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Sino-US container transportation route selection based on the expansion of Panama Canal

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SINO-US CONTAINER TRANSPORTATION ROUTE SELECTION BASED ON THE EXPANSION OF PANAMA CANAL

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Declaration

I certify that all the material in this research paper 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.

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Abstract

With the development of the global economy and the strengthening of world trade activities, especially in the Asia-Pacific region, trade between countries has been prosperous. The massive increase in freight volume has led to the deployment of more and more large vessels, but the navigation coefficient of most canals cannot meet the size requirements of large vessels. This forces the vessel to arrive at the port only by the detour, which increases fuel costs and extends sailing time. To meet the needs of the maritime market, the world's major canal management departments have successively invested in the expansion of the Panama Canal to increase their shipping capacity. After the expansion of the Panama Canal, based on time and cost considerations, the re-selection of the original route has become a pressing issue of concern to the industry.

This paper selects the important liner route between China and the United States - the Far East to the US East Coast as the research object. Firstly, from the supply and demand of the container transportation market in China and the United States, the current situation of container transportation between China and the United States is analyzed, emphasizing the impact of the expansion of the Panama Canal on time and cost of the transportation route.

After that, the Logit discrete model is established for route selection. The selection probabilities of different routes are calculated based on the transportation time and transportation cost of different routes. The route selection is analyzed according to the calculation results. Finally, an evaluation index system is established to evaluate the route selection results.

Finally, based on the above results, the choice of different container transportation routes between China and the United States provides a reference for container liner companies.

KEYWORDS: Extension of Panama Canal; Container Transportation Route Selection; Logit Discrete Model

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1 Introduction

1.1 Research background

China and the United States are the world's two largest economies, and the volume of trade between Asia and America is also growing year by year. The most important route connecting the two continents is the Far East to the US East Coast route. Since the 1990s, the route of cargo transportation on this route has changed significantly, with only 20% of goods passing through the Panama Canal (80% in 1980) and 80% through interstate railways or highways (20% in 1980). Since the 21st century, cargo on the route has been transported from the west coast to the east coast mainly via US interstate railways and highways, or container vessels with a capacity of over 8,000 TEU have been taken to the Suez Canal, and then transported to the east coast of the United States by rail and road from countries such as Nicaragua or Colombia.

At the same time, with the development of large-scale vessels, the capacity of the Panama Canal is insufficient. Therefore, improving the canal capacity and expanding the canal have played an essential role in enhancing the competitiveness of the Panama Canal. The expansion project of the Panama Canal officially kicked off on October 22, 2006. The project was initially planned to be completed in 2014, but the cost was seriously overrun and the completion time was pushed back to 2016. By then, the annual capacity of the Panama Canal will reach 17,000, and the annual cargo traffic will increase from the previous 300 million Panama Canal to 600 million Panama Canal according to the original plan.

The liner routes from the Far East to the US East Coast are mainly composed of the

eastbound route through the Panama Canal and the westbound route through the Suez Canal. However, the opening of the Nicaragua River and the further expansion of the Suez Canal have made the Far East to the US East route increasingly fierce, and the Panama Canal has become increasingly inferior in the Far East to the US East Coast routes. Therefore, the expansion project of the Panama Canal has brought an excellent opportunity for the canal, and it also affects the choice of transport routes for liner shipping companies.

Since the financial crisis in 2008, the international container liner shipping market has experienced a period of significant fluctuations in freight rates, large-scale mergers and acquisitions in the liner industry, and overall loss of liner companies. In the second quarter of 2016, the company entered the recovery rebound stage and achieved good results in 2017, while the confidence of the liner industry has gradually picked up. However, when everyone is full of confidence, influenced by external political, economic and trade, as well as the liner industry itself, the average value of China's export container freight index in 2018 is basically the same as the 2017 freight rate. Although in the current Sino-US trade friction background, the overall performance of international container transportation in 2018 is still at a reasonable level, but in the industry's view, the market has not yet reached expectations, and the industry once again presents a "black cloud".

According to Clarkson's data, the rapid development of emerging Asian economies has driven regional trade to overgrow. In 2018, the volume of container shipping within the region increased by 6.45% on a year-on-year basis, 6.29% higher than that of the North-South route and also higher than 5.83% of the Pacific route. The container shipping volume growth of the Asia-European route decreased on a year-on-year basis. The continued growth of intra-regional cargo volume will also

have an essential and long-term impact on the route structure and fleet structure. On the one hand, the increase in the capacity of routes within the region can be used as an important supplement to the business of the east and west trunk routes, and it will also promote the generation of direct routes in some regions, which in turn will divert the volume of east and west routes. From the perspective of freight rates on different routes, Far East-South America, China-Southeast Asia, which performed well in 2016-2017, declined on a year-on-year basis, while freight rates in the Far East-North America route, which were significantly affected by Sino-US trade friction, rose sharply.

Affected by the current industry confidence recovery and the cost competition of ultra-large container vessels, according to Clarkson data, the total container delivery volume in 2018 totaled 1,408,500 TEU, an increase of 18% over 2017. Among them, container shipping capacity delivery above 10,000 TEU accounts for 82%. As the competition situation of the global container liner alliance and the main liner giants has become more stable, the alliance route cooperation has gradually been put into practice, and the influence of alliances has been deepened. The three major alliances and major liner companies in the world have carried out different levels of route adjustment. As of December 2018, the number of new and route upgrades for liner companies was as high as 47. On the whole, several major alliances have reduced the Far East-US West route, and have increased or upgraded the capacity of the Far East-US East Coast route and optimize some Far East-Europe routes at the same time. In addition, there are 15 new routes in Southeast Asia, including 8 from China, 7 from Japan and South Korea, and 2 upgrade routes. The North-South route has also begun to attract the attention of some liner companies.

Affected by market expectations, the proportion of global container idle vessels is

generally low, showing a “first drop and then rise” trend throughout the year. As of October 2018, the global container vessel idle capacity ratio was 3%. Although the market growth was less than expected, new vessel orders continued to improve. In 2018, the new contracted volume of container vessels was 1,120,500 TEU, an increase of 41.8%. At the same time, in the first half of 2018, Hyundai Merchant Marine announced the ordering of 13 23,000 TEUs container vessels and 8 super-large container vessels of 14,000 TEUs. Evergreen announced the order to build eight super-large container vessels of 11,000 TEUs, leading to a large scale container vessel orders increased. The increase in requests for a large number of ultra-large container vessels will further intensify competition in the industry, increase the competition threshold for long-distance routes, and more also reduce the transportation costs of the corresponding routes.

The concentration of the liner industry is further improved, and the main liner giants are also facing losses. According to Alphaliner data, the top three Maersk Line, Mediterranean Shipping and COSCO Shipping in December 2018 accounted for 44.6% of the global capacity, while the container capacity of three primary alliance members the OCEAN Alliance, the Alliance and 2M is 6.671 million TEU, 3.776 million TEU and 7.359 million TEU respectively, with market share of 29.4%, 16.6% and 32.5% respectively. The total market share of the three primary alliance members is as high as 78.5%. Judging from the operation of the main liner company in the first three quarters of 2018, although Maersk, CMA and Hapag-Lloyd achieved profitability, profits fell sharply on a year-on-year basis, and many other companies may face losses.

