single ship capacity of more than 8000TEU is that the container traffic volume of each voyage is high, the number of ports to be linked is reduced, and the average cost of each container is about 10% to 12% lower than that of 5000-6000teu container ships, and 30% lower than that of 4000TEU container ships, to improve the operators of container ships Economic benefits.

2.1.4 Transportation demand

As for liner transportation, transportation demand mainly comes from international trade, and more than 80% of international trade freight volume is completed by sea transportation. What supports the development of international trade is the sound and stable development of the economic and trade environment between countries and regions in the shipping network.

2.2 Overview of scope economy

Economies of scope refer to the economy brought about by the scope of manufacturers rather than scale. That is to say, when the cost of producing two products at the same time is lower than the sum of the costs of producing each product separately, the existing situation is called a scope economy. As long as the cost of combining two or more products is lower, there will be a scope economy.

2.2.1 Universal definition of scope economy

1) It refers to that a region has greater advantages than other regions in the continuous development of this industry due to the concentration of human resources, related services, raw materials, and semi-finished product supply, sales, and other linked suppliers required by industry.

2) It refers to the reduction of unit cost caused by the expansion of business scope, an increase of product types, and production of two or more products. Different from scale economy, it is usually the enterprise or production unit that obtains the savings from the unit cost of producing or providing a series of products (different from mass production of the same product). The savings come from distribution, research and development, and service centers (such as accounting and public relations). The scope economy generally becomes the theoretical basis for enterprises to adopt a diversified management strategy. Scope economy is a basic category to study the relationship between the production or business scope of economic organizations and economic benefits.

2.2.2 Scope economy definition of a container shipping network

1) As for the hub port in the container shipping network, because a large number of routes are linked to the hub port, the port gathers a huge amount of relevant manpower and material resources on the service container ships, relevant terminal equipment, port machinery, and the hub port also has the inland transfer function. In terms of yard service, loading and unloading efficiency, transfer service, and additional services (such as packaging goods, etc.), the port has the following advantages: Lower costs and better services. Jia Dashan, Liu Jianxin (1999).

2) For the routes in the container shipping network, when the liner companies design routes, by expanding the number of designed routes, for example, designing two

or more routes at the same time, the unit cost is reduced in the process of operating these two or more routes at the same time. Due to the increase of the route, the number of ships passing through one same port increases, and the annual container throughput increases, so, in that port, there is a certain discount on the vessel fee and terminal handling charge. Li Jing (2005).

2.2.3 Scope economy formula

Scope economy is the economy formed by an enterprise producing multiple products at the same time, when $TC(Q_x) + TC(Q_y) > TC(Q_x, Q_y)$, there is scope economy.

$TC(Q_x)$ is the cost of producing Q_x, $TC(Q_y)$ is the cost of producing Q_y.

Measurement formula, scope economy saving rate:

$$S = \frac{[TC(Q_x)+TC(Q_y)-TC(Q_x,Q_y)]}{TC(Q_x,Q_y)} \tag{1}$$

2.3 Container liner transportation cost composition

This dissertation discusses the scope economy of container shipping networks, and the biggest component of container transportation is the liner container shipping network. GuoZheng and CaoWeiyuan (2019). The international maritime cargo transportation conducted by the shipping company according to a fixed route, several fixed ports along the line, fixed ship schedule, and the fixed freight. It is the most widely used method in the sea transportation of goods. Li Wenhuan (2007)

Therefore, to facilitate the research, this dissertation will mainly take the container liner transportation network as the research object, discusses, and analysis the scope economy of shipping companies when designing multiple liner container routes (with common ports). The liner transportation cost is divided into three types according to the cost structure: capital cost, operation cost, and voyage cost. These three costs are discussed in depth below.

2.3.1 Capital cost

The cost of capital mainly refers to the cost of buying new and second-hand ships by ship companies, mainly including the cost and interest when buying ships.

The cost of capital is expected to be compensated by the income generated during the operation period of the ship. When the ship is fully financed by the owner's cash source, the owner expects that the net cash flow in the future will be able to pay the initial expenses and get some additional compensation - namely profit; When the ship is financed by a loan, the owner expects that the net income in the future will be able to repay the deposit paid in cash when he purchases and builds the ship, as well as the repayment amount of the loan and the interest expense of the loan, and there will be a certain surplus, that is, profit.

2.3.2 Operating cost

Operating costs include ship repair costs, insurance premiums, crew salaries, crew insurance, and all other expenses to ensure the ship is seaworthy. Zhu Yiran (2006)

1) Labor cost

Including wages and salaries, social insurance and pension payments, ship food reserves and crew transportation costs;

2) Repair and maintenance costs

The repair and maintenance costs include all the ship repair and general maintenance costs incurred to make the ship meet the standards required by shipping enterprises and classification societies. Due to the age and technical conditions of the ship, as well as the experience of the shipping enterprises and the management level of the ship operation, the difference between the maintenance and repair fees of the same tonnage of ships is large. The cost of daily maintenance, including annual or special ship inspection (such as an extension of various safety certificates), is quite high. For example, if the ship is damaged or collided, the cost of drydocking that the shipping company does not expect is more considerable. At this time, the cost of repair and maintenance maybe more than 50% of the total operating cost budget.

3)Maritime Insurance

The insurance premium of the ship consists of the basic insurance premium of the hull and machinery, the third-party expenses (protection and compensation), as well as the expenses of motor damage, pollution, and war risk. Although shipping companies pay different fees for their ships, hull and machinery insurance, protection and compensation insurance are essentially compulsory.

4)Administration cost

The general management cost of a ship mainly refers to the direct management cost of the ship. Management functions include crew selection, rotation, transportation, purchase of food and ship supplies, contact with port agents, bunker supply, and establishment and supervision of daily ship maintenance and repair plans. Shipping companies can choose the percentage of internal and external management of the ship so that they can play all their management roles through their onshore personnel, and accordingly, they can contact professional ship managers for all their work. The choice depends largely on the size of the fleet. For example, a shipping enterprise with only one ship will feel that it is uneconomical to carry out all the management functions in its internal scope, while a shipping enterprise with a large fleet has great economic significance to establish the necessary ship management foundation.

2.3.3 Voyage cost

The voyage cost mainly includes the port fee, ship bunker fee, canal fee, and other special expenses incurred in the operation of the voyage.

The voyage of a ship is related to the length of the route, the number and location of the ports it attached, the channel it passes, etc. Wang Xuefeng (2007). The level of voyage cost depends on the distance, average speed, berthing time, bunker consumption, and price level, among which bunker consumption and price level play an important role. The bunker price is directly related to the change of world crude oil price and also affected by the balance of bunker supply and demand in some special bunker loading areas. Besides, the amount of port charges is related to geographical location. Therefore, the cost of the voyage is closely related to the shipping route of the ship.

