9-24-2016

Carrying capacity allocation and shipping routes design for merged container lines

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WORLD MARITIME UNIVERSITY

MSc. in International Transport and Logistics
Class of ITL2016
Unit 6

Subject: **ITL06PRJ-INTEGRATIVE PAPER**

TOPIC: **Carrying Capacity Allocation and Shipping Routes Design For Merged Container Lines**

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Date of Submission: 19th August, 2016

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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 materials are included for which a degree has previously been conferred on me.

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

Zhang Yao

Abstract

In order to meet the requirements of regular service of liner transportation, improve the level of optimizing configuration of liner transportation system, according to the characteristics of calling at multiple ports and the non-stop shipping route of goods of liner transportation, taking into full consideration the cargo demand, maximum load of a single vessel, minimum number of shipping, freight rate levels and other factors to study the goal of maximized operating profit of the vessels during the operating period, establish a mathematical model of optimization of assignment of liners and a mathematical model of carrying capacity allocation and shipping routes design for merged container lines, and introduce the modeling principle systematically. The rationality of the model is verified by solving numerical examples. The calculation results show that: The proposed optimization method can effectively simulate the characteristics of operational organization of liner shipping, which is conducive to making and studying the optimal program decisions of assignment of liners and number of shipping during the operating period. The structure of mixed liner integer programming model is simple, easy to understand, convenient to solve and practical.

Keyword: liner shipping; assignment of liners; lingo; merged container lines; mixed liner integer programming model

Chapter1 Introduction

1.1 Background, motivation and objective

In recent years, the shipping economy has been in a state of depression, meanwhile, the ships keep larger and larger scales, that making a lot of shipping companies capacity increased but the transportation volume decreased. Until 23rd February, 2016, the BDI index fell to 318 points, freight of one container shipped from Shanghai to South America as low as $50. So in 18th February, 2016, COSCO Group and China Shipping Group, these two major state-owned shipping companies decided to merge and restructure, and want to become the world's largest shipping companies. After the reorganization of the container shipping and terminal service supply chain platform will by COSCO management. The company will become the world's fourth largest container shipping company and the second terminal operators. Meanwhile, the fleet management includes 288 container ships. The ships are more than 8000TEU capacity of 84 vessels and total capacity of nearly 160 million standard boxes. This round of restructure will be integrated these enterprise advantaged resources, and provided higher quality service for customers to lay a foundation. In the international respect, after the reorganization, China COSCO Group will homogeneity, increased international competitiveness, and participate the international competition actively. However, such a large enterprise after the merger, the business will be more difficult to integrate, so the research on container routes and capacity allocation will be extremely important. In this paper, I will analyze the shipping routes integration and optimization, by the liner shipping route in the market and its capacity may idle or full as the background.

1.2 Collaborative trend in liner shipping

In the process of transportation organization, the liner company is bound to solve such a problem: How to configure the different types of liner ships to the various routes operated by company to achieve the best economic benefit, which is the problem of assignment of liners. Two basic requirements should be met for the decision of assignment of liner:

1) Be technically feasible, which requires technical parameters of ship to be able to meet the operation condition. This can be judged and solved according to objective factors and practical experience.

2) Be economically reasonable and the most favorable. This is an optimization problem and also the main research content of assignment of liner.

So no matter which collaborative forms, the basic requirements should be In this paper I will mainly introduce the former one. And firstly, I will analyze the relations between these two forms meanwhile introduce the fundamental liner shipping knowledge for analyzing more thoroughly.

1.3 Overview of the research

The main goal of this dissertation is to use linear programming model to analyze the possible solutions which deal with feet redesign avoiding the lines overlap meanwhile capacity re-allocation. In this dissertation, I will take merger container liner shipping company as example to study its strategy. To achieve this purpose, this dissertation will first analyze the history records of these two companies operating conditions before / after merger and liner shipping industry to forecast the future enterprise development trend to make profits and applying models to calculate the profit and loss of different liners optimization and how to deal with shipping capacity rise and fall, and fleet overlap problems. Finally, take merged company to calculate which shipping line is best for it by using the above result. Finally, give the recommendation for merger companies A and B.

Chapter2 Literature Review

2.1 Shipping industry condition and China shipping company re-position (M&A, Alliance)

Today, the global shipping industry downturn, there are large ships, excess capacity , rising operating costs and other phenomena . At the same time , the international shipping industry itself is facing in the world economic integration, the regional grouping of the world economy , the world economy trend in knowledge make customers put forward higher requirements for shipping enterprises China shipping company in this case is also facing more problems on their own development Because domestic liner industry while actively participating in international competition , to expand their international competitiveness , economies of scale , but the late start , good advantage has been captured, such as MAERSK enterprise . At the same time, the enterprise's own industrial structure is unreasonable and the relative capacity is not enough, the division of labor between enterprises is not clear, causing the domestic liner industry concentration is not high and its situation of disorderly competition expand continuously. This situation makes the foreign large liner companies to carve up the domestic market profits that causing the domestic shipping companies in the business crisis. So make a positive development from the enterprise internal structure adjustment, it is not simple to solve funds, loans, sales , revenue and other practical problems , or for the liner shipping enterprise strategic alliance can bring huge advantages , while the shipping enterprises merger can bring greater advantages than all of that .

As the market competition has entered a very intense moment, the liner companies need to expand the scale of operations, reduce operating costs in order to have a competitive advantage in the market. Shipping alliances and M&A are very effective methods. Tough liner companies through the alliance efforts to reduce operating costs, improve profitability. But due to the freight declines continuously, reasonable income makes the liner companies through the alliance to be offset, that resulting the company's overall profitability is low . However, M&A can solve this problem correctly. Therefore, shipping M&A may replace the shipping alliance become the future trend of development. As many factors we mentioned above , so in 18th February , 2016 , COSCO Group and China Shipping Group, these two major state-owned shipping companies decided to merge and restructure , and become the world's largest shipping companies . After the reorganization of the container shipping and terminal service supply chain platform will by COSCO management. The company will become the world's fourth largest container shipping company and the second terminal operators. Meanwhile, the fleet management includes 288 container ships. Considering now containerized transportation form, meanwhile, we also should be closely combined with the changes of container future development, and then making the right strategic adjustment and structure strategy. The fourth change of container liner transportation in the future is mainly the reconstruction of its service mode, and finally forms the container transportation network . At the same time, the speed of container regional specialization development is very fast, The old ship capacity inputs to some new development secondary East-West transportation routes massively, these new shipping routes extend its range to call the areas and ports which only feeder vessels use before. Such as China's Northern bay port clusters, the Pacific coast of Mexico port clusters, and Asia - the east coast of South America serves non-stop route services. But also due to mergers led to a large number of overlapping routes , then merger makes new direct shipping lines opened by amount of capacity continuous accumulation where only calls feeder vessels in the smaller regional port.

2.2 The future development Trend of Global Container Liner shipping

COSCO will rent the container ships and containers of CSCL, so that the CSCL will turn into a leasing company from the liner company. During this process, COSCO will also purchase the leasing transaction of CSCL and increase the business of shipping financial lease and other assets. In the meantime, all the port operation business of CSCL will be sold to the COSCO Pacific Ltd.

The two companies have been deeply suffered from the defects like the same business, high cost, repeated industry chain and are difficult to improve the competitive power. The global economy is undergoing a deep adjustment and the recovery is slow, while the international shipping market is overall downturn, with the increasingly fierce competition. Facing the huge operating pressure, global shipping companies innovate to change in the aspects of alliances, merger and acquisition, asset restructuring, combination between industry and finance and the application of new technology. International liner shipping and related industries present development tendency of professionalization and federalization, and further improved industry concentration.

According to the forecast of the World Bank and the development research center of the State Council, the Chinese annual growth rate is 7% from 2015 to 2020 with the end of the high speed growth of economy and the entry of the new normal. Impacted by the large environmental, the shipping industry demonstrates a pattern of deep adjustment and transformation development, with the improving importance of regional markets and emerging markets. So that is the huge benefit and need to merger for these own-stated companies.