1.2 Research content

Based on a comparative analysis of the current situation of the Far East to the US East Coast routes before and after the expansion of the Panama Canal, this paper further analyzes the impact of the expansion of the canal on the Far East to US East Coast routes. The Logit discrete model is used for route selection. Finally, the comprehensive transportation cost and time cost are selected to select a Far East to the US East Coast liner shipping route. Mainly from the following aspects:

1. The first part of the main body of this paper analyzes the current status of international trade, international container market and Sino-US routes, and clarifies the background of route selection. It then collects data on the time and cost of operation of the Far East to US East Coast routes. Calculating, comparing and analyzing the single-container cost of different routes. Finally, explain the supply situation and trend of the route.

2. The second part of the main body of this paper is based on the expansion of the Panama Canal, analyzing its impact on container transportation in China and the United States, including the impact on the entire container shipping market and related ports and infrastructure, to illustrate the need for the expansion of the Panama Canal.

3. The third part of the main body of the article is to establish the Logit discrete model and calculate the probability of several Sino-US container transportation routes selection through the realization of the model algorithm, and then select and analyze the relatively best route according to the calculation result.

1.3 Research significance

So far, there are three modes of transportation for seaborne cargo from the Far East to the US East Coast, two of which are waterway transportation: transporting through the Panama Canal and transporting through the Suez Canal; the other is the multimodal transport: transporting from the Far East to the US West Coast, and then it is transported by the US West Rail to the US East Coast. The expansion of the Panama Canal has had a profound impact on the global route situation: container cargo from the Far East to the US East Coast will be expanded from the US West Line to the US East Line, giving full play to the economies of scale of the super-large vessels.

The expansion of the Panama Canal has had a profound impact on the container shipping route network, port layout and fleet structure, and promoted the evolution of the global shipping situation. In this regard, based on analyzing the current status of container trade and transportation between China and the United States, the transportation time and transportation cost of different routes of Sino-US container transportation before and after the expansion of the Panama Canal are compared. The route selection model is used to analyze the changes in container flow distribution after the expansion of the Panama Canal. The possible modification of the network situation of the US and China container routes are analyzed, and the decision-making basis for the relevant entities to respond to the expansion of the Panama Canal is provided.

The expansion of the Panama Canal has had an important impact on the layout of global container routes. In particular, China and the United States are the main users of this canal. The expansion will directly affect the choice of container transportation routes, vessel composition and port selection in China and the United States, and affect the routes' design and operation of liner companies. Therefore, analyzing these

effects is a hot spot for shipping companies, ports and shipping administrations.

2 Literature review

2.1 Research on Container Route Selection

Hu Jianwei, Peng Ziliang, and Huang Youfang (2018) built a multi-port anchor and hub-and-spoke hybrid network in the "*Optimization of service network and design of freight route of container liners*", and established a nonlinear mixed-integer programming model with the minimum total operating cost as the target. And use the COSCON in the Asia-Oceania-Europe region to verify the validity of the model. Through sensitivity analysis, it is found that the improvement of port handling efficiency has a significant effect on reducing the operating costs of liner companies; there is a correlation between the fuel cost of the vessel and the operating cost. Therefore, the continued rise in oil prices has forced liner companies to choose to slow down and deploy more vessels to reduce overall costs.

Zeng Qingcheng, Wu Kai, Sun Xiangjun (2016) compare the transportation time and transportation cost of different routes of Sino-US container transportation before and after the expansion of the Panama Canal in the "*Impact of Panama Canal Expansion on Sino-US Routes of Container Transport"*. Using the route selection model to analyze Panama canal after the expansion, the distribution of container cargo flow changes, and analyzes the possible changes in the network situation of Sino-US container routes, providing a decision-making basis for the relevant entities to respond to the expansion of the Panama Canal.

In order to solve the optimization problem of the transportation channel, in the article

"*Route optimization of China-EU container multimodal transport considering various factors*", Li Yumin, Guo Xiaoyan, Yang Lu (2017) comprehensive analysis of the status quo of China-EU container transport, integrated consideration of transportation time, transportation costs and Based on the three factors of carbon emission, a multi-objective optimization model for the optimization of multi-modal transport route between China and Europe is constructed. According to the different emphasis and different needs of multimodal transport participants, the different weights of the three objective functions are determined, and the multi-objective combination is transformed into a single-objective problem by weighted summation; the genetic algorithm is used to solve the problem, and the Pareto solution of the model is obtained by the final iteration. Taking the actual data from Nanjing to Berlin as an example, the results show that the model is feasible and effective, and it can provide a highly guiding optimization scheme for the optimization of a multi-modal transport route between China and Europe.

In the article "Study on the Choice and Process Improvement of F Company's Export Container Maritime Route", Guo Sheng(2013), from the perspective of shippers, aims at cost and time control. He discusses how F Company can reasonably arrange the sequence of shipping routes and determine the container allocation at the hub port, how to reduce the logistics cost and reduce the navigation time by reducing the number of export batches, and how to connect the warehouse with the warehouse. The allocation between warehouses and the difference between delivery notice and actual arrival should be avoided to optimize the route selection.

Liu Lin and Zhu Xiaolin (2017) put forward an optimization model of refrigerated container routes based on sea-rail intermodal transport in the paper "*Optimizing the route of refrigerated container intermodal transport with total cost considered*". The

model is established on the basis of common container multimodal transport and the objective function of minimizing the total cost including refrigeration cost, transportation cost and transshipment cost. After that, the dynamic programming algorithm regards each node as a virtual route. Through the analysis of examples, it is found that the optimal route is different in the case of multi-modal transport of refrigerated containers and multi-modal transportation of ordinary containers. Under the mode of sea-rail transport of refrigerated containers, the refrigeration cost increases, but the total cost decreases. The optimization of the route of sea-rail transport of refrigerated containers is studied. The problem provides a reliable reference for decision-makers in choosing transportation routes.

Lee, Hyangsook Lee, Kang-Dae Choo, Sangho (2016) studied the impact of emissions costs on international container shipping route selection. They developed a freight network model to capture the decisions and interactions of ocean terminal carriers and port terminal operators in port freight systems. The activity-based approach then calculates emission costs as part of the ocean transportation cost function. The study discusses how emissions costs play a role in route changes and why ocean carriers must consider these costs in route decisions.

Radoslav Rajkovic, Nenad Zrnic, Đorđe Stakic, Borut M (2015) analyzed the container transport costs using different liner transport services between the Far East and Serbia and compared the transport costs on various routes. Existing transport routes were observed and hypothetical reviews of the development of new transport routes were conducted to find the best route to provide the lowest transport cost in the container transport process.

2.2 Research on the expansion of the Panama Canal

Li Jian and Yan Yan (2018) set up a competition game model. Taking the Panama Canal Authority and Suez Canal Authority as the leading players, this paper analyzed and simulated the adjustment strategies of the two sides' canal tolls after the expansion of the Panama Canal. The research shows that after the expansion of the Panama Canal, Panama Canal Authority should adopt the strategy of a small reduction of tolls to attract more vessels. The shipping market share of the Suez Canal will be reduced, but the Suez Canal Authority should maintain the current toll level; the two sides should choose strategies aimed at long-term interests in order to achieve higher returns.

