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Study on container linerroute optimization of Southeast Asia route of M Shipping Company

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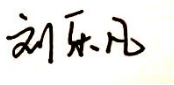
Declaration

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

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

(Signature): 

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Abstract

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Degree: Master of Science

With the success of the"Belt and Road" initiative, the shipping trade between China and Southeast Asia is becoming more and more frequent, the demand for container transportation in the region is growing rapidly, and a large number of South East Asian lines have been opened up, this has led to more confusion in the layout of container liner shipping routes in the Southeast Asia region. The problems of overlapping routes, limited capacity, relatively low level of service, and low quality of crew make it difficult for liner companies to meet the growing demand of container liner transportation, which is not conducive to the long-term development of Southeast Asia's export trade. Given the above situation, this paper adopts the linear programming model based on transportation cost to plan the container liner transportation of the company reasonably, to improve the transportation service quality and reduce the operation cost-effectively.

The main contents of this paper are as follows:

(1)taking the container liner transportation of a company as the main research object, firstly, the main research achievements at home and abroad are listed, this paper introduces in detail the development of company M's Southeast Asian market and the current situation of South East Asian air line's container liner transportation, this paper mainly expounds the problems existing in the container liner transportation of different South East Asian lines periods.

(2)On the premise of satisfying the demand for container freight in the Southeast Asian market, aiming at minimizing the total operation cost of the operation route, using the mathematical method of linear programming, the optimization model of container liner shipping route studied in this paper is established, the final optimization result is obtained by using genetic Algorithm to program and solve the problem.

In the context of the state's advocacy to vigorously develop the cause of high-quality maritime transport, and to meet the needs of port container transport development, an optimization model of container liner shipping routes has been established, a more reasonable and efficient container transport route for company A in Southeast Asia is calculated, and the lowest operating cost of the route network is obtained.

KEYWORDS:Liner company, South East Asian line, Container Liner Shipping, Route Optimization, Genetic Algorithm

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1 Introduction

1.1 Background and problem statement

A container liner is a form of international sea transportation. Container liner transportation is developing rapidly because of its long-range and broad scope, and its development is greatly influenced by the development of the world economy and the growth of world trade. With the rapid development of global economic integration and international trade, the pace of development of China's shipping has been accelerated. In the way of international trade, shipping is the most essential transportation form. According to statistics so far, the ports covered by container liner shipping routes account for more than 85% of the world, and there is still room to rise. With the Belt and Road Initiative and the long-term marine development strategy, China's maritime network is bound to show a gradual expansion of the trend. The emergence of container transportation has realized the convenience, informatisation, and standardization of cargo transportation, and it has rapidly occupied the shipping market. Large capacity, low cost, and low loss are one of its transport characteristics. Container liner transportation is a way of operation in which liner companies provide standardized and repeated container cargo transportation services for most non-periodical carriers by the established routes and ports and following the scheduled sailing schedule. And according to the container tariff calculation and collection of freight.

Encouraged by the Belt and Road Initiative, the economic and trade exchanges between China and Southeast Asian countries are getting closer and closer, which creates development prospects for opening up international shipping routes to Southeast Asia. Ningbo Zhoushan Port, as the hub of the "Silk Road Economic Belt", has actively developed the container transportation of Southeast Asia route and become the port with the fastest growth rate of container liner route density in Southeast Asia. At present, the Southeast Asia route covers the main countries in Southeast Asia and has become a vital trade transit point for Southeast Asia all over the world. Therefore, this paper sets Ningbo Zhoushan Port as the central port, which is very representative.

At the same time, opening up new routes also increase the operating cost of liner transportation in Southeast Asia, which is difficult to meet the needs of the rapid growth of container transportation in Southeast Asia route, and dramatically affects the development of export trade. Therefore, optimizing the route to reduce the operating cost of the route is a significant issue.

1.2 Aim and objectives

Container liner route design is an important strategic decision for liner companies, directly related to route allocation and vessel type selection. It has a long-term impact on the operating cost and benefit of liner companies; with the drastic fluctuation of container shipping market demand in recent years, shipping companies are facing a more difficult competitive situation under excessive capacity.

Since 2009, the impact of liner shipping lines on port cargo demand has become increasingly significant. Because container transport is an indispensable and essential part of the global transport market, changes in the relevant container routes also affect the distribution of international cargo flow from time to time, sometimes adjusting a certain route can make several relevant port traffic demand changes, which will affect the economic efficiency of the fleet transport. Therefore, the optimal design of container shipping routes and ship scheduling is a problem that every liner company needs to solve urgently.