3. The embodiment of scope economy in container allocation

As the equipment to carry goods, and as the extension of the container ship, the container is the operation basis of all the container shipping networks, and the operation cost of the container also accounts for a part of the total cost of the container shipping network. For container shipping lines, the allocation and use of containers is an important part of the business strategy and strategic decision-making of liner companies. Liner companies need to keep container allocation within a reasonable level. If too much, it will cause an increase of container storage cost, maintenance cost, and various fixed costs, etc. Zhao Gang (1997). On the contrary, if too few, it will affect the ship's cargo collection capacity, reduce the voyage investment revenue, and affect the shipping company's reputation.

For liner container shipping companies, the reasonable allocation and use of containers is a major factor affecting the development of the company. For the shipping company's route design, the impact of scope economy on container allocation is rarely discussed. In this section, we will focus on theoretical research to explore the embodiment of scope economy in container allocation.

3.1 Determination of container allocation of liner routes

3.1.1 Influencing factors of container allocation

a. The number of container ships in route

b. Voyage time of container ship

c. Departure interval of container ship

d. Container capacity

e. The utilization rate of container ship

f. Average inland container turnover days and port storage period

g. Container backlog, delay, and repair time in inland

h. The unbalanced volume of containers in different directions of the route

i. Turnover box quantity of Midway port

3.1.2 Calculation method of container allocation

Considering that the ships in the container liner route are usually unable to reach the full load, there are delays in the intermediate port, inland transit and other times, as well as the imbalance of the use of special containers in the round-trip course, the actual container allocation in the route is generally calculated by the following formula. Yang Hualong, Chen Xiaodong (2000).:

$$M = \alpha \cdot K \cdot Q + (1 + \mathrm{C}) \cdot Q_i + M_b + M_R \tag{2}$$

α is the utilization rate of container vessel; Q_i is the container unloading volume of the midway port; C is the container volume coefficient of the midway port， if the turnover time of the midway port container in the inland is less than the departure interval, it is 0; M_b is the quantity increased due to the unbalanced container quantity of different voyage directions; M_R is the total amount of inland repair containers during the turnover period; Q is the rated container capacity (TEU) of container ships; K is the number of sets of containers equipped for the route without the transfer port, and it is also an integral multiple of the rated container capacity of a single ship.

Where k can be determined by the following formula:

$$K = n + 2 + a + b \tag{3}$$

Where, n refers to the number of ships equipped in the route; a, b refers to the number of additional sets of containers to be equipped in the terminal port, which is determined by the following formula:

$$a(or\ b\ or\ c\ \ldots) = \frac{average\ port\ turnover\ time - vessel\ departure\ interval}{vessel\ departure\ interval} \tag{4}$$

3.2 The embodiment of scope economy in container allocation

3.2.1 Container allocation of a single route

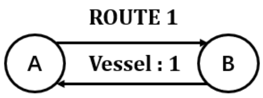

Figure 2 Schematic diagram of the double terminal route

For the calculation of a single route's container allocation, there are only two terminal ports (port A, Port B) as a typical condition, assuming that the port has the same container throughput, the average port turnover days are 7 days, the number of ships on the route is 1, the container capacity of the ship is 1000teu, the container loading rate of the ship is 80%, the departure interval is 7 days, the total inland container repair volume in the turnover period is 60 TEU, and the container capacity of the two ports is the same, then the container capacity m of each port in the route is:

$$m_A = m_B = \frac{M}{2} = \frac{\left[0.8 \cdot \left(1 + 2 + \frac{7-7}{7} + \frac{7-7}{7}\right) \cdot 1000 + (1 + \text{C}) \cdot 0 + 0 + 60\right]}{2}$$

$$= 1230$$

Then the total container allocation of this single route is 2460 (TEU). Gao Wei (2009).

3.2.2 Container allocation of two routes with one public port

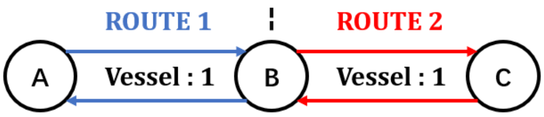

Figure 3 Two routes with one public port

Assuming that port A, B, and C also have the same container throughput, and the volume of containers in and out is balanced. All other conditions are the same as before. Route 1 only connects to port A and B, and Route 2 only connects to port B and C. For ports A and C, since all conditions are the same as above, then $m_A{}' = m_C{}' = 1230$. As for port B, since the number of vessels attached to it has changed from 1 to 2, and the port to which the vessels are heading has also changed from 1 to 2, then $m_B{}'$ can be calculated by the following formula:

$$m_B' = \frac{\left[0.8 \cdot \left(2 + 2 + \frac{7-3.5}{3.5} + 0\right) \cdot 1000 + (1 + \text{C}) \cdot 0 + 0 + 60\right]}{2} = 2030$$

Then the total container allocation of the combination of these two routes is 2030 + 1230 + 1230 = 4490 (TEU).

3.2.3 The saving rate of scope economy on container allocation

It is easy to know that when two routes have a public port, the sum of the total allocation of containers for two routes is 4490 TEU, while the allocation of containers for a single route is 2460 TEU, then the scope economy saving rate:

$$S = \frac{2460 + 2460 - 4490}{4490} = 9.57\%$$

Because of $S > 0$, when two routes have a public port, there existing scope economy, and the saving rate of the scope economy for container allocation is 9.57% in this case, which is quite significant.

3.3 A broader study of economies of scope on container allocation

In the previous section, by studying the difference between a single route and two routes, it is concluded that the two routes have a scope economy when passing the same port. Next, it comes a more in-depth study on the saving rate of the scope economy.

