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Analysis of China Coastal Internal Trade Container Transport Market and Liner Route Design:A Case Study of "Pearl River Delta—Bohai Rim"

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Abstract

Compared with foreign trade transportation, internal trade transportation in maritime has the characteristics of small volume and short voyage, while China's coastal internal trade choose direct routes for a long time. In recent years, with the rapid growth of trade volume, internal trade transportation has gradually adopted the hub-and-spoke route form which combined the conditions of port water depth and hinterland goods to concentrate goods by ship distribution and then transported them to different destinations. Under the "Pearl River Delta—Bohai Rim" background, this article will study the container transportation market of internal trade and explore which type of the ship and which route should be used to maximize the benefits.

Keywords

Internal trade; Shipping route optimization; Evaluating indicator.

1. Introduction

China internal trade container shipping officially started in 1996. It has several basic characteristics, such as start late, slow development and stable situation. With the deepening of the financial crisis, the pace of economic and trade recovery is very slow, and the shipping market ushered in a "cold winter". In this situation, the trend of large-scale ships, market alliance and company merger is speeding up, and the growth rate of foreign trade container throughput is slowing down. At the same time, the internal trade market demand is strong, many cities vigorously develop their own port and shipping undertakings, which will directly make the internal trade exchanges between the north and the South more and more frequent. Therefore, for the internal trade container transportation market relying on the two major economic zones in the north and the south, a perfect route is the basis of all.

For a long time, the coastal internal trade routes are mainly direct connecting routes. Occasionally, because of the scattered supply and small volume of goods, the transit mode of the hub-and-spoke route structure is adopted. However, considering the scale economic effect of large ships, the combined transport network structure is more common in the ocean transportation, and less common in the domestic trade transportation. This is because most of the routes are short If a transfer port is added, it will undoubtedly increase the transfer cost and the length of voyage.

Considering the prosperity of the domestic trade market, the hub-and-spoke route mode is more and more commonly used in the coastal transportation, this paper will analyze the market of the internal trade container transportation of "Pearl River Delta—Bohai Rim" and select the appropriate port, so

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as to form a route scheme to meet the transportation demand of the cargo owner and the profit of the liner company.

Many scholars have studied this problem. (Zhang Haijian, 2007) explored the basic characteristics of the route and the fleet structure, then established a two-level optimization model for route allocation. (Zhang Yan, 2011) makes the operationg profit of the coastal container traffic maximum as the objective function and puts the demand、capacity、network structure and the time unites as the constraints in order to establish China coastal domestic container liner route optimization model. (Chen Kang and Yang Zhong zhen, 2011) considered the government subsidy, carbon emission control and shippers' choices of transport modes, the optimization model of short-distance liner ship route was developed based on tripartite game relations among carriers, shippers and government. In order to improve the route optimization issue of container liners in the offshore area, (Yang Hua long et al., 2014) established a route optimization model of a liner calling at hub ports on trunk line which considering the characteristics of trunk / feeder line in the offshore area with the ring mode. Revenue maximization of liner companies is taken as the objective of the established model under the precondition of meeting the container transport demand in a certain area.

Besides, the shipping voyage simulation which includes the speed adjustment for arrival on-time is introduced by (Du Jian et al., 2017). In the numerical example, the shipping voyage simulation diagram of uncertain arrival time is showed. Meanwhile, the ship capacities, ship rents and cargo rejection compensations under different cargo rejection rate are calculated. (Naima Belayachi et al., 2017) propose an application to represent the MTN, and provide a balanced distribution of containers. The work is based on a heuristic method by neighbourhood. It allows the process of the clients' demands and transfers of full containers as well as the research of empty containers by optimizing the cost of theirs return. In order to satisfy customer demands and maximize the total profit for the whole shipping network, (Zhang Yan et al., 2019) takes the ship speeds as variables, and proposes a container liner shipping network design problem with transit time limits. (Sel Ozcan et al., 2019) proposed a mixed integer programming model for the operational level cargo allocation and vessel scheduling problem. This model aims to assign shipments to routes to decrease total tardiness and construct partial vessel schedules for establishing coordination with port authorities to comply with the berthing time windows.