Wang Jiawei (2017) explores the role of the Panama Canal from a geographical perspective, as well as the background, significance, risks behind the expansion of the Panama Canal and the impact on China. Chen Yuping and Wang Lingfeng (2016) explored the expansion of the Panama Canal to China. The economic and trade logistics industry brings new opportunities. JAVIER MORALES (2016) studied the impact of changes in international oil prices on the total navigation of the Panama Canal. Liu, Wilson, Luo (2016) uses cooperative game theory to analyze the potential impacts of the Panama Canal (PC) expansion on the evolving competitive–collaborative relationships and the distribution of market power among the supply-chain players in the US container-import market. The ocean shipping industry is captured using bi-level optimization models, with the ocean carrier (OC) acting as the market leader. The result shows that the enlarged vessel size passing through the PC will increase the East Coast players' market power by 32 % while hurting the West Coast players by 22%. The sub coalition between the OC and the

West Coast players is most likely to form prior to the PC expansion whilethe OC prefers the sub coalition between the OC and the East Coast players after the PC Expansion, however, the total profit with competitive sub coalitions is always less than the grand coalition's profit. The impacts of possible variations in service costs, as well as charges by the PC, the ports, and the railroad after the expansion, are also analyzed. Lee Min Chern; Chao Lin Ting; Chien Chang Chou; Yuh Ling Su (2015) introduce the evolution of container vessel, and then discuss the influence of Panama Canal Expansion Project on container transport routes in the world. The study shows that the competition in the shipping market depends upon vessel type development.

2.3 Review of relevant research at home and abroad

Research on the optimization of transportation routes has been a hot research topic at home and abroad, mainly due to the need for logistics cost control brought about by economic globalization, and this control is continuous and universal. At present, the study of the Panama Canal in foreign countries is mainly carried out from the legal and technical level, and relatively little research on the interaction between the expansion of the canal and the liner transportation. Relatively speaking, domestic academic research mainly analyzes the impact of the expansion of the Panama Canal on international trade, liner shipping and transport from a qualitative perspective. Moreover, in terms of transportation route selection, most of the previous researches are aimed at the choice of road transportation and multimodal transport routes, while for container liner transportation, more emphasis is placed on route optimization design. In this paper, I consider the transportation time and cost, and select the container transportation route between China and the United States based on the Logit model.

3 Impact of the Panama Canal expansion on the container transport market

3.1 Status of supply capacity of Sino-US container shipping routes

The world's three largest liner routes: Far East - North America, Far East - Europe and the Mediterranean, North America - Europe and Mediterranean routes. The three major liner routes connect the most economically developed sectors of the world – the Americas, Europe and Asia – and the container traffic of the three routes account for more than 60% of the global traffic. Among them, the Far East - North American route, also known as the Pan Pacific route, can actually be divided into two North American routes. On the Far East to North America coast routes, some shipping companies carry out a "pendulum" line, which is between the Far East and the North American coast; some operate a global route: Pacific - Panama Canal - Atlantic - Mediterranean - Suez Canal - Indian Ocean - Pacific Ocean.

3.1.1 Analysis of container vessel types on Sino-US routes

Most of the container vessels in the Far East to the US route are in the range of 5,100 -7,499 TEU, 7,500 -9,999 TEU and 10,000 -12,000 TEU, and the total number of vessels is as high as 85.74%. It can be seen that the large-scale vessel has been reflected in this route, so the expansion of the Panama Canal provides the liner shipping enterprises with the opportunity to expand the fleet size, and also hinders those who are under-funded and only have small container liner shipping enterprises. The container vessel market in the Far East to the US route is undoubtedly developing in the direction of large-scale.

Since the opening of the Panama Canal, the Panamanian government has decided to implement the expansion project in 2006. The shipping industry has been using Panamax vessels designed for the largest size of the Panama Canal Lock (320 meters long, 33.53 meters wide and 25.9 meters draught) as the standard type of vessel. Vessels that exceed the maximum width of the Panama Canal and one more beam width are called super Panamax vessels. It can be seen that the Super Panamax vessel covers a wide range and has no fixed classification, so it has been more widely understood as a container vessel with a ceiling of 56.4 meters wide for a long time in the past. Due to size limitations, new Panamax vessels cannot appear on routes to the Panama Canal. The size of its ship locks has always limited the navigation capacity of the Panama Canal. Many large eastern containers cannot pass through the canal smoothly. Other routes cannot be selected for transmission, and the interests of shipowners have been damaged. The expansion of the Panama Canal has brought vitality to the shipping routes of the Panama Canal and the entire industry. The Panama Canal Authority issued the "NO.A-20-2013 Shipping Announcement", which announced the size requirements for the new Panamax type: 366 meters long, 49 meters wide and 15.2 meters draught.

The new ship lock on the Canal has reduced the size constraints of the vessel, which has a fundamental impact on the route from Asia to the US East Coast: the proportion of goods from the Far East to the US East Coast through the Panama Canal will increase significantly. In addition, the volume of individual container vessels will rise from the current 4,250 TEU to 13,000 TEU and 14,000 TEU. Due to the economies of scale and the increasing trade volume between Asia and the Americas, the new Panamax has become the main vessel type active in the Far East to US East Coast routes.

The transportation distance from China to the United States is far away. The direct shipping distance from Shanghai to Seattle is more than 5,100 nautical miles, and the cargo flow on the Sino-US route is relatively large. Therefore, it is obvious that the large-scale Super Panamax container vessel is more economical. For example, a 5,000TEU container vessel with a speed of 25 knots can increase unit revenue by 67% compared to a 3,000TEU container vessel with a speed of 20 knots. The increase in speed is usually 20% on the Pacific route. Take Maersk's 6250TEU type K-class vessel as an example. For example, it operates on a typical trans-Pacific route. Each container can save $440 per year, and saves $27 per container per voyage. However, when the utilization rate of such a super Panamax vessel is below a certain level, its unit cost advantage becomes an unfavorable factor. Therefore, shipping companies operating on super Panamax container vessels are all members of the alliance with absolute advantage, and the utilization of the container can be guaranteed through alliance and space sharing.

3.1.2 Analysis of the trend of supply capacity on the Sino-US route

Before 2008, about 90% of the Asia-US East Coast service routes were passed through the Panama Canal every year. However, with the trend of large-scale ships, the average capacity of ships on the Suez route reached 7,500 TEU, while the Panamanian route had a maximum capacity of 5,000 TEU before the expansion of the canal, and its average ship capacity was only 4,500 TEU. Therefore, before the expansion of the Panama Canal, the volume of the Panama Canal and Suez Canal routes was almost 1:1 among the service routes from Asia to the US East Coast. The Suez Canal has begun to squander the market share of the Panama Canal, posing a significant challenge to the Far East to the US East Coast route through the Panama

Canal.