3.3.1 Scope economy when the number of routes increases infinitely

Suppose there is a fixed port B, and all the routes attached to port B are consistent with the data of a single route in the previous section. When the number of route attached to port B increases infinitely, the changing chart of the scope economic saving rate is as follows:

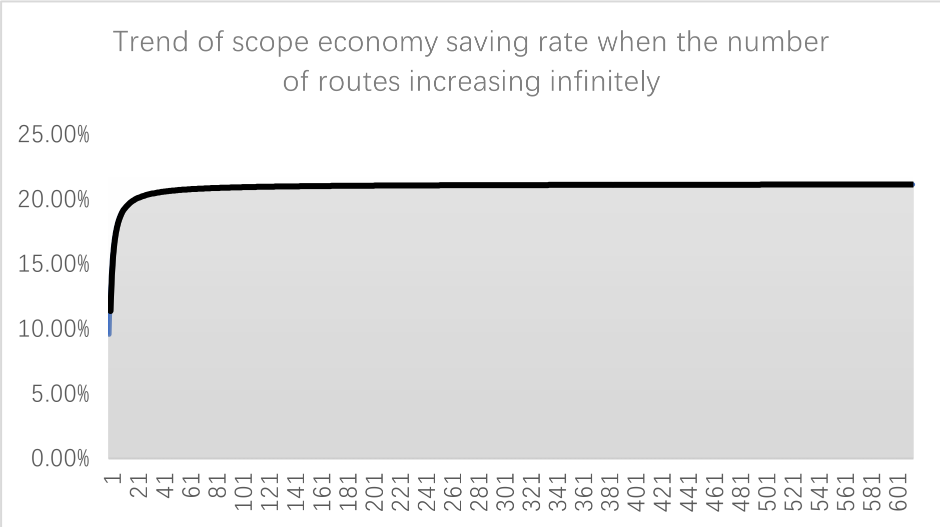

Figure 4 Trend of scope economy saving rate with the number of routes

When the number of routes attached to the same port is increasing, the saving rate of the scope economy on container allocation first rises briefly and rapidly, then continues to rise slowly in a very long period. When the number of routes reaches at 20, the saving rate is 19.9%, and then when the number of routes increases to 300, the scope economy saving rate is still only 21.1%.

It can be seen that although the scope economy saving rate increases with the increase of the number of routes, when the number of routes reaches a certain amount, the container allocation saving amount caused by the scope economy becomes less and less.

3.3.2 The impact of the number of unproductive containers

In the previous section, for the convenience of calculation, assuming that the volume of containers is balanced, there is no increase in the volume of container transportation caused by the imbalance of the volume of containers. Now we discuss the impact of the increase in the number of containers caused by the imbalance of the volume of containers and the change in the number of inland repair containers during the turnover period.

Because in the formula, M_b and M_R are cumulative volumes, so we can directly discuss the total volume of $M_b \& M_R$, that is, the impact of the change of non-productive use of containers on the scope economy. At the same time, assume that the route situation is as shown in Figure 3, which is two routes with one public port. The changing chart is as follows:

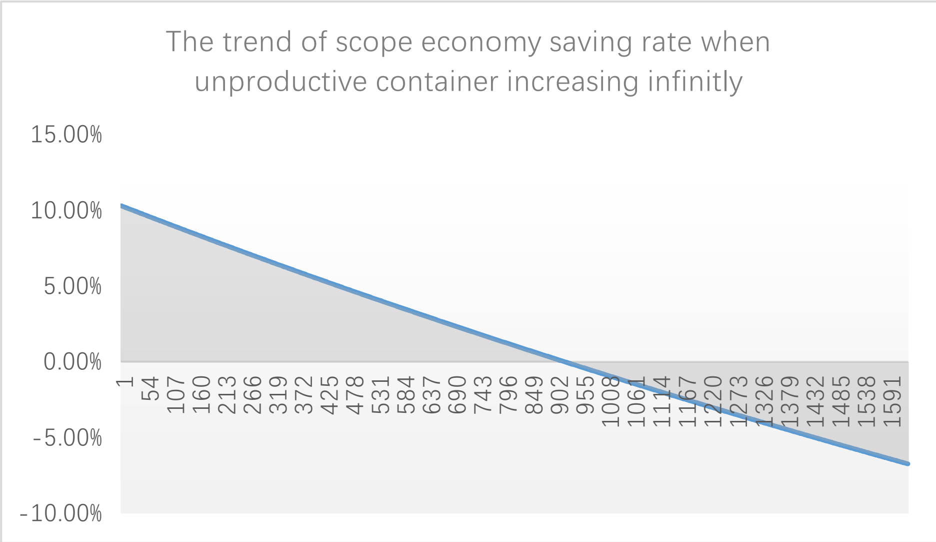

Figure 5 Scope economy saving rate - unproductive container trend

The horizontal axis in the figure is the sum of M_b+M_R, it can be considered that with the increase of the number of non-productive containers, the scope economy saving rate is declining, when M_b+$M_R > 921$, the scope economy disappeared.

Visible, ensure the number of unproductive containers (M_b+M_R) in a certain amount, it is an important prerequisite of the scope economy.

4 The embodiment of scope economy in actual route cost

4.1 Selection of research objects

In the third chapter, based on the theoretical research, we analyze and study the embodiment of scope economy in container allocation, and conclude that the total amount of container allocation of two routes (with the same port of call) has scope economy.

In this chapter, we will discuss the influence of scope economics with practical cases. This paper focuses on the actual cost of liner route total running cost and discusses the embodiment of scope economics in liner route cost.

4.1.1 Selection of shipping company and route

According to Alphaliner's latest data, COSCO Group ranks the third in the world with 2870792 TEU traffic volume. COSCO's container fleet has 87 ships, with a total capacity of 609400 TEU. The container holding capacity is about 3.66 million TEU;

COSCO Shipping Container Transportation Co., Ltd. is responsible for operating several routes, including trans-Pacific routes, European routes, European regional routes, and Atlantic routes. To facilitate the research, China-Japan route is selected as the research object. The main reason is that the voyage between China and Japan is relatively short, the number of ports attached to the route is less than other routes, the weekly import and export container volume is relatively fixed, and the import and export cargo volume is relatively balanced. At the same time, the ship types are all full container ships with similar container capacity, and the above factors are suitable to study and analyze.

4.2 Cost analysis and calculation of a single route

4.2.1 Route operation status

As a container shipping network, China-Japan route is divided into three small routes, namely, the Pan-Asian Kanto line, the Pan Asia Nagoya line, and the Pan-Asian Kansai line. Each route is equipped with an average of three ships, with a ship schedule of 7 days, and all three routes are connected to Shanghai port. The specific route information is as follows:

Table 1 Information of Pan Asian routes

Vessels in route	Ship Capacity (TEU)	Port of call	Route
4	1000	Shanghai-Tokyo-Yokohama-Shanghai	Pan-Asian Kanto
2	1000	Shanghai-Nagoya-Shanghai	Pan Asia Nagoya
2	1000	Shanghai-Osaka-Kobe-Deshan-Shanghai	Pan-Asian Kansai

The time spent on each route is shown in the table below:

Table 2 Time spent on Pan Asian routes

Route	Total port stays time (h)	Total wharf operation time(h)	Total flight time (h)	Total range (nm)	Average speed (KN)
Pan-Asian Kanto Line	68.25	50.5	143.775	2119.675	14.805
Pan Asia Nagoya Line	45.65	33.35	125.05	1854.9	14.83
Pan-Asian Kansai Line	62.3	46.8	126.5	1657.05	13.115

4.2.2 Capital cost

1) Ship purchase and depreciation cost

At present, eight ships are operating on China-Japan routes, which are 1000 TEU ships. According to Clarkson, the average purchase price of 1000-1100teu container ships is 19.61 million US dollars. Since 1996, considering that the purchase cost of second-hand ships changes with the service life of the ships, it is not convenient for research and analysis, so it is assumed that all the ships in this example are new brought.