2.3 Review of relevant transportation databases

First, I will literature related to influence factors for the capacity allocation and route design and thereafter literature related to algorithm of simulated annealing and scatter search these two algorithm. There are many factors influencing the shipping capacity, the content of which involves many and complex. We can simply divide it into several parts: cost, freight, ship, anchored in the port of choice, origin and destination ports, sailing distance and time, uncertainties (such as port congestion time, weather, ship and port technology issues), etc. , which are required by mathematical modeling that we defined independent and dependent variables. Bronomo, (2010) realizes that choosing the fitful vessel this problem as a subset of the set. Because this problem is equivalent to map the dependent variable y pair n-x, and in particular between x and x that also owning a unique mapping, that means these factors also influence each other. One argument for the fuel price is (Steffen Wagner, 201.Ronen, 2011.Qi and Song, 2012), it can be said to control the whole process of shipping operation. Ronen (2011) also mentioned another factor; speed. Like a taxi, the fare is given in the given kilometers. However, once more than this figure, the fare will be increased in multiples. Similarly, sail faster, the faster fuel consumption, the higher its cost. Although the fuel cost increases continuously, but the ship speeds up and shorten the sailing time, reduces ship operating costs. Steffen Wagner (2015) referred to lower fuel prices can affect the shipping business getting the double operating profits for operators, despite this conduction will dilute earnings time, but more advantages than its harm. Qi and Son (2012) refer that port of call for the ship's time has a strict threshold: the container cannot get to the port earlier than its given time, and the time should be maintained in small time period, not exceed more time. Premature arrival, navigation time is short, speed fast, fuel consumption fast. Instead, arrive too late. The port of call's time has randomness and uncertainty that could cause more trouble.

There are many different views for the correctness of the application port time window in the analysis study. In order to Wang and Meng(2012a) on robust algorithm. Wang and Meng (2011) designs of multi-route, multi-ship size adaptation. Brouer et al. (2013b) doesn't apply port time window for designing the schedule model to recover the vessel running time when vessel appears disturb problems. In Wang et al. (2014) dynamic route programming method applied for port time window, but the conclusions are not fit for the actual situation. In general, ship sailing through the same port twice and more is very common. But Wang et al. (2014) gets the opposite conclusion. From the above analysis it can be extracted: relationship between port operators and airline operators is hard to coordinate, Meng (2014) can through optimizing the design the ship sailing schedule to scientific planning management and real-time computing to ship operations. Each port of call and the carriers have detailed records accessed to the port in-and-out times and berthing time, Norstad et al (2011). Rake et al, 2011. Pam Davy, 2011), this is similar to sailing schedules. Wherein, Pam Davy (2011) uses a nonlinear optimization model to calculate it, and that's more realistic and reliable results. For empty containers, idle capacity problems, the solutions are very huge. Yin and Kim (2012) focus to analyze changes in tariff and freight optimization. Bu et al. (2012) designs empty freight relocation according to the contract. Bell et al. (2011) through the port rotation service method to resolve the problem of empty container allocation. And Arnone et al. (2014) is reducing the difficulty of transport modes via multi-transportation way. The method of analysis the impact of these design and capacity allocation has many types, such as Feng Meng (2012) resolve the relationship between carrier and forwarder. Zurheide and Fischer (2011) is performed simulation of liner slot booking to achieve transfer possibilities.

In the former literature, that doesn't get comprehensive analysis or solve the problems of NP-hard in designing the route allocation way, only in studying special issue, the data may not be suitable for other specializing conditions. For example, focus on the impact of fuel price on shipping only or impact of empty container of containers only. It's like a hill climbing algorithm, getting the optimal solution for local aspect not overall. In the previous literature, Most of them don't consider the shipping entire optimization. But in this piece of paper, considering to the shipping cyclical nature, multi-shipping or connect-shipping, carried out overall optimizing the capacity of the multi routes multi ship sizes and ship rent in the two circumstances - freight rise and fall, fall condition is a main study direction according to the present industry. By application simulated annealing optimal algorithm to verify the practicality of the model. The reasons for the application of algorithm are: the practicality of the simulated annealing algorithm in this area has been confirmed, very simple and accurate. I will consider the decision variables about which influenced the merged companies. Thereafter, consider the probable coming problems after merger.

2.4 The Relevance between merged liner and shipping alliance

2.4.1 The specific content of the capacity cooperation of lines between the container liner companies

The basic content of the capacity cooperation of lines includes Space/Slot Co-Charter/Exchange, Space/Slot Charter, Joint Dispatch of Ships and so on. Space charter, which the most fundamental and basic form in the three basic forms, is a space sale of two parties, namely, one party buy and the other sale; and the other two forms are also come from the space charter.

2.4.1.1 Slot Charter

Slot charter means one who wants to rent the space, not rent the vessel directly as individual, but rent space with partial fixed number from other operators who have space in this route to operate related routes.

Through renting space as well, the shipping company recombine the shipping company not being used to a new shipping network. In this paper I turn the transformation process of port of destination, transshipment and departure into a virtual node, and the loading and unloading in transshipment process are respectively expressed as two directional lines linking the virtual nodes and ports. Such a reticular directed lines form the transportation network. Thus the container cargo can be sent to any node of port in the network through different routes. Figure 1 shows the operating routes of a container liner company：

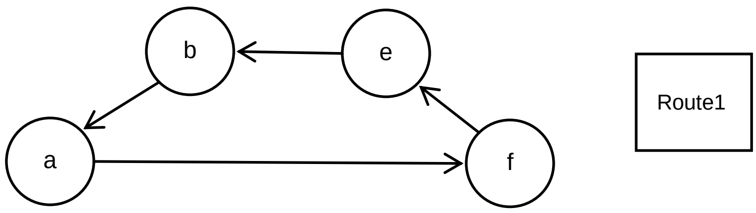


Figure1 - Container Liner Company Operating Routes

And another liner shipping company operating route：

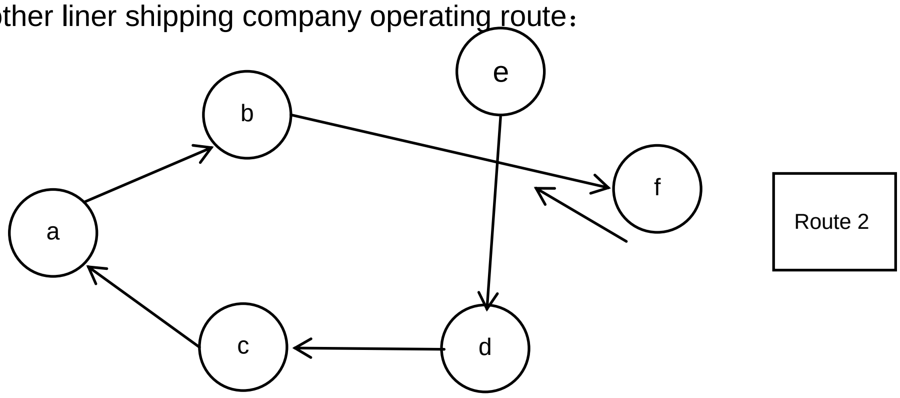


Figure2 - Another Liner Shipping Company Operating Route

Two routes of common ports are separately a, b, e and f. The two companies are sharing space cooperation agreement, the two companies will jointly operate two routes, also we can go two separate heading into a transportation network simulation, so the formation of the new joint container transportation network as shown in Figure 3:

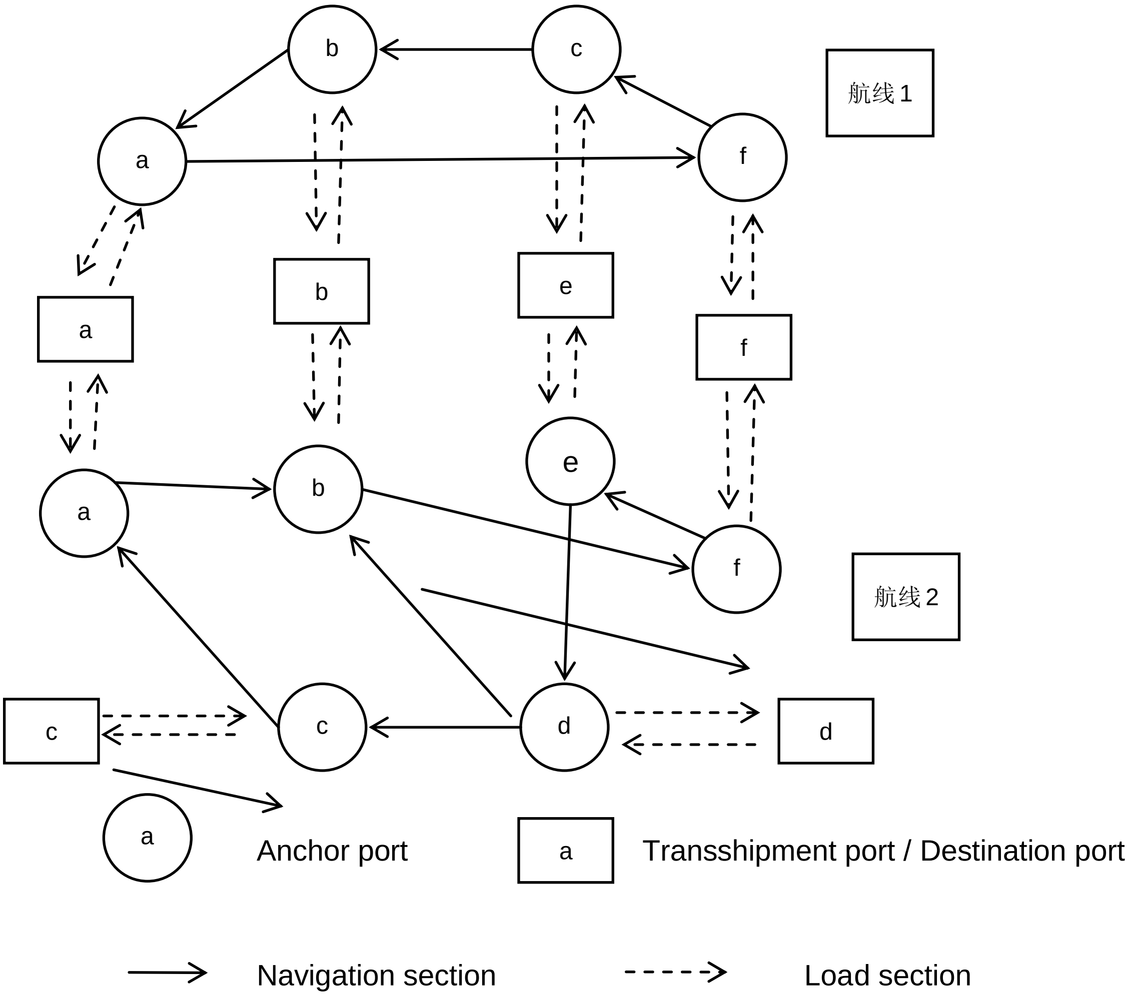


Figure 3 New Joint Container Transportation Network

As shown in figure, the call ports of route 1 are a-f-e-b-a, and the call ports of route 2 are a-b-f-e-d-c-a. From this we can know that the containers sent from c to f have two routes to choose. One is that only use vessels of shipping company in route 2 to transport with the route of c-a-b-f; another is that transport the containers to port a through route 2 first, then tranship them from port a to port f by vessels in route 1, with the route of c-a-f, which saves a part of the cost to get the bigger benefit. Through the integrated structure shown in the figure, we can simply the transportation route of containers to directional network graph. In this network of operations, the definition of each node is described as follows: (1) Nodes of port: the call ports in different routes in the shipping network, represented by circle. (2) Navigation lines: navigation line in different main lines represented by black thick directed lines in the figure, at the same time, due to the knowable shipping practice and directions, both ends linking different nodes. (3) Nodes of transshipment: virtual node corresponding to the node of port, represented by square node in the figure, as they can also be the actual start and end points of different containers, linking with other ports via loading and unloading routes in the network. (4) Loading and unloading routes: routes linking nodes of port and transshipment represented by dotted lines. These routes are also directed, and show different status of different containers in the port by directed routes.

2.4.1.2 Space / Slot co-charter / Exchange

Space/Slot Co-Charter/Exchange means the bidirectional space trading relationship between the two parties, namely, both of the two parties buy the others space, that is, one party sale his space to the other party, meanwhile, he buy the space of the other party's. Exchange, which is easy to understand, is in a certain period of settlement (usually the whole agreed period as it's easy to settle), both parties use the space of the others with the same value as it needs not to deal with other fund settlement; when the value of the space is different in the statistics (the value of unit space or the number of voyages in each route), it is necessary to carry out appropriate settlement to calculate the price margin of space rental. However, this is often ignored leading to misunderstanding in actual practice. Besides, if the time of the agreement is long, there will be a large calculation and statistics to get the corresponding margin at the end of the agreement, thereby wasting a lot of time. Therefore, a relatively clear and scientific idea is the Space/Slot Co-Charter/Exchange, which is used in each settlement period (usually a month) to settle the rental margin between the two parties and make a record.

On the basis of maintaining the original routes, different operators carry out another space rental with each other. In this way, operators can, on the basis of maintaining the original routes, increase the using time of routes, expand the sphere of influence of shipping, improve the quality of shipping and develop the industry competitiveness with the same investment. Thus we can easily see, in the shipping service nowadays, there is almost no operators can completely rely on the personal service to meet the requirement of shippers in the aspects of schedule and coverage. As a result, it is indispensable to cooperate with other operators. The investment of space in Co-Charter has little effect on the whole investment, which is one of the important and effect way to improve the competitiveness and efficient performance.

2.4.1.3 Joint dispatch of ships

Joint Dispatch of Ships means the two parties agreed to jointly investor maintain, set and operate a route. Both parties input the transport capacity that: agreed how much one party can be invested into the route decides his rental number of space. Two or more operators allot the number of viable space through each party's specific number of routes, call ports, inputting vessels. The agreement concluded in one or more lines can enable everyone participating in cooperation to open more new market with less input, deeply reduce the barriers to entry and exit and the risk of investment.

In this example, A invests 8000 TEU space (2*4000 TEU), accounted for one-half of the four vessels with a total space 16000 TEU space. Therefore, A assumes that it will use 2000 TEU space in each vessel. As for the two 4000 TEU vessel A invested, using 2000 TEU space of each vessel and rent the remaining 2000 TEU while B and C rent 1000 TEU respectively. Then B and C invest a vessel with 4000 TEU space respectively and use 2000 TEU space of their own vessel, namely:

Table 1 Example for the Own Ship and Rent Ship

Ship Investment party	ship	TEU				
					Own used	Total space of single ship
		A	B	C		
A	A-1		1000	1000	2000	4000
A	A-2		1000	1000	2000	4000
B	B-1	2000		1000	1000	4000
C	C-1	2000	1000		1000	4000

This calculation on this four ships is using a total of 8000TEU (2000TEU*4=8000TEU) space, equivalent to it in four ships using the two ships in total 8000TEU space, therefore, A doesn't need in the B and C in the use of space to pay their corresponding money; By the same reason, assuming both B and C respectively in four ships, each ship use 1000TEU space, also do not need to pay the corresponding money and they can complete the corresponding cycle sailing routes of shipping. Otherwise, they should make the difference between the compensation and the actual settlement of the difference, which between each other in accordance with the contract.