The paper is organized as follows: Section 2, is dedicated to the analysis of China internal trade container transport market. In Section 3, is dedicated to the internal trade container liner route design and calculation of relevant indicators to obtain the optimal route outline. Section 4, is dedicated to the sensitivity analysis and a conclusion with some perspectives in Section 5.

2. Analysis of China Internal Trade Container Transport Market

2.1 Overview of the Main Ports on the "Pearl River Delta-Bohai Rim" Route

The "Pearl River Delta-Bohai Rim" route is full of ports with different sizes and functions, which are linked together to form China's coastline. Some ports information is listed (see Table 1).

Table 1 Container throughput of eight ports

Port's Name		Shen Zhen	Guang Zhou	Tian Jin	Ying Kou	Quan Zhou	Xia Men	Wen Zhou	Fu Zhou
Container Throughput($\times 10^4$TEU)	2012	2172.8	1474.4	1230	495.3	169.7	720.2	51.8	182.5
	2013	2327	1550	1300	530	170.1	800.8	57	197.8
	2014	2403	1661	1400	567.3	188.5	857.2	60.4	221.8
	2015	2421	1567	1411.3	610	201.5	918.3	56	237.3
	2016	2397.9	1682	1450	615	209.1	961.4	56.2	260.8

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As this article selects examples as research targets, a large amount of relevant information has been collected in the preliminary preparations for subsequent use. From the above table, it can be seen that the container throughput is increasing year by year, and some ports with smaller throughput may only be used as routes. Port of call instead of port of departure and port of destination. In addition to statistical analysis of the throughput of each port, the port loading and unloading rates were also obtained: 370 RMB / TEU for empty containers, 555 RMB / TEU for heavy containers, and the port loading and unloading efficiency was 50 TEU / h per crane.

In terms of routes, based on comprehensive consideration of the port's throughput and geographical location, four routes were finally set up (see Table 2).

Table 2 Total range of each route(unit:nm)

Route 1	Ying Kou-Fu Zhou-Guang Zhou-Quan Zhou-Ying Kou				Total distance
Distance among each port	1002.8	425.8	343.5	1085.1	2857.2
Route 2	Tian Jin-Quan Zhou-Guang Zhou-Fu Zhou-Tian jin				
Distance among each port	1090.0	343.5	425.8	1007.7	2867.0
Route 3	Ying Kou-Quan Zhou-Shen Zhen-Fu Zhou-Ying kou				
Distance among each port	1085.1	490.1	572.4	1002.8	3150.4
Route 4	Tian Jin-Wen Zhou-Guang Zhou-Xia Men-Tian Jin				
Distance among each port	869.4	564.1	347.9	1085.6	2867.0

2.2 Internal Container Ship Status

With the rapid development of the logistics industry and the support of relevant national policies, domestic trade container shipping has developed rapidly, especially under the adverse effects of the financial crisis. The development of domestic trade shipping has made up for the losses caused by the downturn in ocean shipping. The “South-North” line of China's internal trade routes is very important, responsible for more than 50% of China's domestic trade container shipping volume.

The “North-South” line is the main transportation capacity of various large shipping companies, and it is mainly large ships, and most of them are own ships. On the short and medium routes, many small and medium-sized enterprises, including large enterprises, use bareboats, time charters or voyage charters. The method of leasing ships to increase its own shipping capacity, but the short shipping lines only supplement the domestic trade container market, so large vessels are still the main force of the market. With the popularity of internal containerization in China, more and more sources of goods are being loaded into containers. Edible oil, coal, and grain are now available in containers.

When selecting a ship, the shipping company is very interested in the speed, power, fuel consumption and other information of the ship. Due to the short voyage of the coastal domestic trade routes, the proportion of port expenses in the voyage cost is relatively large, but the fuel cost is still one of the main parts of the voyage cost, so reducing the fuel consumption cost by reducing the speed is still the main competition mode of most enterprises.