According to the service life of a container ship for about 20 years, assuming the residual value after depreciation is 10%, the annual depreciation cost of the ship is 19.61 × 0.9/20 = 0.88 million USD / year. Pan Zhigang (2013).

4.2.3 Operating cost

According to the data given by maritime intelligence, the operating cost of 1000 TEU Container Ships Operating in the China-Japan route is about 3250 US dollars per day, including crew wages, ship maintenance, and other costs.

Table 3 Daily operation cost of container ships with different capacity

DWT	TEU	Daily operating cost (USD)

1.2	1000	3250
3.5	2900	4400
4.8	4500	5100
6.5	6000	5500

4.2.4 Voyage cost

1)Port fee

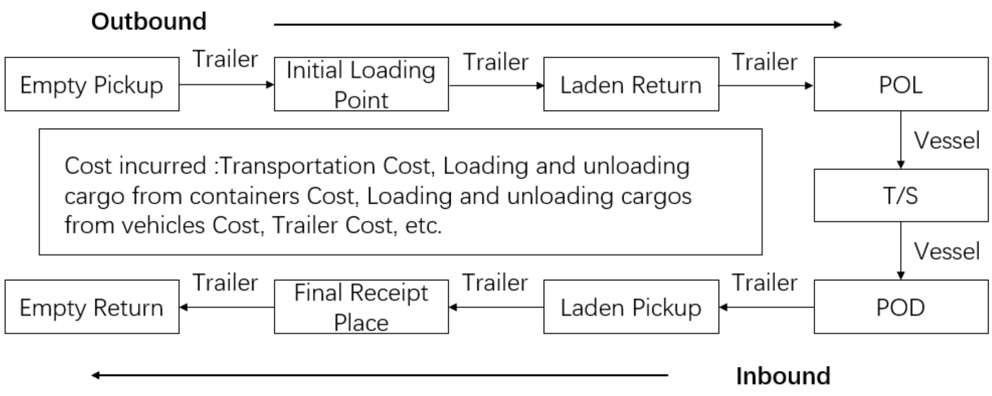

Figure 6 Operation flow and cost of container import and export

In the form of an analytical chart, the above figure briefly describes the various port expenses and the occurrence process involved by liner companies in the process of import and export. The main cost sources are freight handling charges (containers, vehicles, ships), port charges generated by loading and discharging, port charges generated by ships, etc. Tan Yu (2005).

According to the charging standard of Shanghai port, the port operation fee is as follows:

Table 4 Shanghai port operation costs

Loading and unloading of container		Loading and unloading of vehicle		Labor scope corresponding to operation cost rate
Min charge (RMB)	loading and unloading cargos (RMB/DWT)	Min charge (RMB)	loading and unloading cargos (RMB/DWT)	

1180	100	1180	90	Remove the general reinforcement of 20’GP, unload them from foreign trade ships to the wharf, and transport them to the storage yard or lighterage in the port by using non-low flat trucks, stack them by category, and load them into the freight trucks from the storage yard; or unload the 20’GP from the freight trucks to the storage yard, stack them by category, and load them into foreign trade ships by using non-low flat trucks or lighterage in the port for general reinforcement. Loading and unpacking ordinary goods of less than 10 tons. The loading and unloading of empty containers shall be transferred to the storage yard, and then the loading and unloading operations shall be carried out. Labor cost incurred by port operation

Berthing fee and pilotage fee (RMB):

Table 5 Berthing and pilotage charges

Berthing fee	foreign trade	Wharf, pontoon (productive)		DWT×day	0.25
		Anchorage		DWT×day	0.05
		Port(non-productive)		DWT×h	0.15
	Domestic trade	Wharf, pontoon (productive)		DWT×day	0.08
		Wharf, pontoon (non-productive)		DWT×day	0.12
pilotage	foreign	Pilotage distance	Under 40000 net tons	DWT	0.45

	trade	within ten nautical miles	40000-80000 net tons		0.4
			80000-120000 net tons		0.375
		Over range part with pilotage distance more than 10 nautical miles		DWT*nm	0.004
		Gate crossing Guide		DWT	0.14
		Change berth in port		DWT	0.2
	Domestic trade	Pilotage within ten nautical miles		DWT	0.18
		Over range part with pilotage distance more than 10 nautical miles		DWT/nm	0.0018
		Change berth in port		DWT	0.135

Port tug benchmark fee: as the average length of the Pan Asian route ships is about 120 meters, according to the tug charging standard, it should be 6750 yuan / tug.

Cargo port fee & port facility security fee:

Table 6 Cargo port fee and port facility security fee

Project			unit	Rate standard	
				Import (RMB)	export (RMB)
Cargo port fee	Foreign trade container	GP	20’	34	17
			40’	68	34
		RF and DG (heavy containers) for class I dangerous goods	20’	68	34
			40’	136	68
	Domestic trade container	GP	20’	7	7
			40’	14	14
		RF and DG (heavy containers) for class I dangerous goods	20’	14	14
			40’	28	28
port facility security fee	Heavy containers		20’	8	8
			40’	12	12

The estimated quantity of containers generated by voyage:

According to the data provided by the Shanghai port, the volume of import and export containers per voyage of each ship is 300 TEU. To calculate the volume of import and export containers per voyage of other ports, it is assumed that the volume of loading and unloading containers at ports is directly proportional to the loading and unloading time, so the volume of import and export containers at ports can be calculated based on the loading and unloading time, and it is assumed that the volume of import and export containers at other ports is the same, and the following table is obtained:

Table 7 Estimated number of containers generated by voyage

Route	Port	Average Parking time per ship (h)	Average loading and unloading volume per ship per voyage	
			Import (TEU)	Export (TEU)
Pan-Asian Kanto Line	Yokohama	11.03	230	230
	Tokyo	14.58	304	304
	Shanghai	14.38	300	300
Pan Asia Nagoya Line	Nagoya	12.6	330	330
	Shanghai	11.45	300	300
Pan-Asian Kansai Line	Tokuyama	9.65	272	272
	Kobe	9.75	275	275
	Osaka	12.5	352	352
	Shanghai	10.65	300	300

At the same time, assuming that the port charges of each port of the route are the same as those of Shanghai port, then through all the above information, it can be calculated that the port charges of a single ship in the voyage = the loading and unloading container total volume of a single ship × the average charges of each TEU + the port charges of a single ship.