The above content shows that Slot charter is the basic of the two cooperation forms of Space/Slot Co-Charter/Exchange and Joint Dispatch of Ships. Space/Slot Co-Charter/Exchange and the Joint Dispatch of Ships are come from Slot charter. In the three basic forms, the main goal of Space/Slot Co-Charter/Exchange and the Joint Dispatch of Ships is that liner companies expand their own shipping schedule, improve the turnover of the vessel, and the shipping companies are still in accordance with the scheduled route capacity plan to carry out the operation of the ship. The two route capacity cooperation forms are basically making exchange of equal value and number of space in different routes or one route in cooperation, which is easier to make decision and settlement. And the rental space may relate more to the type of vessels, the number of vessels and routes, especially that the problems of how to rent space and how to allot the rent space need studying deeply.

2.4.2 Fundamental content about affect of merger

Affect of merger:

（1）Be able to operate large vessels with lower operating costs per TEU per mile.

（2）Merger of management networks can enable the carrier to run more direct call routes by large vessels, and reduce the transfer cost and feeder ship transportation cost.

（3）Merged new company can achieve the integration of organizational institutions and reduce stuff needed. One way to reduce the cost of human resources is to merge the regional headquarters, and move the regional headquarters to areas with lower cost. Management costs of regional headquarters can also be reduced by office automation.

（4）Efficiency is reflected not only in the scale economy, but also in the complementary advantages. The merged company is strongly competitive in all important routes. Besides, the more balanced resources disposition of the new company can make it easier to cope with the fierce change and the fluctuant market.

（5）The direct correlation between shipping industry and the development of international economy and trade is very notable and the former is driven and restricted by the latter. In recent years, the world economy is overall in the deep adjustment.

2.4.3 Overview of research

Overall, I can know that the merger and alliance has a lot of same points. Both of them are aimed to goal the optimization of carrying capacity and ship routes design for the container companies in this downturn circumstance. The both hard question for them is how to distribute the boxes reasonably. But I think the alliance form can be more difficult than that of merger’s because that’s involved more complicated questions such as profit distribution between companies - in the latter contents, I will use the cooperation model to introduce the part of basic model content, that is also because the two forms applying the close or same basic model . However, merged container lines are the trend now that is because most of container companies’ profits decreased sharply, they cannot stand the hit, so we need to find the new integrated ways to change its internal operating conditions. The alliance is so complicated and slow to these companies which they need to change it. Otherwise, they will face the hard condition of bankrupt. So by now, merger is a very quick and reasonable way to help these companies.

The following chapters I will also focus on the space and distribution problems of the merged container liner companies, and illustrate through relevant examples.

Chapter3 Modeling of the Ship Deployment and Ship Routes for Merged Lines

In this paper, I will mainly resolve the problem about the part of routes design for merger.

3.1 Problem definition

For a certain scale of liner fleet , I can through the cargo supply survey, and forecast its freight demands and freight rate between any port in the operating shipping lines during the study period. It requires I design an optimal route distribution and an optimal ship schedules. On the basis of technical feasibility, make the shipping company to obtain the best economic benefit.

Liner companies in transportation organization process is necessary to solve such a problem: how configuration the liner shipping fleet in different types of ships to a company operating the route, and then fleet can make the best economic benefits, namely, liner shipping arrangement.

General liner ship assignment model, basically to limit the capacity constraints and supply (volume) as the constraint condition, with minimum cost or maximum profit as the objective function, and then the establishment of linear relationship, to form a distributive problem of linear programming model.

Traditional liner ship assignment model is often the transportation expenses of the whole shipping lines transportation network as the target function of the optimization and seeking the minimum, namely: in a transportation network, how to determine the various routes of transportation flow or voyage, the flow does not exceed each ship in different routes voyage cap, and meet the requirements of the start point and the end point of the process, and the total cost of transportation is minimized. The objective function is expressed as the cost of the whole transportation system. In the model, objective function can pursuit system total cost minimum, the total cost of the system including the ship transportation cost and opportunity cost. It is generally believed that voyage cost should include the capital cost of the ships, voyage operating costs and voyage changing cost. In our country, the voyage operating cost and voyage changing cost are called fixed cost and variable cost.

Because for a quite period of shipping market will be sustained in a capacity is greater than the cargo volume from now and then, coupled with large container ships and other factors driving and operating strategy of the shipping company is under the precondition of satisfying the users' freight demand as much as possible to reduce the

configuration of the total cost. Therefore, the speed of capacity allocation based on the sum of shipping idle cost and operating cost are the lowest.
Liner transport accounted for more than 50% of the total revenue of the shipping industry, the main carrier of the liner operators to carry high value goods, the main measures to strengthen competitiveness is to provide excellent service for customers.
Operation of liner shipping also gets the limitation of the government regulations, the minimum shipping frequency, etc.
In liner transportation by ship company bear all the expenses occurred at sea and in port, each voyage profit depends on how much freight revenue is.
In order to ensure the liner present line is the regular operating, ship round-trip voyage times for shipping time interval integer times, also requires the voyage ship time interval is a sub-multiple of the diurnal integral multiples or 24h.
The one ship type on the same route maintains a certain ship frequency, to ensure the regular transport rules.

3.2 Notation Definition

First, I will introduce the basic model for understanding the model structure. As the last chapter said, I will use the cooperation model to introduce the part of basic model content, that is also because the two forms applying the close or same basic model.

3.2.1 Basic model

3.2.1.1Traditional Assignment of Liners and Liner Route Capacity Cooperation

The optimization of assignment of liners means reasonably allotting the vessels with different tonnage (slot) in the liner fleet to corresponding routes of company. What needed to do is not only ensuring the requirement of transport capacity, technology and operation, but also enables the company to get the best economic benefits. The optimization of assignment of liners can be referred to as assignment of liners. During the cooperation of liner companies, it's inevitable to meet some allocation problems, in which the liner won't often change because of the cost and benefit of one company, but be taken into consideration all the vessels of each shipping company cooperated in the whole alliance and the route network.
In the optimization configuration of routes, one important principle needed observed is that allotting proper vessel into proper voyage, which is mainly including the following three aspects: First, the technical problems of vessel (the vessel's size, structure, performance, equipment, navigation performance, speed, etc) should match the operating route. If the navigation performance is adapted to the operation conditions of routes, the endurance and the ability to resist the wind and waves should match the navigation conditions of the corresponding sea area to ensure the safe sailing of the vessel. The ship's speed should meet the expected requirements in sailing schedule.
On the voyage, when the navigation distance and the time spending in port are fixed, the speed decides the time of round trip (schedule), and impacts the number of vessels needed in the route. For this purpose, the performance of speed should meet the various requirements of navigation. Second, the vessel has also comparative

competitive power in the route (the aspects of speed and calling has competitive power). Especially in the increasingly fierce container transport market, a route can't get good evaluation and offer better freight service without the advantages of fast delivery and punctuality. Third, choose the proper vessel to carry on the most proper route according to company's comprehensive evaluation of all routes.

According to the allocation based on the number of routes and ship types, the problems of assignment of liners can be divided in three categories in general: The first kind of problems mainly lays in more allocation problems of routes and ship types. Owing to the inherent technical parameters and features of different ship types and routes, the economy worth putting in is different. It is a complicated task to reasonably carry out the assignment of liners. The second kind of problems is the assignment of single ship type in multiple routes. After proper thoughts, it is not difficult to find that this kind of problems is easier than the former problems, and only needed to study when the freight volume is bigger than the capacity. To solve these problems, it's necessary to start from the technical requirement, excluding the inapplicable routes, calculating economic indicators respectively, and preferentially assigning the vessels to the routes with better operational and economic value until finishing the assignment. The remaining volume can be used to cooperate with other companies and rent their space. After the space rental, it may recalculate the space of own vessels and rental space (this is related to the problems of different results of the reconfiguration of the capacity caused by different cooperation forms of container liner companies). The third kind of problems is the assignment of multiple ship types in single route. This kind of problems is relatively easy as only needed to study when the capacity is bigger than the freight volume. The principle and basic steps of optimized assignment is similar to the second kind of problems. First, exclude the inapplicable vessels, then calculate the operational and economic indicators for each vessel and preferentially assigning the vessels to the routes with better economic effects until meeting the requirement of the freight task.