The purpose of this paper is to optimize the shipping route of container liners in the key region - Southeast Asia, which is to enhance the competitiveness of container transportation of Company M (to give full play to the advantages of container liner transportation, avoid wasting capacity and reduce shipping cost), And according to the market demand, we use the suitable algorithm to solve the model and compare and analyze the solution results to arrive at the optimal container shipping route of Company M in Southeast Asia.

1.3 Scope of the research

This paper takes the container liner transportation of the Southeast Asia route of Company M as the research object and adopts a combination of quantitative analysis and qualitative analysis to analyze the problems of its transportation routes. By integrating the container liner routes of different schedules and re-optimizing the target routes, we can solve the problem of repeatedly sailing to the same port for different schedules, to minimize the operation cost. Firstly, taking Ningbo Zhoushan Port as the central port, we analyze the current situation of Company M's Southeast Asia route operation and conduct a problem analysis. Secondly, a container liner shipping route optimization model is established to minimize the total operating cost. Finally, the model is solved and validated to provide route optimization solutions.

1.4 Structure of the research

Generally， the study consists of a literature review, data and methodology, analysis and discussion, and finally conclusions and recommendations.

Chapter 3 first outlines the theory of container liner planning, and then analyzes the operation of the Southeast Asia route in the context of Company M. The problem is analyzed in terms of route design. Chapter 4 first introduces the sailing cost and then establishes a model with the minimization of the total transportation cost of the shipping company as the objective function. In Chapter 5, the model is solved for the ports of the route, and the optimization scheme of the liner route and the improved cost can be obtained. Chapter 6 is a summary and recommendations.

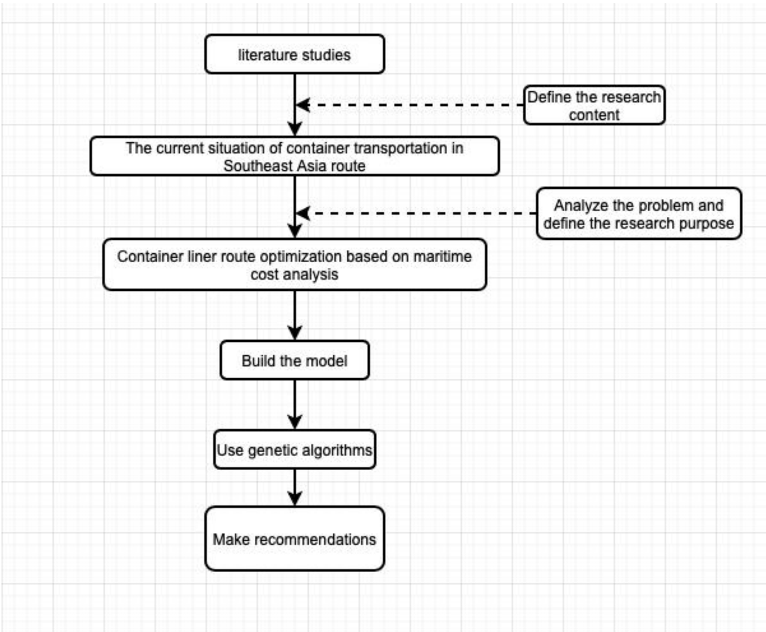

Figure 1 Research Road map

2 Literature review and Related Theory

2.1 Literature review

Network optimization of container liner shipping is a technique shipping companies use to reduce costs and improve efficiency in their cargo handling. It involves optimizing the entire network of ports and fleets, ship schedules and routes, and optimizing the use of containers, ports and terminals. By finding the most cost-efficient and low-risk routes, ports and fleets, shippers can reduce the time, fuel and resources wasted in transporting goods across the globe. This optimization ensures better customer service, cost-effectiveness and reliability. Furthermore, it helps reduce operational costs, reduce environmental footprint, and ultimately improve their competitive position in the market.

Container shipping has become a cornerstone of the world's import and export trade and is increasingly permeating some traditional shipping methods. It is one of the most important cargo transportation worldwide. Maritime containerized cargo transport has been the cargo transport group with the greatest growth potential, accounting for approximately 60% of the market value of containerized maritime cargo transport. (Stopford, 2009).

The content of container ship routing and scheduling research lags behind theory and practice, especially in the face of the growing volume of maritime container shipping and the rate of progress in probability theory, mathematical statistics and computer science and technology. There were three main problems: maritime container broadband routers, vehicle scheduling, and route network design(Tran et al., 2015). Wang suggests how to address the issue of allocating sea containers with reference to combining profits (P-CA). In addition, the global demand for containers depends on transport costs, which looks much like the 'elastic demand' in the literature for cargo transport LAN connections relative to large cities. If such an effect is to be achieved, it is essential to reduce the cost of the newly positioned product of reefer containers to address the problem of how to allocate reefer containers considering coordination between container shipments(Zheng et al., 2015). Using a genetic algorithm, two optimization models were constructed to solve the design and production of a global container LAN connection in Central Europe (Zhao et al., 2015). A framework was proposed for a Standing Augmented Inland Shipping (SAS) LAN connection structure to integrate various activities in the maritime container liner cargo chain(Wang et al., 2016), which contains the specific processes of container loading and unloading, post-shipment, stopover at seaports through the adoption of proxy servers, transit waiting, and overland transportation.