Before the expansion of the Panama Canal, due to the high single-container cost of the 4,500TEU vessel, the shipowner chose to consider the US West Coast reloading of sea-rail combined transport and even the Suez Canal. However, after the expansion of the Panama Canal, vessels of more than 8,000 TEU can be directly linked to the East ports, and the cost of transporting single containers through the entire waterway is greatly reduced. With the opening of the third group of new locks in the Panama Canal, the acquisition of a more competitive navigation fee for the large container vessel compared to the Suez Canal will help the Panama Canal to regain some market share from the Suez Canal. Liner transport companies are also investing more and larger container vessels on the eastbound route from the Far East to the US East (i.e. via the Panama Canal). Besides, after the expansion, the 8,000-12,000 TEU vessel can be used from Asia via the Panama Canal to the US East Coast port, while the capacity of shipping from Asia via the Indian Ocean and Suez Canal, and finally the transatlantic to the US East port is basically the same type of vessel. But through the Panama Canal, the route has a shorter sailing time and is, therefore, more competitive.

With the opening of the Panama Canal after the expansion in 2016, the average vessel size on the trade routes from Asia to North America and the US Gulf has increased dramatically, and the average vessel size currently exceeds the trade routes from Asia to the West Coast of North America. The largest vessels presently deployed on the West Coast trade routes from Asia to North America are two 17,816 TEU vessels, and there are four vessels on this route ranging from 14,000 TEU to 15,999 TEU, as shown in Table 3.1.1.

Table 3.1.1 Ships of different capacities in Asia to Europe and the US routes

Capacity of vessels /TEU	Number of container vessels		
	Asia - North Europe	Asia - US West Coast	Asia - US East Coast
20,000+	33	0	0
18,000 - 19,999	46	0	0
16,000 - 17,000	9	2	0
14,000 - 15,000	40	4	5
12,000 - 13,999	25	33	27
10,000 - 11,999	9	36	8
8,000 - 9,999	46	11	98
6,000 - 7,999	14	59	42
0 - 5,999	17	50	15

Source: BlueWaterReoorting

As shown in Table 3.1.2, from October 2015 to October 2018, the average size of vessels from Asia to North America and the US Gulf increased by 48.6%, from 5,848 TEU to 8,690 TEU. Mainly due to the opening of the third lock of the Panama Canal in June 2016, the canal can handle more than 14,000 TEU vessels. This waterway can only handle vessels below 5,000 TEU before expansion. According to Blue Water Reporting, 13 of the 18 routes serving Asia - North America's East Coast and US Gulf trade use the Panama Canal, while the remaining five routes rely on the Suez Canal. Due to the expansion of the Panama Canal locks, the average shipping size of the trade routes from Northern Europe to the West Coast of South America increased by 117.6% during the reporting period from October 2015 to October 2018, from 3,757 TEU to 8,174 TEU. All three routes currently deploying capacity on this

trade route use the Panama Canal. To date, the largest container vessel sailing through the Panama Canal is the 14,414 TEU vessel operated by CMA - CGM.

Table 3.1.2 Average capacity of container vessels

Trade route	2015	2016	2017	2018	Rate of change
Asia - North Europe	11,711	13,561	13,390	14,193	21.2%
Asia - Mediterranean	9,754	10,841	11,649	12,223	25.3%
Asia - US West Coast	7,539	7,831	7,977	8,136	7.9%
Asia - US East Coast	5,848	7,000	7,163	8,690	48.6%
Asia - South America West Coast	6,608	7,370	7,700	8,051	21.8%
Asia - South America East Coast	7,153	8,605	9,178	7,556	5.6%
Asia - Mexico	6,402	7,775	8,239	8,451	32.0%
Asia - the Middle East	7,850	7,705	7,925	7,955	4.9%
Asia - India	4,838	5,413	5,908	5,887	21.7%
Asia - Africa	4,124	4,419	4,794	4,774	15.8%
Asia - Oceania	3,736	4,058	4,178	4,354	16.5%
North Europe - North America	4,385	4,563	5,191	4,928	12.4%
North Europe - Mexico	4,566	4,975	6,501	6,369	39.4%

North Europe - Mediterranean	7,345	7,794	8,519	7,939	8.1%
North Europe - South America West Coast	3,757	4,845	7,342	8,174	117.6%
North Europe - South America East Coast	6,684	6,770	6,903	6,376	-4.6%

Source: BlueWaterReporting

From October 2015 to October 2018, the average vessel size from Asia to the US Gulf increased by 32%, from 6,402 TEU to 8,451 TEU, while the average vessel size from Northern Europe to the US Gulf increased by 39.5%. It is increased from 4,566 TEU to 6,369 TEU. Much of this can be attributed to Mexico as a whole as a booming manufacturing hub, especially in car manufacturing centers. In October 2017, Drewry Shipping Consultants said: “Mexico has grown into the seventh-largest automobile manufacturing country in the world, and a large part of the containers shipped to Mexico are the raw materials and components for manufacturing automobiles. These raw materials and components are entrusted to more and more auto assembly plants and suppliers. New investments by Kia, Toyota, BMW and Daimler Benz will increase Mexico's auto manufacturing capacity to 5 million units in 2022.” The expansion of the Panama Canal has little impact on the increase in the average vessel size of trade between Asia and Mexico and Northern Europe to Mexico. According to data from BlueWater Reporting, only one of the nine routes currently serving Asia to the US Gulf trade uses the Panama Canal, and only one of the six routes serving North Europe to US Gulf trade uses the Panama Canal. Naturally, as the average capacity of container vessels continues to increase, the

number of container vessels deployed on each route continues to decrease, as shown in Table 3.1.3.

Table 3.1.3 Number of container vessels

Trade route	2015	2016	2017	2018
Asia - North Europe	257	210	225	209
Asia - Mediterranean	285	270	270	242
Asia - US West Coast	306	284	250	259
Asia - US East Coast	283	206	212	197
Asia - South America West Coast	121	103	95	107
Asia - South America East Coast	59	37	37	49
Asia - Mexico	133	103	95	108
Asia - the Middle East	226	203	184	159
Asia - India	315	306	318	245
Asia - Africa	233	206	212	200
Asia - Oceania	129	139	127	126
North Europe - North America	157	143	124	133
North Europe - Mexico	44	50	42	42
North Europe - Mediterranean	270	254	266	262
North Europe - South America West Coast	40	41	26	27
North Europe - South	29	29	23	28

America East Coast				

Source: BlueWaterReporting

3.2 Status of Sino-US container shipping routes

Judging from the current bilateral trade between China and the United States, China's exports to the United States mainly focus on mechanical and electrical products, daily necessities, clothing, household products and some high-end manufacturing spare parts, and the export of low-end and mid-range manufacturing industries has increased on a year-on-year basis. China's imports of US goods mainly include aviation, machinery, medical, organic chemistry, optoelectronics and other high-addition industries, and minerals, agricultural products, wood and waste paper, plastic rubber, meat fish and other raw materials or primary products, and the United States in fossil fuels the jewelry and precious metal products, agricultural and animal products, wood products and pharmaceuticals increased by a large margin on year-on-year basis; the bilateral trade between China and the United States was more complementary. In 2018, affected by the adjustment of tariff policies between China and the United States, some cargo owners shipped in advance, and some European and American vessel owners also affected the supply of market capacity, which in turn led to the increase in freight rates in the Far East-North America route, while avoiding high taxes. The United States has increased its entrepot trade, especially from China to Southeast Asia and then to the United States. The three major alliances have successively adopted the evacuation measures on the trans-Pacific route. The shipowners' investment in this route will affect the future freight rate fluctuation in no small extent.