In the problems of container liner route capacity cooperation, first, allot the capacity by relevant mathematical model according to their own capacity, and then consider cooperating in route capacity with other shipping companies after finding the problems of their own inadequate capacity configuration, and solve the current problems and complete expected freight volume through borrowing the capacity of other shipping companies. The allocation of route capacity cooperation often has to consider the requirements and interests of different companies, and carry out optimized assignment of liners, which belongs to problems of assignment of liners with multiple routes and ship types. When optimally adjusting the routes, after basically determining to choose a certain kind of ship, it is necessary to analyze and compare from the view of all companies whether the economic effects can be better if choose the other routes of company. This is a comprehensive evaluation and selection. Company should not only make their own routes best, but also give consideration to the interests of other companies.

The basic thinking of taking allocation of route capacity cooperation by linear programming is: First, determine the available ship types, tonnage of ship by conversion of various ship types, all routes and the freight volume of routes of company within a certain period, then make a reasonable distribution to vessels in line with certain goals and constraint condition(like completing the task or capacity restriction), and make sure if taking the route cooperation to reduce the total cost according to the results of distribution. There are some main steps in solving the allocation of route capacity cooperation problems as follow: First, collect and analyze the original data, and calculate relevant parameters according to the need. The needed information of allocation of liner includes the situation of cargo flow (the flow direction and capacity in certain period), data of vessels (number, volume, operating time, etc.), relevant expenses (constant expenses, variable expenses, opportunity cost, etc.). The models of minimum cost, maximum profit and multiple goal programming can be established according to the modeling demand on the basis of the above data. Second, establish the route optimization model. According to the specific characteristics of the problem to be solved, reasonably determine the objective function, decision variables, parameters and constraint conditions of the mathematical model. Third, derive the optimal solution to determine the optimal plan of route planning. Forth, analyze the result of current capacity allocation. Finally, according to the result of their own capacity allocation to consider the form of cooperation and make allot capacity again to see if it is beneficial for the reduction of total system cost, the increase of profit or the implementation of other goals.

3.2.1.2 Minimum cost model

Here we take the shipping charge of whole route transport network as an optimized object function, and commit to seeking its minimum value. That is, in the transport network, how to allot the traffic flow or number of voyages to ensure the flow will not exceed the restriction of the total number of voyages of each vessel in different routes, the required volume in each ending and seek the lowest freight. The objective function is expressed as: making the cost of whole transport system lowest.

The operation of liner routes needs a great deal of cost. So the assignment of liner is for reasonably integrated transport vessels in the routes to form an optimal distribution and to make the operation cost of liners in programming lowest and the economic effect largest. Suppose the liner company operate routes L1, L2, L3~Ln; Forecast the forward freight volume of route J in the planning period at q, and the contained ship types are m with loading capacity of N1, N2, N3...Nm respectively; the number of type 1 ship is m. The max number of round-trip voyage finished by a type i ship in route j in the planning period is n. The total cost of finishing a round-trip voyage in the route j by type 1 ship is C_{ij}. Now require to allot this ship $(=\sum_{i=1}^{m} m)$ to these routes reasonably to obtain the lowest cost and the best economic effect. The cost model of assignment of liners can be determined by the following formula:

$$\min Z = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij} x_{ij} + \sum_{j=1}^{n} \delta_j u_j + \sum_{i=1}^{m} e_i y_i \qquad (3\text{-}1)$$

s.t.

$$\sum_{j=1}^{n}\frac{1}{n_{ij}}x_{ij}\leq m_i \qquad i=1,2\Lambda\ \text{m} \qquad (3\text{-}2)$$

$$\sum_{i=1}^{m}N_i x_{ij}+u_j-v_j=Q_j \qquad j=1,2\Lambda\ \text{n} \qquad (3\text{-}3)$$

$x_{ij}\geq 0;\ u_j\geq 0;\ v_j\geq 0;\ y_i\geq 0$; i=1,2…m; j=1,2…n (3-4)

Among them: Z is the total cost of the system

i=1, 2 ...m is the number of ship types and j=1, 2....n is the number of routes;

c_{ij} represents the cost of a voyage finished by type i ship in route j;

x_{ij} represents the number of voyages finished by type i ship in route j in planning period, which is the decision variable;

n_{ij} represents the max number of voyages that can be finished by type i ship in route j in planning period;

δ_j represents the opportunity cost of unit volume in route j, which is defined as freight rate of route j;

u_j represents the volume not accept for carriage in route j;

e_i represents the daily idle charge of type i ship;

y_i represents the idle period of type i ship in planning period;

N_i represents the container carrying capacity of type i ship;

m_i represents the number of type i ship;

Q_j represents the forward traffic volume of route j.

In the constraint conditions, (3-2) for the transport capacity constraints; (3-3) means the transport demand constraints.

The objective function is seeking the lowest cost C_{ij}, which represents the cost of a voyage finished by type i ship in route j. Generally, the navigation costs should include the cost of vessel and operating route and the changeable cost of change of voyage. The route operating cost and the route changeable cost are respectively called fixed cost and changeable cost. These costs mainly include:

The capital cost, the actual cost of the purchase of a ship, is the basic cost of a vessel, including loans, interest and taxes, etc. It calculates on the basis of annual capital cost in the voyage estimate. The annual capital cost can be equivalent to depreciation expense and the annual depreciation amount is the ratio of the ship's capital cost to the ship's economic life, by which can get the daily amount of depreciation of vessel further. In the short term, the capital cost can be seen as fixed cost. Fixed cost is the recurrent maintenance costs to keep vessel in a state of seaworthiness. Sailed or not, it should be paid for operation, so it's also called operation cost without changing with the specific voyage. The factors included are: crew wages and other related expenses (like training fee, labor insurance, welfare, etc); ship insurance and protection and indemnity; ship maintenance cost (like paint cost, spare parts cost, maintenance cost, etc.); lubricating oil costs; material cost; business administration fee, which is all the costs incurred in management work like scheduling business, commerce, finance, maintenance and safety supervision, for the operation demand of various administrative departments and agencies set in company. Voyage changeable cost is the cost incurred in transport of specific voyage, including: fuel cost; harbor use fee (like agency fees, waterway dues, tonnage tax, berthing fee, etc.); pilot age dues and towage; goods handling charge; canal tolls; dispatch and demurrage charges; crew navigation allowance, etc.. In the specific study of practice problems, the size and type of costs are depending on the specific circumstances.

In addition to the ship transportation cost, the total system cost also includes opportunity cost, capital cost of capacity and the storage cost. At peak times of shipment, the "reject loading" will occur. Using the concept of opportunity cost, "punish" the opportunity loss caused by not being shipped cargo to accept for carriage of cargo as far as possible. Besides, comparing with tramp service, the punctuality rate of liner shipping is very important, and the dispatch frequency is also fixed. In order to guarantee the sailing date, the vessel must set sail even if the volume is little. The loading capacity utilization rate of liner is concrete reflection of this phenomenon. For providing good logistics service to the owner and keeping higher dispatch frequency, the capacity actually input of liner is always greater than demand. In order to control the waste of capacity, the capital cost of capacity exceeded volume demand is taken into consideration. In the operation process of liner, some fluctuations occur frequently in the actual transport demand compared with expectation, which leads to the corresponding change of the scale of the operating vessels, transportation cooperation and idleness of vessels, as a result, producing the cost of idleness. If add constraints, such as restrictions on capital and transport of dangerous goods, can limit the feasible region of the solution of the objective function and make the solution of the objective function reflect the actual situation better. Our traditional assignment of liners uses this kind of linear programming model or its deformation, like the profit model.