（1） An overview of container liner shipping

Container liner shipping is a form of shipping in which cargo, usually cargo containers, are loaded onto a vessel for shipping purposes. This type of shipping has become increasingly popular in recent years due to the ease of movement and convenience it provides for businesses who need to transport goods from one place to another. Containers are loaded onto the ship and then shipped to their destination, where they are unloaded and placed onto trucks or other forms of transport. This form of shipping is often much more affordable than other methods due to its efficiency.

The cost of container liner shipping is generally determined by the size and weight of the containers being shipped, and the distance it must travel between ports. The vessels used in container liner shipping are typically large container ships, and in some cases, barges are also used for shorter trips. To ensure that the cargo is safe, a properly lined container must be securely sealed to protect from the elements.

The design of container liner shipping networks, the management of containers, includes the repositioning and allocation of empty containers(Imai et. al., 2009). It explores the question of whether the container liner shipping industry will be oligopolized as a result of alliances. A theoretical framework for port connectivity from the perspective of the world container liner shipping network was proposed and was defined as the impact on the liner shipping network when the evaluated port is unable to provide transshipment operations(Jiang et. al., 2015) . It optimized the design of optimal fuel sourcing for each port in a liner network operated by a container liner.

In terms of liner shipping industry, global seaborne trade volumes rebound to pre-epidemic levels in 2021. From 2014 to 2019, driven by macroeconomic growth, global seaborne trade volume grows year by year; in 2020, affected by the New Crown epidemic, global seaborne trade volume declines by about 4% compared to 2019; in 2021, global trade demand gradually recovers and basically returns to 2019 level.

From 2017 to 2021, the global merchant fleet capacity grows year by year, but the growth rate gradually slows down. 2021, the global fleet capacity reaches about 2.2 billion dwt. As global ship deliveries total 86 million dwt in 2021, a slight decline of 3%, resulting in a further slowdown in the growth rate of global ship capacity.

（2） Fleet planning and route design optimization

Sun proposed optimising the container transport path under the cooperation of capacity and designed the container path selection model under the overall optimal condition. The model takes the lowest cost of container delivery as the objective function and is solved using the genetic algorithm LINGO and CPLEX computer tools, which is of great reference significance to the daily operation and scheduling of liner companies and route planning(Sun, 2006) .

An integer linear programming model with chance constraints is developed for the short-term LSFP problem, assuming a normal distribution of cargo transport demand between any two ports on each liner route (Meng et al., 2010). The theme Meng is to stimulate more research in this emerging field with practical relevance(Meng et al., 2014). Designing a multi-period planning horizon liner shipping logistics network using mixed integer programming has the function of profit-maximising (Purba et al.,2017). Giovannini developed a simple model for a fixed route scenario that factors in freight rates as well as fuel prices and cargo inventory costs as part of the overall decision process(Giovannini et al.,2018).

Although some studies have proposed joint planning models that capture multiple decision problems simultaneously, none of the current studies integrate the decision problem at the joint four tactical levels. This state-of-the-art gap must be addressed if such an effect is to be reached (Pasha et al., 2020). A global optimal model is given for the liner shipping decision problem at each tactical level, and this paper aims to maximise the revenue of liner shipping operations by optimising the paths for long-distance transport operations. to further enhance the attractiveness of public transport as a sustainable mode of travel (Ren et al., 2020). The sailing speed optimisation problem involves the selection of sailing speeds for different legs of a voyage rotating along a given port. The vessel scheduling problem lists the scheduling of vessels in different ports (e.g. arrival times, loading and unloading times, departure times). A comprehensive review of the liner shipping literature reveals that the current literature on strategic decision-making focuses only on these aspects (Pasha et al., 2020). Cheaitou takes container ships as an example to explore route and speed optimisation for container liner shipping.

Although several studies have proposed a joint planning approach that can handle multiple strategy problems simultaneously, they have yet to be able to integrate strategy problems at four strategy levels. To address this problem, Pasha developed a set of global optimization models from strategy level to strategy level to achieve maximum benefit (Pasha et al., 2020). These differences have a significant impact on the number of containers, fuel consumption, and operating costs of the line. To address this problem (Wang et al.,2021), this project proposes to study the problem of joint deployment, sequencing and scheduling of multiple types of ships on a single route. This project proposes to construct robust optimization models and solve them using a two-stage stochastic linear programming (SLP) approach for three different FGD methods (fuel switching, scrubber, and LNG dual-fuel engine) (Zhao et al.,2021).