2) Ship bunker cost

The bunker cost of a ship depends on the speed of the ship, the power of the ship's main engine, and the amount of water discharged. The power of the main engine of the ship can be derived from the displacement of the oil ship and the speed of the ship. The formula is as follows:

$$P_i = \frac{\Delta T^{\frac{2}{3}} \times v_i^{\ 3}}{C} \tag{5}$$

In formula (5): P_i is the main engine power of the ship (kw); T is the displacement (ton); v_i is the speed of ship i (kn); C is the naval constant.

According to the relationship between bunker cost and power, the formula of bunker cost and speed per day for ship I can be deduced as follows:

$$K_i^0 = 24 \times 10^{-6} \times C_f \times g \times P_i = 24 \times 10^{-6} \times C_f \times g \times \frac{\Delta T^{\frac{2}{3}} \times v_i^{\ 3}}{C} \tag{6}$$

In formula (6): C_f is the bunker price, ($); g is the consumption rate of bunker (g/ k W h).

In this paper, the research object is 1000 TEU Container Ships. According to the ship information, the displacement is about 12000 tons.

As for the cost of ship bunker, due to the coming into effect of the IMO 2020 sulfur limit order, the sulfur content of the emissions shall be within the limit when the ship enters the pollution discharge control area. As the ship in this example is a 1000 TEU ship, it is not suitable to install the desulfurization tower economically, and the policy of COSCO Group also prefers to use low sulfur oil, so it is assumed that all ships use low sulfur oil instead of desulfurization tower. The selection of the desulfurizer and low sulfur oil is not discussed here.

According to the guidelines for entering the pollutant discharge control area, the ship begins to prepare for a series of oil change operations one hour before entering the Emission Control Area (ECA), and changes the high sulfur oil into the low sulfur oil when it reaches the boundary of the ECA approximately. At the same time, the low sulfur oil shall be replaced with diesel oil immediately after leaving the ECA. In the China-Japan route, the number of nautical miles the ship runs in the pollutant emission control area is approximate as shown in the following figure:

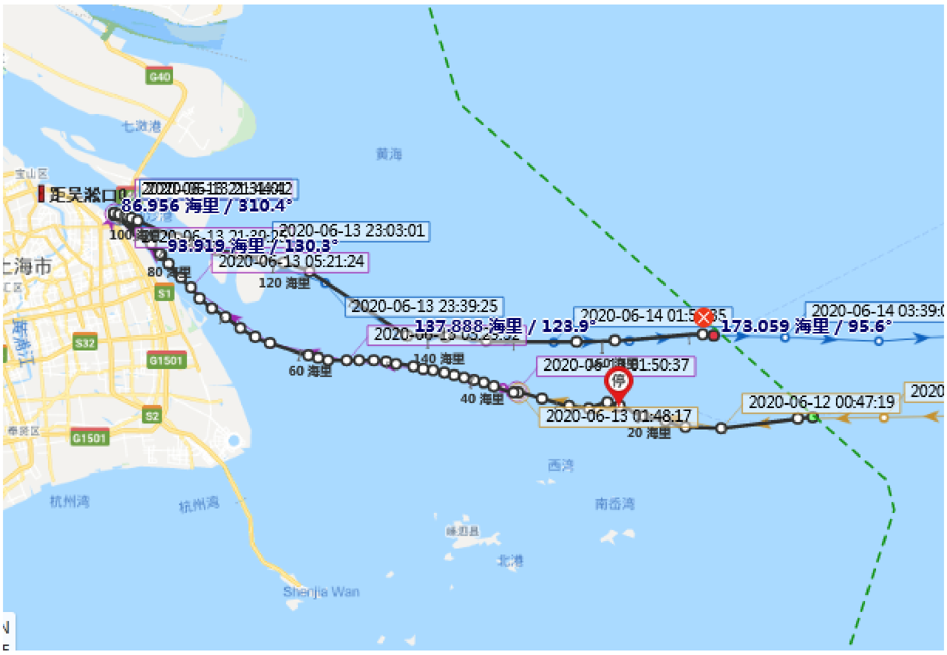

Figure 7 Route within ECA

About 173.059 nautical miles in total, the green dotted line is the boundary of ECA, and the black line is the ship's track in ECA.

Different bunker prices are as follows:

Table 8 Bunker price

COMMODITY	PRICE	UNIT	UPDATED
IFO 180	297.41	$US/MT	2020/6/12
IFO 380	258	$US/MT	2020/6/12
MGO	437	$US/MT	2020/5/22
MGO 0.1%	432	$US/MT	2020/6/12
VLSFO max 0.5%	370	$US/MT	2020/6/12

It is assumed that the general bunker oil used by the ship is IFO380 and the low sulfur oil is VLSFO Max 0.5%. Niu Bohui (2019).

The bunker cost of ship voyage shall be calculated respectively according to whether it is in the emission control area.

4.2.5 Total cost of a single route

According to the above data of operating cost, voyage cost, and capital cost, Jiangshan (2000), the total cost of a single route can be calculated as follows (USD):

Table 9 Total cost of a single route

Route	Bunker cost/year	Operating fee/year	Port fee/year	Ship depreciation fee/year	Total transportation cost/year	Average cost per TEU
Pan-Asian Kanto Line	1871454	1186250	2657035	882450	6597190	229
Pan Asia Nagoya Line	2117067	1186250	2651093	882450	6646215	231
Pan-Asian Kansai Line	1817671	1186250	2657113	882450	6697616	233

4.3 Cost analysis and calculation of multiple routes

In this section, we will analyze the cost of the container shipping network composed of the three different routes of the above ports, and calculate the total annual running costs of the combination of these three routes.

4.3.1 Sources of container shipping network cost reduction

Through the research in Chapter three, we know that multiple routes linked to the same port have economies of scope and reduce the total container allocation. However, in reality, due to the influence of various policies (national policies, enterprise policies, etc.), the average cost of routes when a shipping company operates multiple routes is less than that of a single route. The scope economy caused by the internal scale economy of the shipping company and the cost calculation under the influence of the policy is discussed below.