In the second half of the year, with the advent of the traditional transportation season,

the market transportation demand performed well. In addition, affected by the US government's tariff increase, the cargo owners have accelerated the implementation of the contract to avoid additional costs, thus stimulating a further increase in market transportation demand. Despite the continued expansion of the route capacity, the supply of space is still tight, and the market freight rate has climbed all the way. The Shanghai Export Container Freight Index issued by the Shanghai Shipping Exchange shows that in November, the freight rates of the US West and the US East Coast respectively hit a high of 73 months and 42 months respectively. In December, with the Christmas supply coming out, the transportation demand dropped significantly, the excess capacity began to appear, and the market freight rate showed a correction trend. On December 14, 2018, the freight index of China's exports to the US West and the US East Coast issued by the Shanghai Shipping Exchange were 812.72 points and 1013.14 points, respectively, up 34.1% and 29.8% from the end of the previous year. In 2018, the average freight index of China's exports to the US West and the US East route was 686.00 points and 894.95 points, respectively, up 6.6% and 5.1% from the previous year.

3.2.1 Multimodal transportation (shipping and railway)

The destination port of the first eastbound route from the Far East to the US East Coast is the ports of the US West. When the goods arrive at the west port of the US by sea, they are transported by rail to the East Coast then, i.e. MLB. In principle, the route takes about 18 days, but it needs to be transferred on the way, and the consistency is weak. The entire delivery time of the goods may reach 22 days. MLB is mainly subject to road transportation in the United States. The total freight rate will increase or decrease due to changes in national highway and rail freight rates, and the transfer will also lead to cargo damage. However, relatively speaking, the

road and rail transportation capacity of the United States is stronger than that of other countries, and it can achieve “door-to-door” transportation, so more customers choose this route. The Far East to US West route has always been a battleground for military strategists. In the routes that have been opened up, the US-West route accounts for 2/3 of the total, and its freight volume accounts for 80.4% of the entire Sino-US container shipping market. However, among the goods directly connected to the US West, 1/2 are transported to the US East by a mini land bridge. Because compared to the Far East to US East waterway transportation, its transportation time is about a week, but the cost is 400 to 600 US dollars per TEU. In addition, the western US ports have been crowded in recent years, such as the current throughput capacity of the Port of Long Beach. It is no longer possible to arrange new routes and operational plans. From time to time, there is always a phenomenon that the dockworkers strike and delays. Due to the increase in the number of operations and the cumbersome procedures, this has also caused the cargo and carrier to weaken the control of the goods and create instability. This is also one of the reasons why the Far East to US East Waterway has gradually warmed up in the past two years. However, due to the superior natural conditions of the western ports of the United States, the opening of the Far East to the US West route is less than that of the US East. Therefore, for shipping companies that have just entered the Sino-US container shipping market or who are weak, the Far East to the US West route is still the best choice.

3.2.2 Eastbound route (via Panama canal)

The first eastbound route from the Far East to the US East is the route through the Panama Canal, namely ALL WATER, and the total sailing time is generally no more than 25 days. Due to the restrictions of the Panama Canal locks, the vessels on the

route before the expansion were basically fourth and fifth-generation container vessels (4,500 TEU-5,000 TEU). But the main problem with the Panamanian fleet in the world is that its age is old and the vessel's engine is far below the fuel efficiency of the new generation of vessels. These new generation vessels include new vessels that have just been shipped, as well as vessels that have moved from the Asia-Europe route to Asia-US East Coast route. Although the number of containers currently transported by the US East Coast Waterway of the Panama Canal is small, the actual 12% of the container traffic of China and the United States comes from or is shipped to the East Coast, but it is covered by the mini land bridge transportation of the United States. Potential transportation demands in the eastern United States have not been released, so there is an excellent potential for the US East Waterway transportation. The main ports of call are New York, Norfolk, New Jersey, Savannah, Miami and other ports. For the US East Coast route, its transportation time is about a week longer than that of the US West Coast via a small land bridge. For example, it takes about 29 days from Shanghai to New York Harbor (depending on how many ports are called in the route). Therefore, the Far East to the US East Coast route should be suitable for that with a large proportion of goods, low prices, and short delivery times. Therefore, the Far East to the US East Coast route is still very attractive for Chinese cargo owners to export labor-intensive goods.

One of the main advantages of choosing to open the Far East to the US East Waterway route is to reduce the cost of empty container return shipping. Because the containers on the West Coast of the United States are multimodally transported to the US East, it is difficult to find the return goods after unloading. After being transported back to the US West Port via multimodal transport, it will be returned to China by sea. This will cost a lot of empty containers and the shipowner will bear the cost. If it is directly shipped back to China from the US East Port, it will save a

considerable amount of money, which is also an important reason for the shipowners to favor the US East Waterway transportation in the past two years.

3.2.3 Westbound route (via Suez canal)

This route is relatively secluded. Generally, the shipping companies have invested less capacity to develop this route, because this route spans too many areas, including East Asia, the Indian subcontinent, the Middle East, and the Mediterranean port, before the vessel can reach the US East Port. Calculated according to a classic pendulum route through the Suez Canal, it takes nearly 84 days to travel to and from a voyage. The time from Shanghai to New York is about 37 days. Although the freight rate is cheap, the delivery time is too long, which is greatly reduced the satisfaction of the owner of the goods. Therefore a small percentage of the volume of goods transported through this route each year. In order to reduce costs, liner shipping companies will set up many ports of call on the route, and the freight volume of this route is mainly the number of containers between the ports. The goods from the Far East to the US East that use this route are generally not urgent and can be stored for a long time. As long as the freight rate is low enough, you can also get some bargains that are not tight in delivery. Although the current number of pendulum routes is small, the main reason is not that the return on investment is low, but the investment is too large and the risk is too high, but for those shipping alliances and large shipping groups, it is still profitable. Because they have an extensive and complete network of goods and channels to support, the supply is guaranteed. For shipping companies, the benefits of opening a pendulum route are self-evident. A route can connect three major economic regions, Asia-Europe, Europe-US, Asia-US, which will significantly help establish its position as a global carrier.

3.2.4 Comparative analysis of time and cost of different transportation routes from the Far East to the US East

Container shipments currently exported from Asia are usually transported by US rail and road from the US West Coast to the US East Coast, or by large vessels of more than 10,000 TEU to the US East Coast through the Suez Canal. After the expansion of the Panama Canal, although the tolls may increase, the congestion of the West Coast ports in the United States, coupled with the current pressure on the railway carriers to continue to withstand the rising costs of fuel, equipment and infrastructure, has led to the transfer of container trade between Asia and the US East Coast. It is a priority for all waterway through the Panama Canal. The expansion of the Panama Canal can accommodate larger vessels. The economies of scale of the large-scale vessel will change the situation of large quantities of goods transported by the US West Coast of the Pacific Ocean to the US East Coast or through the Suez Canal to the US East Coast via the Mediterranean Sea.