3.2.1.3 Profit model

Usually, the ultimate goal of the shipping company is not seeking the lowest total cost of system, but pursuing the highest total profit (the total transport income minus total cost). In the container liner shipping market, the freight and volume can be various. The different plan of assignment of liner adopted by company can bring different result of total income, which leads the change of total profit. Therefore, the lowest system cost doesn't mean highest system profit.

Objective function: $$\max P = \sum_{j=1}^{n} fi\left(Q_j - u_j\right) - \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij} x_{ij} \quad (3\text{-}5)$$

P means profit.

F_i means freight rate on j route.

Q_i means the predicted forward cargo volume of the j route in the programming period is Q_j.

U_j means the un-carried cargo capacity on the *j* route.

c_{ij} means the cost of the i type ship completed the one round trip on the j route.
x_{ij} means the round trip voyage times of i type ship on the j route in the programming period, it is the decision variable.

Because of $\sum_{j=1}^{n} f_j Q_j$ is the constant, so the formula can be equivalent to:

$$\min K = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij} x_{ij} + n\sum_{j=1}^{n} f_j u_j \qquad (3\text{-}6)$$

(As long as the "net profit" to "rate", the pursuit of the lowest cost is equivalent to the pursuit of maximum profits, in line with the actual business goal)

In the network analysis of the shipping system, the analysis of the cost information is the most important method. The above content is the corresponding modeling analysis through the cost-effectiveness of route assignment system of the liner company. However, consider about the present with prevailing shipping alliance from the perspective of cost effectiveness, can obviously not bring more effective business strategy for the shipping company. The formation and development of the shipping alliance enable the shipping enterprises to cooperate and share with members, and thus change from cost saving type to service value added type, from individual profit to mutual benefit and win-win result. It also provides owner more diverse service and meets more and more demands of owners by fastest and most excellent perfect service. To this end, the route planning of the liner company also developed from developing own interests previously, to cooperating with more liner companies in the routes to profit, which makes the companies get a balance of interest in every link.

3.2.2 Mixed integer linear programming model

3.2.2.1 Definition

Integer programming means some or all of the variables of the program are restricted to be integers. If in the linear programming model, the variable is restricted to an integer, it is called integer linear programming. Currently, the popular method to solve integer programming is only applicable to integer linear programming. There is no way to solve all integer programming effectively at present.

3.2.2.2 Classification of integer programming

If not special specified, it is refers to the integer linear programming generally. The integer linear programming model can be broadly divided into two categories: When the variables are all restricted to integer, it calls pure (complete) integer programming.

3.2.2.3 Characteristic of integer programming

When the original linear programming has the optimal solutions, after the independent variables are restricted to integer, the integer programming solutions will be as follow:
①If all the optimal solutions of the original linear programming are integer, the optimal solutions of the integer programming is consistent with the optimal solutions of the linear programming.
②No feasible solution to the integer programming.

3.2.2.4 Classification of solving method

(1) Branch and Bound Method, which can be used to solve the problems of pure or mixed integer linear programming.
(2) Cutting-Plane Method, which can be used to solve the problems of pure or mixed integer linear programming.
(3) Implicit Enumeration Method, which can be used to solve the problems of 0-1 integer programming.
Filtering implicit enumeration method;
Branch implicit enumeration method.
(4) Hungarian method, which can be used to solve the problems of assignment problem (the special circumstances of the 0-1 programming).
(5) Monte Carlo method, which can be used to solve all kinds of problems.

3.2.3 Basic assumptions in mathematical model

Study period is one year, one quarter, one month or other unit time .
Liner companies operate the routes are G totally, among of these are traditional multi port of calls, goods direct shipping route, namely, the ship from the departure port sailing along the one direction, midway can anchor many different ports. When it reaches the terminal port, unloading all the goods and then return the departure port after the new goods loaded, it will carry on the next round voyage. Every ship can be loaded and unloaded at multiple ports in round trip, and it doesn't require the ship arrive the same port between the inbound and outbound routes.
Shipping companies' operating route network can anchor ports total number N, all affiliated port numbers for 1 ~ n, each route inbound and outbound ports have been already identified.
In the study period, there are K ship types available.
Freight demand and freight rates between the ports have been predicted or determined.
In container volume TEU as a unit for measuring ship carrying capacity and its volume of freight demand.
Between the two round trip anchored ports, the freight is not the same necessarily, that is $\boldsymbol{F_{ij}}$ not equal F_{ij} necessarily.
Pre- determination of the number of ship round-trip voyage through the various types of vessels can be completed at the best speed in the period of study time.

In order to improve the service quality, the shipping company will maintain stable schedule in its business shipping route, namely, to stipulate the routes of minimum shipping voyage.
The ship on a given route of the round-trip voyage cost will not be affected by the change of voyage carrying capacity.

In the formula (7) to (14):
Z, as the objective function, represents the transport profit of liners in the study period;
x_{hij}, as the decision variable, represents the volume completed by liners between port i and port j in the route h in the study period;
y_{hm}, as the integer decision variables, represents the numbers of voyage of type m vessel in route h;
F_{hij} represents the freight (excluding loading and unloading charges) between port i and port j in route h;
C_{hm} represents the operating cost of the previous voyage completed by type m vessel in route h, including fixed cost and changeable cost;
V_{ij} represents the predicted or determined freight demand between port i and port j in the study period;
np_h represents the total number of calling ports in the inbound journey of h route;
nd_h represents the total number of calling ports in the outbound journey of h route;
PP_h represents the set of calling port number in the inbound journey of h route; Pd_h represents the set of calling port number in the inbound journey of h route;
AP_{hr} represents the set of the first r calling port number in the inbound journey of h route, r= 1,2...nph-1;
DP_{hr} represents the complementary set of AP_{hr} in the set of PP_h, namely, $PP_h=AP_{hr}\cup DP_{hr}$, r= 1,2...np_h-1; AD_{hr} represents the set of the first r calling port number in the outbound journey of h route, r= 1,2...nd_h-1;
DD_{hr} represents the complementary set of AD_{hr} in the set of PD_h, namely, $PD_h=AD_{hr}\cup DD_{hr}$, r= 1,2...nd_h-1;
θ_{hm} represents the average loading rate of type m ship in route h ($0\leqslant\theta$ hm$\leqslant1$);
CA_m represents the maximum carrying capacity of a single type m ship;
Q_h represents the minimum number of shipping set by liner in route h in study period;
B_{hm} represents the max number of voyages that can be completed with optimum speed by a type m ship in route h in study period;
N_{max} represents the number of available type m ship in the study period.

3.3 Optimization Model

3.3.1 Mathematical model before merged shipping lines

For the above problems, to the fleet profit (income minus voyage operating cost) maximum as the goal , the establishment of a multi - port anchored liner ship with mathematical model for :

$$\max Z = \sum_{h=1}^{G}\left(\sum_{i=1}^{n}\sum_{j=1}^{n} x_{hij}F_{hij} - \sum_{m=1}^{K} C_{hm}y_{hm}\right) \quad (3\text{-}7)$$

The constraint conditions are:

$$\sum_{h=1}^{G} x_{hij} \le V_{ij}$$

i= 1,2,…,n; j=1,2,…,n ; (3-8)

$$\sum_{i\in AP_{hr}}\sum_{j\in DP_{hr}} x_{hij} \le \sum_{m=1}^{K} y_{hm}\theta_{hm}CA_m$$

h=1,2,...,G; r=1,2,...,np_h-1 (3-9)

$$\sum_{i\in AD_{hr}}\sum_{j\in DD_{hr}} x_{hij} \le \sum_{m=1}^{K} y_{hm}\theta_{hm}CA_m$$

h=1,2,...,G; r=1,2,...,nd_h-1 (3-10)

$$\sum_{m=1}^{K} y_{hm} \ge Q_h$$

h=1,2,...,G (3-11)

$$\sum_{h=1}^{G} \frac{y_{hm}}{b_{hm}} \le N_m^{max}$$

m=1,2,...,K (3-12)

$$x_{hij} \ge 0$$

h=1,2,...,G; i=1,2,...,n; j=1,2,...,n (3-13)

$$y_{hm} \ge 0$$

h=1,2,...,G; m=1,2,...,K (3-14)