1) Port cost reduction

According to the notice of the Ministry of communications on the “Preferential charges for foreign trade ships and cargo ports”, if the shipping companies carrying import and export containers in Shanghai and Tianjin ports and in Dalian and Qingdao ports have reached more than 150000 TEU and 80000 TEU respectively in the last year, then this year, the handling charges for import and export containers passing the above four ports are 20% preferential according to the rate specified in the regulations on foreign trade charges.

According to the data provided by Shanghai port, the number of containers that COSCO passes through Shanghai port more than 150000 TEU, so it enjoys 20% discount.

In addition, according to the statistics of net tons of arriving ships in the previous year, for the shipping companies whose net tons of arriving ships respectively reach or exceed 30%, 20% and 10% of the total net tons of arriving ships in the port, the shipping expenses (Guide shipping fee, transfer and berthing fee, pilot detention fee, mooring and disembarkation fee, berthing fee and tugboat fee) incurred in the port in the current year in addition to the ship's port charges are under the regulations of the people's Republic of China According to the “port charging rules (foreign trade part) of the Ministry of communications of the people's Republic of China”, 20%, 15% and 10% of the rates are respectively granted.

According to the berthing data provided by Shanghai port, the total net tonnage of COSCO's ships passing through Shanghai Port accounts for 17% of the total net tonnage of all the ship companies passing through Shanghai port. Therefore, according to the preferential conditions, the shipping fee enjoys a 10% discount.

2) Decrease of the ship purchase cost

According to the data released by the shipyard, when purchasing about 1000 TEU ships, the total discount is about 7% - 12% for every 10% increase in the number of ships ordered at the same time.

3) The decrease in cost of ship bunker oil

COSCO Group has been implementing centralized bunker oil procurement since 2003. With China national gas (Singapore) Co., Ltd. as the operation center, it focuses on the annual purchase volume of about 3 million tons of marine bunker oil and provides bunker oil supply for more than 600 ocean-going ships of the group by means of straight-line purchase, bulk purchase, futures hedging, etc. Chen Tianming (2006).

The obvious advantage of COSCO centralized purchase is that it can combine the purchase demands of different units of the enterprise, and reduce the cost by increasing the purchased quantity, which is the significance of traditional scale economy.

For this example, through the service of opening different routes, the overall ship operation volume increases, and the bunker purchase volume also increases, thus reducing the bunker purchase cost, which is due to the scope economy caused by scale economy.

According to the online purchase price data related to shipping bunker oil, the purchase unit price is lower than the market price by USD 12.9. According to the bunker price of 258 USD/MT in June 2020, the preferential rate of bunker oil purchased by the group is about 5%

4.3.2 Total cost of container shipping network

Through the above cost analysis, all kinds of preferential discounts are brought into the calculation process, and the overall cost of the container shipping network combined with three routes is obtained as follows. Wu Xiaochuan, Zhao Yifei (2015). (expense unit: USD):

Table 10 Cost of container shipping network

Bunker cost/year	Operating fee/year	Port fee/year	Ship depreciation fee/year	Total transportation cost / year	Average cost per TEU
5515885	3558750	6397620	2514983	17952599	208

4.4 Embodiment of scope economy in cost and broader discussion

4.4.1 Embodiment of scope economy in cost

In the previous section, by collecting specific data for analysis and calculation, the annual operating costs of these three routes and the annual operating costs of the container shipping network including the above three routes are obtained respectively. Then the scope economy saving rate of the annual total cost of the container shipping network is as follows:

$$S = \frac{[6597190 + 6646215 + 6697616 - 17952599\,]}{17952599} \times 100\% = 11.08\%$$

It can be seen that in reality, the container shipping network composed of multiple routes (with the same port of call) has the scope economy.

4.4.2 Broader discussion of economies of scope

For the three container liner routes studied in the case, the liner transportation network composed of them has a scope economy, which is reflected in the decline of the average per TEU cost of the whole network. For the container shipping network, the average per TEU voyage cost is 208 USD, while for a single route, the cost varies from 229 to 233USD.

Scope economy does play a role in reducing costs in the transportation network composed of these three routes. However, if the number of routes increases, or the number of routes with ships increases, and the scope economy also increases, then the number of routes and the number of ships with ships will increase indefinitely. Obviously, such situation is not possible to exist in real life.

The main reason is that as the number of routes increases and the number of ships allocated increases, the management and scheduling cost of the shipping company also increases, and the increase of this cost exceeds the profit growth brought by the increase of routes and ships allocated.

To study the impact of route and ship numbers on the scope economy, it is necessary to determine the impact of route number and ship allocation on the scheduling and operating costs of shipping companies. The following information is obtained through Alphaliner and Seaintel:

Table 11 Revenue of each shipping company and number of ships

Container shipping company	Total income (million USD)	Benefit before tax (million USD)	Total Cost (million USD)	Container ships operating
APM-Maersk	24299	700	23599	660
CMA CGM Group	21120	1575	19545	476
ONE	17907	72	17835	213
COSCO Shipping Group	13336	434	12902	471
Hapag-Llody	11966	493	11473	234
Evergreen Line	5069	162	4907	189
OOCL	6108	232	5876	61
YangMing	4412	26	4386	92
Zim	2978	135	2843	57
Hyundai M.M.	4715	-382	5097	66
Wan Hai Lines	2046	106	1940	92

In order to obtain the relationship between the number of container ships equipped by the shipping company and the total annual cost of the shipping company, a linear regression equation is established. Through regression analysis, the following linear regression results are obtained:

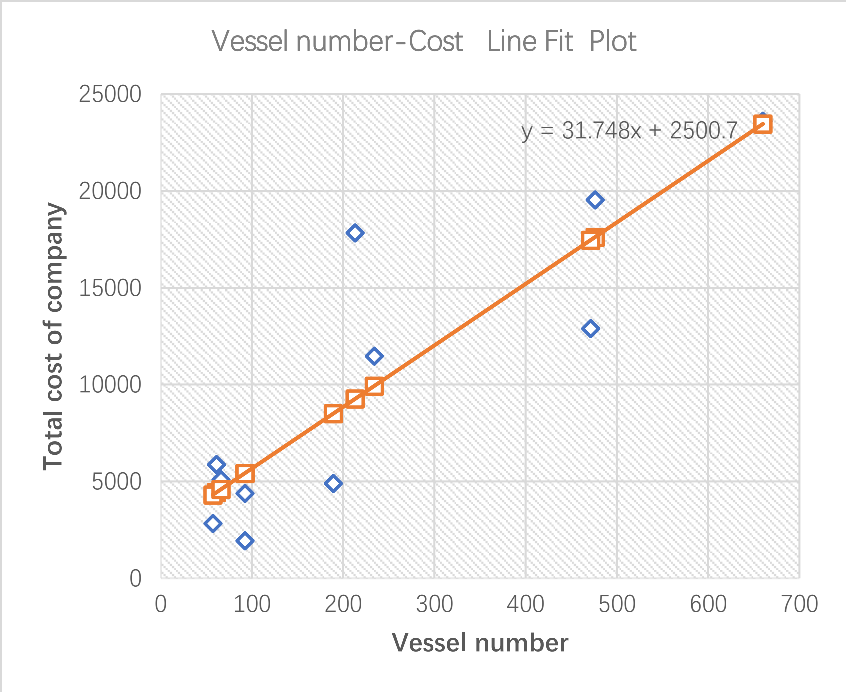

Figure 8 Regression curve between ships owned and annual operating cost of ship company