In this paper, the following four ships are selected on this route according to the carrying capacity, and the relevant information is shown in the table below (see Table 3). Because of the difference of the container capacity, speed and fuel consumption, it can be used in different schemes.

Table 3 Relevant ship information

Vessel Name	TEU	Ship Cost (USD 10000)	Speed (knots)	Fuel consumption(t/d)		Diesel consumption(t/d)	
				12kn	14kn	12kn	14kn
XIN CHANG SHA	4250	4600	13.08	69	88	2	2

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TIAN FU HE	5100	6460	12.7	100	108	2	2
HAI SI 1	2400	1970	14.0	38	41	2	2
DA XIN HUA LIAN YUN GANG	1700	2470	14.4	32	36	2	2

2.3 Operation of "Pearl River Delta-Bohai Rim"

In the northern Bohai Rim region, there are China's famous heavy industry bases and grain production areas, so most of the goods in this area are grain and steel. The Pearl River Delta has a well-developed processing industry. Most of the goods in this area are processed semi-finished products, textiles and clothing, and light industrial products.

The "Pearl River Delta-Bohai Rim" route, as one of the three major domestic shipping container routes, provides a stable increase in freight for water transportation and has a positive role in the development of shipping routes. However, there are some problems with the transportation on this route, such as: strong seasonality of cargo sources and large fluctuations in volume; single source structure, high dependence on basic sources , etc.

3. Evaluation of Container Liner Routes

Based on the analysis of port conditions, the following four routes were formulated:

① YingKou-FuZhou-GuangZhou-QuanZhou-YingKou;

② TianJin-QuanZhou-GuangZhou-FuZhou-TianJin;

③ YingKou-QuanZhou-ShenZhen-FuZhou-YingKou;

④ TianJin-WenZhou -GuangZhou-XiaMen-TianJin.

This paper selects four investment performance indicators as the evaluation indicators, which are: net present value, necessary freight rate, internal rate of return, and investment repayment period. However, before these four investment performance indicators are obtained, the ship's operational work indicators and financial results indicators must first be calculated.

3.1 Operational Indicators

Round trip voyage time = full distance / (sailing speed)

Port loading and unloading time for round-trip voyages = import and export freight volume / (loading efficiency)

Round-trip voyage loading and unloading time (days) = (Sum of loading time at each port in one way + Sum of loading time at each port in one way) / 24

Operation time of round-trip voyages (days) = sailing time + berthing time

Annual operation period = 350 days

The average number of round trips per ship = annual operating period / round trip operating time

the number of ships required = round-trip voyage operation time / schedule

Annual cargo volume = average container capacity of the ship × number of ships required × average round tripof each ship × 2

(PS. loading rate 80%, shift 3 days)

3.2 Financial Performance Indicator

The financial results index needs to calculate the total transportation cost, that is, the expenses incurred by the shipping company to provide cargo transportation services. According to the regulations of the Ministry of Finance of China, the total transportation cost is composed of four parts: fixed cost, navigation cost, management cost and financial cost. The residual value of the ship is

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calculated at 10% of the cost and the depreciation period is 25 years. The straight-line depreciation method is used to calculate the annual residual value of the four types of ships, that is, the value of the equipment is evenly distributed within the expected service life of the ships.

Crew expenses generally need to consider two standards, one is the crew standardization, that is, the standard equipment of the type of crew members to be demonstrated, plus 30% of the berths on the fixed standard; the other is the crew standard. The repair cost is the cost for regular maintenance of the ship to maintain the technical status of the ship's operation and restore the partially lost working capacity. In the demonstration of ship type schemes, in order to make the ship types schemes comparable, estimates are generally made at a certain rate of the ship price. New ships are drawn at 2.5% of the price. The calculation formula is: annual maintenance cost = number of ships required for 2.5% of the cost of the ship.