The ship voyage operating costs can be determined by the formula C_{hm}:

$$C_{hm} = \frac{d_h}{24S_{hm}}\left[f_m p_h^f + g_m^s p_h^g + H_m\right] + M_{hm} + t_h^M H_m + C_{hm}^p \quad (3\text{-}15)$$

In the formula (15):
d_h represents the sailing distance of type m ship in each voyage in route h;
S_{hm} represents the speed of type m ship in route h;
f_m represents the fuel consumption of propeller of type m ship in unit time;

g_m^s represents the fuel piece of propeller in route h; gsm represents the fuel consumption of generator of type m ship;

p_h^g represents the fuel piece of generator in route h;

H_m represents the daily operating expenses (daily capital cost + crew wages + maintenance cost + insurance premium + charge + other expenses);

M_{hm} represents the canal dues in each voyage through the canal of type m ship in route h;

t_h^M represents the time of demurrage due to objective reasons in route h;

C_h^p represents the port charges in each voyage of type m ship in route h, assumed only related to type and route without changing with volume in each voyage.

In the above optimization model, formula (8) is the constraint conditions of volume, requiring the volume of certain cargo transported by vessel not to exceed the freight demand; formula (9) and (10) are respectively constraints of cargo load carrying capacity in the positive and negative two direction of each calling port, as the total amount of cargo carried on board should not exceed its cargo load carrying capacity in this route (the product of maximum loading capacity of a single vessel and the average loading rate of vessel in this route) after loading (unloading) cargo and on the way to next port; formula (11) is the constraints of minimum number of shipping in the route, as in the study period the total number of shipping in one route completed by all vessels should not less than the minimum number of shipping in the route required by liner company; formula (12) is the constraints of number of each type of ships, as the total number of each type of ships should not exceed the specified number of each type of ship; formula (13) and (14) are non negative constraints of decision variables. Formula (7) to (14) constitutes a complete mixed integer linear programming model.

3.3.2 Mathematical model after merged shipping lines

$$\max Z = x_{hij}F_{hij} + \omega_{hm}e_h q_h - C_{hm}y_{hm} \qquad (3\text{-}16)$$

s.t.

$$\sum_{h=1}^{G} x_{hij} \le V_{ij}$$

i=1,2,...,n; j=1,2,...,n (3-17)

$$\sum_{i\in AP_{hr}} \sum_{j\in DP_{hr}} x_{hij} \le \sum_{m=1}^{K} y_{hm}CA_m + \omega_{hm}q_h$$

h=1,2,...,G; r=1,2,...,np_h-1 (3-18)

$$\sum_{i\in AD_{hr}}\sum_{j\in DD_{hr}} x_{hij} \leq \sum_{m=1}^{K} y_{hm}\theta_{hm}CA_m + \omega_{hm}q_h$$

h=1,2,...,G; r=1,2,...,nd_h-1 (3-19)

$$\sum_{h=1}^{G}\frac{1(\omega_{hm}+y_{hm})}{n_{hm}} \leq N_m^{\max}$$

m=1,2,...,K (3-20)

$$x_{hij} \geq 0$$

h=1,2,...,G; i=1,2,...,n; j=1,2,...,n (3-21)

$$y_{hm} \geq 0$$

h=1,2,...,G; m=1,2,...,K (3-22)

$$\omega_{hm} \geq 0$$

h=1,2,...,G; m=1,2,...,K (3-23)

$$q_h \geq 0$$

h=1,2,...,G (3-24)

Both (3-7) and (3-16) this two objective functions have close constraints. The different contents are, (3-23) and (3-24). In terms of the added contents of profits of rent out idle ships for company to make profits and decrease the operating cost (including the idle fees). And the number of maximized round trip voyage is same of y_{hm} and ω_{hm}. After merger, (3-18), (3-19) and (3-20) need to analyze the influence of rented space. That is the important differences by compared with the objective function (3-7). The large ship sharing agreement began to tend to allow smaller carriers to join, to expand the coverage of the global shipping line. The shipper for shipping enterprise service quality complaints, that the shipping enterprise discrimination in different carriers is not enough. In the foreseeable future, at a period of time, the imbalance between supply and demand of the shipping market will be normalized, container supply capacity will gorge oneself capacity demand, whether the slowdown and idle capacity has become a key decision of shipping enterprises.

3.4 Solving problem

The analysis shows that there are no practical significance of some variables and constraints in the model. For example, if i = j, xhij means the volume of containers transportation through each ports of call; Vij is demand of each ports of call to the given port container transportation. In prior to using the mixed integer programming method to solve the model , I can choose two ways to manage these variables and constraint. Here are processed by the following:

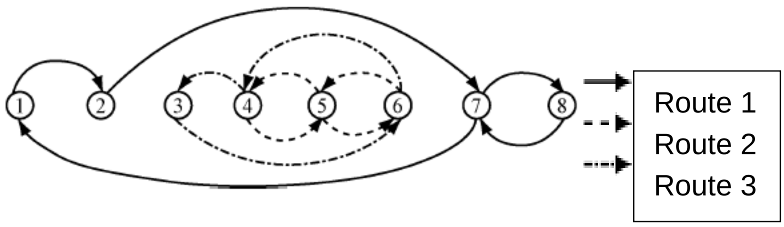
In determining the model parameters, to non anchored port pair (i, j) on the h th routes, set in advance to the F_{hij} is a proper negative value, it also can guarantee the optimal solution that there is no capacity volume between the port pair (i,j) when the ship sailing . Namely $x_{hij} = 0$; in the constraint condition (3-10), for all the lines cannot anchor the port pair (i,j), made $V_{ij} = 0$.

To eliminate these variables and constraints from the model using second processing method can reduce the variables and constraints of the model, and improve the solution liner speed effectively.

Chapter4 Mixed Integer Mathematical Model and Its Application for Case Study

4.1 Algorithm Solution

A shipping company operates 3 Asian container routes. The specify route chart is shown in figure 4.



(Note: 1-port 1, 2-port 2, 3-port 3, 4-port 4, 5-port 5, 6-port 6, 7-port 7, 8-port 8)

Figure 4 – The A Shipping Company Operates 3 Domestic Coastal Container Routes

This shipping company has a number of ship  types and maximum single capacity volume is shown in Table 2. For the convenience of calculation, this example assumes all types of ships' average loading rate on the route are same, taken the value of θ is 0.7; During the study period- 1a, the route of the affiliated port and a number of minimum shipping voyage are shown in Table 3; Predict or identify the ports of call between the demand of cargo transport volume and freight are found in Table 4; Various types of ships on the route of maximum round-trip voyage times and voyage costs about A company can be shown in Table 5. After A and B company mergers, various types of ships on the route of slot space fees are shown in Table 6; Various types of ships on the route of maximum round-trip voyage times and voyage costs about B company are shown in Table 7; Among them, due to the restrictions of objective conditions, type 1 ship cannot operate on route 1.