This paper will use Shanghai Port as the representative of China's coastal ports, while the United States Long Beach and New York Harbor as the representative of the US West Coast port and the US East Coast port. Assume that the container vessel capacity from Shanghai Port to Long Beach Port is 8,000 TEU, and the container vessel capacity from Shanghai Port through the Suez Canal to New York Harbor is 12,000 TEU. Before the expansion of the Panama Canal, the canal was able to pass a container vessel of 4,000 TEU capacity and, after expansion, it could pass a container vessel of 8,000 TEU - 12,000 TEU. Due to the high average utilization rate of container vessels on Sino-US routes, and the economic relationship between the two countries has fluctuated by the Sino-US trade war in recent years, the economic and

trade relations have maintained a stable development momentum under the state's macro-control, and the development prospects of the container trade and transportation market are good, so for the convenience of calculation and comparison, the calculation is based on the full load condition of the vessel. When calculating the container transportation time and cost, the specific container transportation related data obtained by collecting the data are shown in Tables 3.2.1 to 3.2.3:

Table 3.2.1 Related data

Capacity of vessel /TEU	4,000	8,000	1,2000
Rent of container /($/d)	0.89	0.89	0.89
Time charter rate /($/d)	11,750	27,800	35,500
Speed /kn	20	20	20
Average time of vessel in port /d	1.0	1.5	1.7
Fuel consumption (t /d)	85	135	165
Fuel price($/t)	437.3	437.3	437.3
Panama canal toll of single container /$	90	90	90
Transit time of Panama canal /d	0.6	0.6	0.6
Toll of Suez canal /$	/	518,040	518,040
Transit time of Suez canal/d	0.46	0.46	0.46

Source: Clarkson sin and Maritime service

Table 3.2.2 Port operation fee

	Chinese port			US port		
Capacity of vessel /TEU	4,000	8,000	12,000	4,000	8,000	12,000
Port operation fee/$	539,130	805,800	1,208,700	574,149	854,140	1281,210

Source: http://www.portshanghai.com.cn

Table 3.2.3 North American land bridge freight rates and distances

Time for transshipment/ d	American rail container rates		Speed/(km/h)	Distance/（km）
	Base price/$	Run base price/($/km)		
2	210	0.95	60	4,500

Source: Surface Transportation Board

According to the data in the above table, the transportation time and cost from Shanghai to New York can be calculated in Table 3.2.4:

Table 3.2.4 Transportation time and cost between Shanghai and New York

	Via Panma canal			Multi-mo del transport ation	Via Suez canal	
	Before expansi on	After expansion				
Capacity of vessel /TEU	4,000	8,000	12,000	8,000	8,000	12,000

Total time /d	24.5	25.5	25.99	19.98	31.44	32.3
Cost per day per container/$	28.15	23.42	21.31	52.67	20.40	17.62
Cost per container/$	689.68	597.21	553.85	1052.35	641.51	569.24

As can be seen from Table 3.2.4, after the expansion of the Panama Canal, the 12,000 TEU container vessel has an absolute single-container cost advantage through the Panama Canal, and the average cost per container per day is second only to the container vessel via the Suez Canal, but the transport time of the 8,000 TEU and 12,000 TEU container vessels which shipping through the Suez Canal is too long, causing that there is no single container cost advantage for container vessels that pass through the Suez Canal, while the route of multimodel transportation has a higher average cost per container per day. Taking into account the time and cost factors, the 12,000 TEU container vessel that passes through the Panama Canal is highly competitive.

3.3 Impact of Panama Canal expansion on the Sino-US container transport route

3.3.1 Status before and after the expansion of the Panama canal

As the world bridge connecting the Pacific Ocean and the Atlantic Ocean, the Panama Canal is located in the middle of the Republic of Panama and is the most crucial shipping channel for the world's shipping. The Panama Canal was officially opened in 1914 and was under US occupation and control. In 1999, the United States formally handed over the canal sovereignty to the Panamanian government. The parameters of the Panama Canal are 81.3 km in length, 13 to 15 m in water depth,

and 150 to 204 m in width. The Panama Canal is transported through a first-class ship lock. The canal has six ship locks, namely the Miraflores Lock which is a two-level ship lock, the Pedro Miguel Lock which is a one-level ship lock, and the Gatun Lock which is a three-level ship lock. The technical parameters of the ship lock are 33.5 meters wide and 305 meters long. Due to the series parameters of the ship lock and the water depth, the length of the vessel that can pass the canal before the expansion is 294 meters, the maximum vessel width is 32.3 meters, and the maximum draught is 12.04 meters. The container vessel that meets this standard is about 3,500 TEU - 4,000 TEU Panamax, and the maximum bulk carrier and tanker loading are about 70,000-76,000 tons. It takes 9 hours for the vessel to pass through the canal.

Before the expansion of the Panama Canal, the rapid development of the global fleet and the significant vessel size trend allowed only 45% of the world's capacity (in terms of deadweight tons) to pass through the Panama Canal. However, since the middle of 2016, the Panama Canal has opened a new lock. The maximum vessel width allowed for the passage of the vessel has increased from 32.3 meters to 49 meters. As a result, the global fleet's capacity through the Panama Canal has further increased to 79%. In April 2018, the Panama Canal Authority announced that the maximum vessel width allowed to pass from June 2018 was further increased to 51.25 meters, and the limitation of vessel length remained at 366 meters (the new ship lock has a length and width of 427 meters and 55 meters respectively). Obviously, the market impact of this modification of the vessel's width limit is far less significant than the opening of the previous new ship lock, but it still further increases the capacity of the global fleet through the Panama Canal to 82%. In the container vessel sector, all 12,000-15,000 TEU container vessels are able to pass the Panama Canal (although some of the vessels' length is slightly above the official

requirements), and in June 2016 only 46% (in terms of the number of vessels) of the world's 12-15,000 TEU container vessel can pass through the Panama Canal. In addition, the theoretical modification of the vessel's width limit will allow more Newcastlemax bulk carriers, Suezmax tankers and some larger LNG carriers to pass through the Panama Canal.

Since the opening of the Panama Canal, the Panamanian government decided to implement the expansion project in 2006. The shipping industry has been designing a Panamax vessel (294.1 meters long, 32.3 meters wide, 12.04 meters draught) with the largest size of the Panama Canal lock (320 meters long, 33.53 meters wide and 25.9 meters draught) as a standard vessel type. vessels that exceed the maximum width of the Panama Canal and one more beam width are called super Panamax vessels. It can be seen that the Super Panamax vessel covers a wide range and has no fixed classification, so it has been more widely understood in the past for a long time as a container vessel with an upper limit of 56.4 meters wide. Due to size limitation, the new Panamax vessel cannot be found on the route which shipping through the Panama Canal.