According to the original value and use of the ship, the shipping company proposes a price guarantee. The value of the insured value varies with the age and technical status of the ship, but in the demonstration stage, it is assumed to be equal to the cost. The annual insurance premium rate also changes with various factors such as old and new, size, voyage length, cargo type, navigation area conditions, etc., but it mainly increases with the age of the ship. The relationship between the insurance rates of Chinese domestic trade coastal ships and their ages is shown in the Table 4.

Table 4 The relationship between insurance rates and boat age

Boat Age(Year)	<4	5-9	10-14	15-20	20-24	>25
Insurance Rates(%)	0.6	0.68	0.8	0.99	1.2	1.3

According to the above table, assuming the life of the ship is 25 years, the average annual insurance rate of the ship= $\frac{(0.6\times4+0.68\times5+0.8\times5+0.99\times6+1.2\times5)\times vessel's\ price}{100\times25}$

3.3 Sailing Cost and Financial Expenses

What needs to be calculated is the fuel cost and diesel cost per voyage of a single ship, and then the total annual fuel cost. Taking the average value of the port fuel prices involved, the price of IFO380 is 257 USD / t, and the price of MGO is 505 USD / t. The toll rate for ships in China is 1.06 USD / t, of which the regular tonnage tax is 0.06 USD / t, the special tonnage tax is 0.05 USD / t, and the lighthouse fee is 0.06 USD / t. Due to the complexity of the domestic port data, the average port charge per port is 0.7 USD / t.

Before calculating the capital cost, you need to determine the investment plan of the ship and calculate the ship investment P . Now choose a financing condition: 70% of the price of the ship is paid within 7 years after the delivery of the ship at an annual loan rate of 8%. The principal and interest are paid once a half year, and the company's benchmark return is 8%. The investment in ships is P = p×30% + p×70%×(A/P,4%,14)×(P/A,4%,14). Among them, p is the cost of the ship, (A/P,4%,14) is the capital recovery factor, which is calculated to be 0.09467, and (P/A,4%,14) is an equivalent present value factor, which is calculated to be 10.56312. Capital expenses for 1-7 years during the loan repayment period is A_1=0.3×P(A/P,8%,15) + (1-0.3)×P(A/P_1,8%,7) - R×(A/F,8%,15) = 0.1695P - 0.0368R. It can be calculated that the capital costs of 5100TEU, 4250TEU, 2400TEU, and 1700TEU in the 7th and 15th years are 1071.262, 762.818, 326.685, 409.600, and 202.586, 144.256, 61.779, and 774.579 million, respectively.

3.4 Ship Revenue

$$F_y = Q \cdot f \quad (1)$$

$$A = F_y - T_C + C \quad (2)$$

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Among them, F_y represents the annual income, f represents the freight rate, A represents the annual revenue, T_C represents the annual total cost, and C represents the annual capital cost. The Table 5 is calculated by taking the ship speed of 12 kn and f = 1420USD/TEU as an example. In addition, shipping companies will incur some management costs, which is assumed to account for 15% of the total operating expenses.

Table 5 Annual revenue at 12 knots (Unit: 10,000 USD, i=vessel type, j=route)

Aij	i=1	2	3	4
j=1	137655.936	125402.5	69163.32	46464.67
2	137447.3664	111314.4	69010.64	46371.97
3	147273.312	120362	65689.88	51234.74
4	137447.3664	125228.7	69010.64	46371.97

3.5 Net Present Value

$$NPV = \sum_{i=1}^{n} A_j(P/F, i, j) + R(P/F, i, n) - P \quad (3)$$

Among them, n indicates the economic use period (year), j represents the serial number of the economic use period of the ship (j=1,2,...,n), A_j represents the j-year income value (yuan), and i represents the benchmark return rate of the shipping company (8%), P represents the ship investment (yuan). In the calculation of NPV, the income of each year needs to be converted into the present value and accumulated. Take A11 as an example to calculate the annual return value. The NPV is shown in the Table 6 below. Similarly, the net present value of the 32 schemes can be obtained.