At the same time, the regression equation:

$$y = 31.748 \times x + 2500.7 \quad (7)$$

Where y is the annual operating cost of the liner company and X is the ship configuration (own ship & Charter ship).

To bring this result into the case study of China-Japan route, the formula was modified to some extent:

$$y_{sino-jp} = P \times (31.748 \times x_{sino-jp} + 2500.7) \quad (8)$$

Where $y_{sino-jp}$ and $x_{sino-jp}$ is the annual operating cost and ship allocation of China-Japan route. P is the proportion of the annual operating cost of China-Japan route in the total annual operating cost of COSCO Group. In this case, $\frac{17.95}{12920}$ =0.14%.

When a new container ship is added to the China-Japan route, the overall operating cost of the China-Japan route will increase by 31748000*0.14%= 44 447.2 USD for each additional ship. At the same time, other vessel costs are still existing.

The final results are as follows:

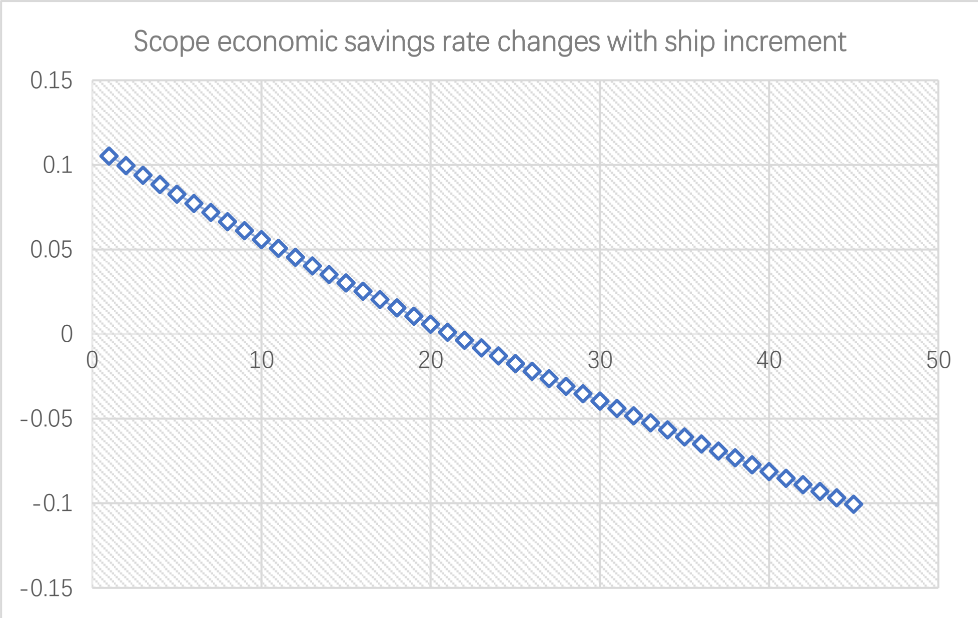

Figure 9 Change of Scope economy saving rate with ship increment

In the figure, the horizontal axis represents the new increased ships based on the original number of ships, and the vertical axis represents the scope economy saving rate.

It can be seen from the figure that when the ship increment exceeds about 21, the scope economy disappears. Therefore, when designing routes, container liner shipping companies need to consider the increase of dispatching cost and management cost caused by the increase of ships, as well as the design of reasonable routes.

5. The role of scope economy in risk reduction

For a shipping company, many factors affect the route revenue, such as the impact of national policies, the relationship between countries, regional security, stability, and so on. Zhao Ling (2001). If we only consider the impact of route allocation, container allocation, and other factors on the route cost, we may suffer huge losses in the changeable international situation. For example, the reduction of Sino-US trade volume caused by Sino US trade war may affect the container transportation volume of the route, thus reducing the voyage revenue and leading to the loss of shipping companies.

If the shipping company operates multiple routes at the same time, and other routes provide stable profit sources after the impact of Sino US relations, then the total loss of the shipping company can be reduced, so that it has a better ability to resist risks. Lu yjian, Li Guanzhong (2001).

Therefore, this chapter will discuss scope economy from the perspective of portfolio investment risk reduction.

5.1 A study on China-America route & China-Africa route

In this section, we will take China-America Route and China-Africa route as the research objects, respectively, to discuss the rate of return when the shipping company only operates China-America route, and the rate of return when operating China-Africa route at the same time.

The reason why the study of China-America routes is based on the further decline of Sino-U.S. relations at present. At the same time, due to the impact of Sino-U.S. trade war, the volume of goods trade has also been greatly reduced. The study of China-Africa routes is based on the strategic plan put forward by the 21st Century Maritime Silk Road. The two important routes related to the development of the shipping industry in the future might be China-America routes and China-Africa routes, so here choose these two routes as the research objects. Cheng Xiaoyun (2003).