The navigation capacity of the Panama Canal has always been limited by the size of its ship locks. Many large container vessels of shipowners cannot pass through the canal smoothly, and have to choose other routes for transportation. The interests of shipowners have been damaged. The expansion of the Panama Canal has brought vitality to the shipping routes via the Panama Canal and the entire shipping industry. The new locks on the canal have reduced the size constraints of the vessel, which has a fundamental impact on the route from Asia to the US East Coast : the proportion of goods from the Far East to the US East Coast through the Panama Canal has increased significantly. In addition, the volume of individual container vessels has

increased from the current 4,250 TEU to 13,000 TEU or even 14,000 TEU. Due to the economies of scale and the increasing trade volume between Asia and the Americas, the new Panamax has become the main vessel type active in the Far East to US East Coast routes.

Considering the choice of means of transportation of goods, after the expansion of the Panama Canal, the all waterway route is directly linked to the US East port, which is an impact on the transportation route of the US West Port which transfers cargo to the destination by land transportation. Taking the export of goods from Shanghai to New York as an example, if it is arranged to take the US West Port to reload the railway to New York, it takes 17-18 days theoretically, but due to the need to change the mean of transportation and the lack of continuity in the process, the final time is likely to be 22 days or more; if it is arranged directly all waterway route which shipping through the Panama Canal, the integrated route will take only 22 days to reach the destination, but its transportation is more consistent and safe.

3.3.2 Impact on ports and their infrastructure

The ports of the Far East to the US East Coast route mainly involve Asian ports, Panama ports and the US East ports. In addition to the US East ports, the draft of the entire route ports can basically meet the requirements of the new Panamax vessel. The biggest challenge for the expansion of the Panama Canal to the US East Port is how to evacuate large quantities of goods that are rolling in. Before the expansion of the Panama Canal, although the ports on the East Coast could dock vessels designed according to the main scale, there are still many restrictions and challenges facing the port.

Three main factors are restricting the acceptance of container vessels at the port: water depth, length of dock shoreline, container bridge cranes. In order to meet vessels of more than 10,000 TEU, the port firstly reconstructs from the above three aspects. As of the beginning of 2014, only New York-New Jersey Port, Norfolk Port, Port of Miami, Charleston Port and Baltimore Port have dredged the berth to 15 meters. The container berths of other major ports in the US East Coast and the US Gulf are more than 10 to 13 meters deep. Savannah port, which is 12.8 meters, will be dredged to 14.6 meters in the future, and the dock shoreline will be extended to 640 meters; Jacksonville Port and Florida Port are actively carrying out the "Mile Point" project to dig deep St. John River; Alabama also digs its harbor to 14 meters.

Other constraints include the evacuation capacity of the port, the ability of the road and rail network transport system to evacuate cargo to the port, and the port facilities. The Port of New York-New Jersey has carried out dredging channels to 15.24 meters and road improvement to the port. At the same time, the port also increased the vertical height of the Bayonne Bridge to 215 feet, or 65.5 meters. The original clearance height of the Bayonne Bridge is 151 feet, or 46 meters, which is an obstacle for the new Panamax.

In addition, new Panamax vessel cranes have been added to several ports in the US East Coast, such as the port of Miami and Savannah port. Each crane can lift 22 containers at a time. The previous small cranes have a lifting capacity of only 13 containers. The investment upgrade of port facilities and equipment not only improves production efficiency, but also enhances the competitiveness of the port. The expansion of the Panama Canal has forced airlines to increase investment and construction of infrastructure.

4 Sino-US container transportation route selection based on Logit discrete model

4.1 Description of the problem

Before the expansion of the Panama Canal, Asian-exported container cargo was usually transported by US rail and road from the US West Coast to the US East Coast, or by large vessels of more than 8,000 TEU to the East Coast through the Suez Canal. After the expansion of the Panama Canal, although the tolls of the canal have increased, the congestion of the West Coast ports in the United States and the ongoing pressure on the railway carriers to continue to withstand the cost of fuel, equipment and infrastructure have turned the container trade between Asia and the US East Coast into the all waterway route which shipping through the Panama Canal has become a priority. The expansion of the Panama Canal can accommodate larger vessels. The economies of scale of large-scale vessels have also changed the way a large amount of cargo is transported by rail from the West Coast of the Pacific to the East Coast of the United States or by the Suez Canal through the Mediterranean transatlantic to the East Coast of the United States.

Route selection is a complex issue that requires a combination of factors. In general, when there are “m” modes of transportation to choose from, the possibility of choosing a particular mode (such as mode “i”) depends on the transportation cost, transit time and other aspects of the various modes of transport (eg. the quality of the transport service, the value of the goods, whether it is dangerous goods and whether it is an emergency cargo, etc.). The likelihood of selecting transport mode “i” is

substantially the same as the observed relative frequency of selecting the transport mode or the market share of the transport mode. The simplest and most widely used route selection model is the Logit discrete selection model.

4.2 Building models and solving

4.2.1 Precondition

Before building a mathematical model, make the following assumptions about the original problem:

(1) When making choices between different routes, only the transportation time and transportation cost factors are considered.

(2) In the calculation, λ is 3×10^{-3}, k is 6.85; reference material is *Northern Sea Route Effect on Model Shiff & Modal Choice*, because the maritime context of the two has great similarity, it is considered that the parameter setting of the data has the same applicability here.

(3) Due to the high average utilization rate of container vessels on Sino - US routes, and the economic ties between the two countries have become increasingly close in recent years, economic and trade relations have maintained a stable development momentum, and the container trade and transportation market have good development prospects. Therefore, for the convenience of calculation and comparison, the calculation is based on the full load condition of the vessel.

4.2.2 Variables and parameters

X_i: route selection probability;

λ: constant, about 3×10^{-3};

C_i: generalized cost, $C_i = P_i + kt_i$;

k: a value constant reflecting the relative cost of time, which is about 6.85;

P_i: transportation cost of transportation mode i;

T_i: transport time of transport mode i.

4.2.3 Building a model

The Logit formula is derived by making assumptions about the characteristics of the selection probability. The specific calculation formula is:

$$X_i = \frac{e^{(-\lambda ci)}}{e^{(-\lambda c1)} + e^{(-\lambda c2)}} \quad (1)$$

Extend the above model to a variety of transport modes or probabilistic choices between routes, the model is:

$$X_i = \frac{e^{(-\lambda ci)}}{\Sigma e^{(-\lambda ci)}} \quad (2)$$

4.2.4 Algorithm implementation

According to the above method and the data of Table 3.2.4 , the probability of selection of different routes from the port of Shanghai to the port of New York before and after the expansion of the Panama Canal is calculated. The results are shown in Table 4.1.