Table 6 NPV (Unit: 10,000 USD)

Nears	Income	NPV Coefficient	Aj
1	124525.0207	0.9091	115185.6441
2	124525.0207	0.8264	106717.9427
3	124525.0207	0.7513	98748.34142
4	124525.0207	0.683	91525.89021
…	…	…	…
15	123682.4011	0.2394	38959.95635
$\sum A$			1062239.726
R(P/F,10%,15)			1831.41
NPV	$\sum A + R(\text{P/F},10\%,15) - p$		1005931.136

3.6 Required Freight Rate , Internal Rate of Return and Pay Back Period

Find the RFR based on the value of Average Annual Cost, AAC = K + P(A/P,i,n) - R(A/F,i,n). IRR is the discount rate when the total present value of capital inflows is equal to the total present value of capital flows and the net present value is equal to zero. On the basis of calculating the net present value, if the net present value is positive, the higher discount rate in this net present value calculation shall be used for calculation until the calculated positive value of the net present value is close to zero. Continue to increase the discount rate until a negative net present value is measured. If the negative value is too large, reduce the discount rate and measure to a negative value close to zero. According

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to the discount rates of the adjacent positive and negative two net present values close to zero, the internal rate of return is obtained by linear interpolation.

$$\mathrm{PBP} = \frac{\lg(\frac{A}{A - p_i})}{\lg(1+i)} \tag{4}$$

In the formula, a represents the benchmark return rate of 10%, and p represents the product of the investment amount of the ship and the number of ships. The larger NPV and IRR, the better; the smaller PBP and RFR, the better. So the Comprehensive Index = NPV + IRR - PBP - RFR. According to the Table 7, the comprehensive index of A24 is the largest, which is 0.439577. As a result, the scheme of ship type 2 traveling route 14 at a speed of 14 kn will be best.

Table 7 Comprehensive index

Route	Vessel Type	NPV	RFR	IRR	PBP	Comprehensive Index
1	5100	0.691373	0.69832	0.36305	0.480802	-0.1247
2	5100	0.690761	0.703196	0.362735	0.481211	-0.13091
3	5100	0.751709	0.580564	0.355308	0.441251	0.085202
4	5100	0.707605	0.497385	0.371413	0.417287	0.164346
1	4250	0.668304	0.500337	0.49038	0.325602	0.332744
2	4250	0.593498	0.45886	0.490057	0.314062	0.310633
3	4250	0.643269	0.447413	0.472268	0.289154	0.37897
4	4250	0.671061	0.446286	0.492375	0.277574	0.439577
…	…	…	…	…	…	…
1	1700	0.204933	0.699802	0.421556	0.42258	-0.49589
2	1700	0.203324	0.638147	0.418304	0.364277	-0.3808
3	1700	0.212806	0.580334	0.437468	0.348648	-0.27871
4	1700	0.213016	0.578627	0.437893	0.348316	-0.27603

4. Sensitivity Analysis

When studying the impact of changes in fuel prices and imported sources on NPV, it was found that the slope of the fuel cost curve is close to negative infinity, indicating that the sensitivity of the NPV of the optimal ship type scheme to changes in fuel prices is basically zero, which is The relative level of NPV is basically unaffected by changes in fuel prices. With the rise of cargo flow, the net present value (NPV) also rises, showing a positive correlation, see Table 8.

Table 8 Sensitivity analysis

Changes in sensitive factors(%)	-30%	-20%	-10%	0	10%	20%	30%
Import sources	692960.5	773899.7	854920.5	935941.21	1016959.5	1097980.3	1181569.8
Freight	677021.6	763328.2	849797	935941.21	1022245.3	1108551.9	1192141.3
Fuel	1110733.9	1052469.7	994205.5	935941.2	877677	819412.7	761148.5
Light diesel oil	941063.3	939356	939356	935941.2	937648.6	937648.6	937648.6

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5. Conclusion

Based on the current status of trade between China's major coastal ports, this work aims at maximizing operating profit, and based on solving practical problems, the optimal solution is obtained.

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