4.2 Problem for Applying Algorithm

Table 2 -Number of Ship Types and Maximum Single Capacity Volume

Ship Type	Quantity/ship	Maximum Single Capacity/TEU
1	3	1000
2	3	2200
3	4	4250
4	5	5100

Table 3 - Port of Call on Each Routes and a Number of Minimum Voyage During the Study Period

Route	Inbound Port of	Outbound Port of	Minimum Voyage

	Call	Call	Times
1	1278	871	120
2	654	456	180
3	643	36	90

Table 4 -Ports of Call between the Demand of Cargo Transport Volume and Freight

Destination									
Depar ture	1							15.3 **2450**	10.5 **3500**
	2							10.9 **3045**	8.4 **3800**
	3						4.7 **2350**		
	4			15.9 **2700**		10.1 **1900**	2.4 **2500**		
	5				15.2 2000		7.3 2300		
	6			20.5 **1300**	12.5 **1200**	8.7 **1100**			
	7	11.0 **1000**							7.8 **2300**
	8	9.3 **1300**						3.4 **1000**	
Note : the above data is volume of cargo demand (million TEU) ; the below bold data is freight. For the convenience of calculation, in this case, I take different routes overlapping routes' container freight rates are the same.									

Table 5 -Various types of ships on the route of maximum round-trip voyage times and voyage costs about the A company

Route		1	2	3
Ship Type	1	-	40 **40**	42 **40**
	2	15 **330**	40 **80**	42 **75**
	3	17 **475**	45 **126**	48 **120**
	4	17 **570**	48 **140**	55 **130**
Note : Above data is the maximum round-trip voyage times , and the below bold data is voyage cost (million) . "-" means the 1st type of ship can not be configured on the 1st route .				

Table 6 - Various types of ships on the route of slot space fees after A and B company merged

		Ship Type			
		1	2	3	4
Ship Route	1				
	2				
	3				
Slot Space Fees		0.08	0.05	0.06	0.07
Note: On the same routes, the slot space fees are same; Million /TEU.					

Table 7 - Various types of ships on the route of maximum round-trip voyage times and voyage costs about the B company

Ship Route			1	2
Ship Type	1	30 **32**	40 **40**	48 **60**
	2	16 **80**	40 **65**	42 **70**
	3	20 **250**	17 **386**	35 **160**
	4	45 **120**	30 **180**	45 **110**
Note: Above data is the maximum round-trip voyage times, and the below bold data is				

voyage cost (million) .

4.2.1 Solving calculation and result analysis

Use formula (3-7) to formula (3-14) and formula (3-17) to formula (3-21) to solve the problems, the form has total G * n^2 + G *k (namely, quantity of 12) variables are integer variables; There are quantity of 83 constraints conditions :

$$n^2+\left(\sum_{h=1}^{G} np_n - G\right)+\left(\sum_{h=1}^{G} nd_h - G\right)+K+G-n^2+\sum_{h=1}^{G}(np_h+nd_h)+K-G$$

According to the characteristics of problems, I can eliminate the variables are : x_{hij} (h=1,2,...,G ; i= j) and x_{hij} (h = 1,2,...,G ; i or j doesn't the port of call on the h route) , and y_{11} (in this calculation example, 1st ship route cannot allocate the 1st ship type); It can eliminate the constraint conditions including formula (3-8): when i = j corresponding to the constraints and (i, j) is not any route's port pair corresponding to the constraint conditions. In the case, the effective variable is a number of 30 (see Table 6) after eliminating the class of variables and constraints, and the integer variable is a number of 11, and the effective constraint condition is a number of 37. After the elimination of these variables and constraints, the speed of the model can be improved greatly. The same meaning of the objective function (3-16).

With the mixed integer linear programming model to solve the problem, the optimal solution is shown in table 6. According to table 5 schemes arrangement of fleet, in addition to part of the cargo transport demand from the ports of call 1 to ports of call 7. This scheme can satisfy transport demand of table 4 among the ports of call. I can verify the right of calculation results to ensure the establishment of formula (9) ~ formula (13). And then , the optimal calculation results (y value) is only according to the cargo transport demand to determine, however, each route specific voyage times should need according to the freight flow distribution characteristics to determine it further.

4.3 Optimal model results for the case study

From the form of optimization results, the present example has multiple optimal solutions, but the objective function value of the optimal solution (value of *z*) and fleet route scheme (see table 8 and table 10) are same, the only difference is cargo volume (x_{hij} from 6th port of call to 4th port of call is different as an example in table 8). Obviously, when the two port of goods are FLC but on the different routes however the same freight, the flow of cargo can be appropriate transfer between the different routes' ship (with overlapping segment), the only reason for causing the optimum solution non-unique is that the former transfer way cannot change the transport total revenue or total cost. The optimal solution of the multi value also indicates that there is adaptive by shipping arrangement scheme to cargo flow in a certain range of variation according to the set of the optimization result. Through the performance of A company's freight volume and the number of voyage merger between table 8 (before merger) and the combined table 10 (after merger), I can know that: limited by a given route and ship, A company expand the fleet size and capacity after mergers, the change rate of x_{hij} significantly (basic numerical increased), but change rate of y_{hm} is not big.

At the same time by the impact of table 5, Z value increases significantly, meanwhile, we can use the formula to solve the problem $N_{m}^{max} - \sum_{h=1}^{G} \frac{y_{hm}}{B_{hm}}$, then we can get the condition of average idle ship in different types during the study period (see table 9) . By comparing Table 8 and table 10, after the merger of A and B company, according to the present shipping market has excess capacity, A and B company - a part of the rental accommodation (Table 6) for the company to reduce the number of idle ship and get profits.

Overall, after the merger of the A and B company after the integration of the Z- profit capacity increased, compared to the company operating conditions before the merger of A company can be significantly improved.

Table 8 -Optimum Solution

Variable	Optimum value	Variable	Optimum value	Variable	Optimum value	Variable	Optimum value
X_{112}	2.1	X_{171}	11.0	X_{363}	20.6	y_{23}	0
X_{117}	12.361	X_{265}	8.7	X_{343}	15.9	y_{24}	0
X_{118}	10.5	X_{264}	0	X_{336}	4.7	y_{31}	0
X_{127}	10.9	X_{254}	15.2	y_{12}	1	y_{32}	59
X_{128}	8.4	X_{245}	10.1	y_{13}	68	y_{33}	0

X_{178}	7.8	X_{246}	2.4	y_{14}	61	y_{34}	77
X_{187}	3.4	X_{256}	7.3	y_{21}	120	z	264 945
X_{181}	9.3	X_{364}	12.5	y_{22}	60		

Table 9 - Each Ship Types' Average Idle Ship Condition during the Study Period

Ship Type	Quantity of Idle Ships
1	0
2	0.06
3	0.03
4	0.04

Table 10 - Optimum Solution after A and B mergers

Variable	Optimum value	Variable	Optimum value	Variable	Optimum value	Variable	Optimum value
X_{115}	2.5	X_{172}	10.8	X_{362}	20.3	y_{23}	0
X_{118}	15.3	X_{268}	9	X_{344}	16	y_{24}	0
X_{119}	10.1	X_{264}	0	X_{335}	5.2	y_{31}	0
X_{126}	14	X_{255}	15.2	y_{12}	1	y_{32}	63
X_{128}	12.2	X_{247}	13.8	y_{13}	68	y_{33}	0
X_{175}	7	X_{248}	2.8	y_{14}	63	y_{34}	79
X_{186}	3.5	X_{253}	7.2	y_{21}	90	z	283 265
X_{181}	9.6	X_{364}	14.1	y_{22}	60		

Table 11 - Each Ship Types' Average Idle Ship Condition During the Study Period After A and B Mergers

Ship Type	Quantity of Idle Ships
1	0
2	0.03
3	0
4	0.01

Chpater5 Conclusions and Future Research

According to the characteristics of form and goods of multi port liner shipping route, to set up a mixed integer linear optimization model for liner shipping. Model in pursuit of the maximum fleet profit during the study period, more fully considering the freight demand, the maximum carrying capacity of single vessel, the minimum frequency of ship, freight rate and so on. More objective reflecting the characteristics and rules of shipping organization. For large liner fleet, although the variables and constraints of the model are more, the scale is larger, but it can achieve the goal of fast solving through variable reduction. Finally, the feasibility of the proposed model is verified by the simulation and optimization of the route distribution scheme of a certain ship fleet during the research period. The model structure is simple and easy to understand and practical.

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