Since $C_i = P_i + kt_i$,

Before expansion : $C_1=P_1 + K \times T_1= 689.68 + 6.85 \times 24.5 = 857.51$

$C_2=P_2 + K \times T_2 = 1052.35 + 6.85 \times 19.98 = 1189.21$

$C_3=P_3 + K \times T_3 = 641.51 + 6.85 \times 31.44 = 856.87$

$\Sigma e^{(-\lambda ci)} = e^{(-3 \times 10\text{^-}3 \times 857.51)} + e^{(-3 \times 10\text{^-}3 \times 1189.21)} + e^{(-3 \times 10\text{^-}3 \times 856.87)} =$

0.18105

$$X_1 = \frac{e^{(-\lambda ci)}}{\Sigma e^{(-\lambda ci)}} = \frac{e^{(-3 \times 10\text{^-}3 \times 857.51)}}{0.145571} = 0.421$$

$$X_2 = \frac{e^{(-\lambda ci)}}{\Sigma e^{(-\lambda ci)}} = \frac{e^{(-3 \times 10\text{^-}3 \times 1189.21)}}{0.145571} = 0.156$$

$$X_3 = \frac{e^{(-\lambda ci)}}{\Sigma e^{(-\lambda ci)}} = \frac{e^{(-3 \times 10\text{^-}3 \times 856.87)}}{0.145571} = 0.423$$

Since $C_i = P_i + kt_i$,

After expansion ： $C_1 = P_1 + K \times T_1 = 597.21 + 6.85 \times 25.5 = 771.89$

$C_2 = P_2 + K \times T_2 = 553.85 + 6.85 \times 25.99 = 731.89$

$C_3 = P_3 + K \times T_3 = 1052.35 + 6.85 \times 19.98 = 1189.21$

$C_4 = P_4 + K \times T_4 = 569.24 + 6.85 \times 32.3 = 790.50$

$$\Sigma e^{(-\lambda ci)} = e^{(-3 \times 10\text{^-}3 \times 771.89)} + e^{(-3 \times 10\text{^-}3 \times 731.89)} + e^{(-3 \times 10\text{^-}3 \times 1189.21)} + e^{(-3 \times 10\text{^-}3 \times 790.50)} = 0.33421$$

$$X_1 = \frac{e^{(-\lambda ci)}}{\Sigma e^{(-\lambda ci)}} = \frac{e^{(-3 \times 10\text{^-}3 \times 771.89)}}{0.156781} = 0.296$$

$$X_2 = \frac{e^{(-\lambda ci)}}{\Sigma e^{(-\lambda ci)}} = \frac{e^{(-3 \times 10\text{^-}3 \times 731.89)}}{0.15678} = 0.333$$

$$X_3 = \frac{e^{(-\lambda ci)}}{\Sigma e^{(-\lambda ci)}} = \frac{e^{(-3 \times 10\text{^-}3 \times 1189.21)}}{0.156781} = 0.084$$

$$X_4 = \frac{e^{(-\lambda ci)}}{\Sigma e^{(-\lambda ci)}} = \frac{e^{(-3 \times 10\text{^-}3 \times 790.50)}}{0.156781} = 0.287$$

Table .4.2.1 Result

	Via Panama canal		Multi-model transportation	Via Suez canal
Before expansion	0.421	\	0.156	0.423
After expansion	0.296	0.333	0.084	0.287

4.3 Result

The results show that the probability of choosing the Panama Canal in the different routes of container transportation to the US East Coast port is basically equal to the probability of choosing the Suez Canal and far higher than the multimodel transportation route. After the expansion of the Panama Canal, the probability of choosing the transport route via the Panama Canal is further improved, and the selection probability of other transportation routes is relatively reduced, which is consistent with the generalized cost of container transportation of different routes.

Among the calculation results, the probability of selecting the multimodel transportation route is significantly lower than the other two routes, which is also consistent with the actual situation. This route is mainly subject to road transportation in the United States, and the total freight rate will increase or decrease due to the changes in national highway and rail freight rates, and transferring will also cause time loss and cargo damage. However, relatively speaking, the road and rail transportation capacity of the United States is stronger than that of other countries, and it can achieve “door-to-door” transportation, so the route still occupies a certain proportion in US transportation. The infrastructure of the West Coast port of the United States is relatively better than that of the East Coast port, and the depth of water in the West Coast port is deep enough to meet the draught requirements of large vessels. In addition, useful rail links can be directly connected to the US city

centre and no longer have to be transported to the city centre via the East Coast. Therefore, for a long time, the second route shared more cargo transportation from the Far East to the US East Coast.

The results of calculation show that before the expansion of the Panama Canal, the probability of choosing the westbound route of which shipping through the Suez Canal was the highest, occupying a relatively large proportion, and the proportion of the route which shipping through the Panama Canal was reduced after the expansion. The westbound route from the Far East to the US East Coast is transported from the Far East to the Straits of Malacca, the Indian Ocean and the Suez Canal to the Atlantic Ocean to the East Coast of the United States. The route has a long sailing distance and a long voyage time, which is a considerable challenge for the liner shipping companies. In order to reduce costs, liner shipping companies will set up many ports of call on the route, and the freight volume of this route is mainly the number of containers between the ports. The goods from the Far East to the US East Coast that use this route are generally not urgent and can be stored for a long time. In view of the current low utilization rate of the Far East to the US East Coast route, if the Suez Canal is used, there are more ports along the route, including Malaysia, the Persian Gulf, etc. This means that the vessel can load more cargo along the way. Therefore, the westbound route via the Suez Canal is a strong competitor before and after the expansion of the Panama Canal.

However, the results show that before and after the expansion of the Panama Canal, the route via the Panama Canal was highly probable and increased after the expansion of the canal. The potential competitive advantages in terms of cost and time brought about by the expansion of the Panama Canal led to all waterway routes which shipping through the Panama Canal has become a relatively short-term,

cost-effective transportation method for container trade from China to the US East. After the expansion of the Panama Canal, the 12,000 TEU container vessel over the Panama Canal not only has a single-container cost advantage, but also has a low average cost per container per day, and the transportation time is relatively moderate. The expansion of the Panama Canal has an essential impact on the layout of the global container route. In particular, China and the United States are the main users of the canal. The expansion directly affects the choice of container transportation routes, vessel composition and port selection in China and the United States, and affects the route design and operation of liner companies.

5 Conclusions and prospects

Based on the time and cost analysis method, the transportation time and cost of different routes of Sino-US container trade routes before and after the expansion of the Panama Canal were compared horizontally and vertically. At the same time, the multidimensional Logit model was used to calculate the selection probability of different routes before and after the expansion of the Panama Canal. The results show that: After the expansion of the Panama Canal, the 12,000 TEU container vessel over the Panama Canal not only has a single-container cost advantage, but also the average cost per container per day is low, and the transportation time is relatively short. At the same time, after the expansion of the Panama Canal, the probability of selection of transport routes which shipping through the canal has increased, and the probability of selection of other transport routes has decreased relatively, indicating that the potential competitive advantages in terms of cost and time brought about by the expansion of the Panama Canal can promote the all waterway route which shipping through the Panama Canal to become a relatively short-term, cost-effective mode of transportation for China's container trade to the US East. Therefore, the US East port should give due consideration to the expansion of the port to meet the arrival of large vessels. The liner company should give due consideration to the re-layout of the container transportation route network. In addition, after the completion of the Nicaraguan canal in Central America, the container shipping cost will be further reduced as the larger container vessel is put into use and the canal competes with the Panama Canal. The Sino-US container trade transportation network will become more complicated. These deserve further exploration.

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