By querying the relevant data, the container traffic volume (TEU) of China-America routes and China-Africa routes over the years is obtained as follows:

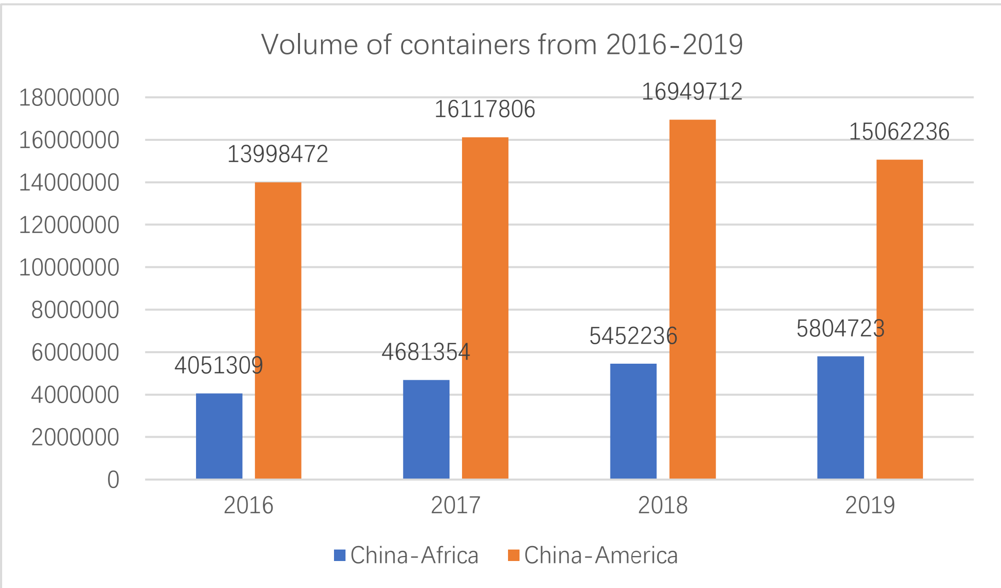

Figure 10 Total volume of container transportation in 2016-2019

Table 12 Annual change of total import and export volume of containers

Years	China-America	China-Africa
2016	/	/
2017	15.14%	15.55%
2018	5.16%	16.47%
2019	-11.14%	6.47%

The container transportation volume in the figure is the total volume of import and export containers from China to Africa and from China to the United States. The research data is from 2016 to 2019. In 2020, due to the impact of the COVID-19, the traffic volume of each route all reduced, which is not good for research and analysis. Therefore, only the container transportation data before 2020 will be studied. The data in the table is the increment of container traffic volume per year compared with the previous year.

It can be seen from the table that due to the impact of Sino-US trade war, the traffic volume of China-America routes in 2019 reduced by 11.14%.

5.1.1 Research on single route yield

Because the revenue of the shipping company is linked with the volume of the shipping container, if the volume of the shipping container is low, the ship's vacancy rate will increase, and the profit of the shipping company will decrease.

Assuming that the shipping company only operates China-America routes, based on 2016, assuming that the freight rate of each TEU Container is 1500 USD, and the investment return rate is set as 10%, and the investment amount is set as 100 million USD. Then the annual container transportation volume that meets the 10% investment return is 73333teu.

Assuming that the change of container traffic volume on China-America routes is consistent with the data in the previous section, the annual change of container traffic volume is the same in Table 12. At the same time, assuming that the annual investment amount increases by 10% compared with that of the previous year, the income statement of China-America routes of shipping companies from 2016 to 2019 is as follows, Wang Lijie (2015).:

Table 13 Revenue of China-America routes in 2016-2019

Year	Investment	Price (USD/TEU)	Volume (TEU)	Income (TEU)	Rate of return
2016	100,000,000	1,500	73,333	109,999,500	10.00%
2017	110,000,000	1,500	84,435	126,653,159	15.14%
2018	121,000,000	1,500	88,793	133,190,243	10.07%
2019	133,100,000	1,500	78,906	118,358,524	-11.08%

Similarly, it is assumed that the shipping company only operates China-Africa routes, and the container freight rate per TEU is converted to 934 USD according to the freight index, and all other assumptions are the same, then the income statement of the shipping company for China-Africa routes in 2016-2019 is as follows:

Table 14 Revenue of China-Africa routes in 2016-2019

Year	Investment	Price (USD/TEU)	Volume (TEU)	Income (TEU)	Rate of return
2016	100,000,000	934	117,773	109,999,982	10.00%
2017	110,000,000	934	136,089	127,106,788	15.55%
2018	121,000,000	934	158,498	148,037,553	22.35%
2019	133,100,000	934	168,745	157,608,185	18.41%

In the above two tables, we assume that the shipping company can meet the transportation demand infinitely, and do not consider the increased costs such as competitive cost and operating cost which will rise with the increase of transportation volume.

5.1.2 Integrated operation of China-America route & China-Africa route

Assuming that the amount of capital invested by the shipping company in the routes between China and the United States and China and Africa is the same, the income statement obtained by combining the two routes is as follows:

Table 15 Revenue of combined routes in 2016-2019

Year	Total investment	Total income	Rate of return
2016	100,000,000	110,000,000	10.00%
2017	110,000,000	126,880,271	15.35%
2018	121,000,000	140,614,213	16.21%
2019	133,100,000	137,983,636	3.67%

By observing the revenue of comprehensive operation of two routes in 2019 and the revenue of single route operation of China-America routes,

It is easy to know that when operating both routes, the yield is 3.67% > - 11.08%, which is higher than only operating the routes between China-America routes.

It can be seen that the scope economy can increase the ability to resist risks. When a route cannot obtain the same profits or even losses as before due to various factors, it can rely on multiple routes to share risks simultaneously.

6. Conclusion and Prospect

In this paper, first of all, by theoretical formula derivation, we get that the total amount of container allocation for two routes with the same port of call is less than the sum of the total amount of container allocation for two routes operating separately, which proves that there is scope economy in the container shipping network. With the increase of the number of routes, the scope economy saving rate will not increase indefinitely but tends to an extreme value. With the increase in the number of non-productive containers, the scope economy saving rate is decreasing. Therefore, it can be concluded that the non-productive container volume of the route needs to be within a certain amount, otherwise the scope economy will not be generated.

Secondly, through the collection and arrangement of the actual data, the annual operating costs of the three Pan Asian routes are calculated separately, which verifies the existence of scope economy in the container shipping network between China and Japan.

Finally, by analyzing the historical data of China-U.S. and China Africa routes, it is concluded that the scope economy can increase the ability of shipping companies to resist risks.

The conclusion of this paper can better guide the shipping companies to design routes. According to the above conclusion, when designing routes, first of all, the number of routes should not be designed as much as possible, but within a reasonable range, while the number of routes should be kept within a reasonable range. Finally, it is necessary for shipping companies to design two or more routes operating between different regions in consideration of the international situation and other factors, so as to reduce the huge losses of a route caused by contradictions between countries or other factors.

The year 2020 is a year of many disasters. The relationship between China and the United States has become increasingly tense, and the international situation has become more volatile. Through the research of this paper, we hope to help the shipping company design a better container shipping network, reduce risk, and increase revenue.

At the same time, for the risk reduction of scope economy, the overall anti-risk capability of the container shipping network can be considered after the addition of other routes such as China Europe routes.

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