（3）Container management and configuration

Container management and configuration involves managing and configuring the various software and resources contained within a single container. This includes managing and configuring the runtime environment, scheduling, networking, storage, and application components. It also includes setting up and configuring environment variables, resource constraints and limits, and other configurations. Additionally, security measures such as authentication, authorisation and encryption can be set up and configured. Proper container management and configuration can help ensure container-based applications' reliability and scalability.

There is a fuel management strategy study for a single shipping liner service(Yao et al., 2012). Considering the convexity, non-negativity and univariate nature of the fuel consumption function, this paper gives an efficient outer approximation method to find the optimal solution for a known optimal tolerance (Wang et al., 2012). Taking into account the uncertainty in port time and liner schedule demand, this paper develops optimal vessel schedules on liner routes to reduce fuel consumption (and emissions)(Qi et al., 2012). The theme is the ability to design liner shipping schedules that reduce uncertainty in port operations, including uncertain waiting times due to port congestion and uncertain container loading and unloading times(Wang et al., 2012). These properties further allow us to identify the optimal conditions for optimising the sailing speed of network container ships. Based on this optimality condition, Wang proposes a pseudo-polynomial time solving algorithm in this paper to obtain the optimal container ship sailing speed in a liner shipping network.

Throughout the domestic and foreign research status , there have been some achievements in the research of container liner shipping route optimisation; scholars mainly focus on fleet scheduling, route planning, ship selection, etc., to establish a series of more complex dynamic planning or linear planning models.

Most of the current liner shipping route optimisation problems take liner companies' cost minimisation or revenue maximisation as the model objective and optimise the route, ship type, ship schedule, and other factors. In general, the research on route optimisation mainly includes several kinds; one is to select suitable ports of call and determine the order of ports of call according to the cargo demand and the conditions of ports of call on the route to design the best route for liner, to make a reasonable sailing schedule and so on. However, with the increase of research scope, the increase of influencing factors, and the complexity of the actual problem, most of the models gradually show some drawbacks in the later application, and their practical application should be improved with the specific situation.

First of all, only for a single route ship type and port selection research is more. In contrast, the specific region of the complex route optimisation research is less, the focus of research will often focus on how to make the route cargo transport volume and the highest unit profitability, but did not fully take into account the connection problems of other routes, dry and branch lines are not well connected, the competitiveness of the route set down.

Secondly, most scholars optimise the operating routes on the premise that the ports to be called are known. Usually, in this case, most liner company employees make decisions subjectively by weighing a limited number of standard options based on their extensive sailing experience combined with quantitative analysis of economic costs, making it difficult for scientific research models to be fully applied in shipping. When running simple routes, such choices tend to serve their purpose quickly.

For the optimisation research of container liner shipping routes, many scholars at home and abroad have proposed relevant models and solution algorithms based on their research perspectives, which have strong references to the research of this paper.

2.2 Theory of container liner route planning

2.2.1 Definition of liner shipping

Container liner transportation is a mode of transport in which liner operating enterprises equip dedicated vessels for a specific route based on analysing cargo demand between ports, vessel configuration, and fleet size. These designated vessels travel along the predetermined route, continuously making inter-port transportation, adhering to the pre-set arrival time and the determined port berthing order. Compared to irregular sea transport methods, container liner transportation has fundamental differences, leading to challenges in the optimising port of call and berthing order. However, optimising these factors is essential for ensuring the long-term stable operation of the line while improving its revenue and efficiency.

Liner routes are categorised based on the transported objects into three types-container, general cargo, and passenger. Container-liner transportation typically combines main trunk lines and branch lines to create a network that covers various regions. It facilitates the easy interchange of containers across different regions, making the transportation process smooth and efficient. Besides, liner routes can be divided into direct routes and multiple-section routes, depending on their organisational structure. Direct routes involve calling at multiple ports consecutively and are generally preferred. On the other hand, the multiple-section routes involve the cooperative transportation of trunk lines and branch lines.

An optimised route system is beneficial for liner companies as it leads to cost savings and improved service quality of the line, further enhancing international competitiveness. Companies often use sophisticated algorithms and simulation models to optimise the port of call and berthing order. Accurate predictions of demand and capacity constraints are used to identify the optimal routing decision. An optimised route can reduce voyage duration, lower fuel consumption, higher resource and asset utilisation, and increase revenues.

Container-centred ships, ports, freight stations and other infrastructure have been widely distributed worldwide, making liner container cargo flow with significant geographical characteristics. As far as China's inland river and coastal traffic is concerned, both the Yangtze River and coastal areas are rich sources of commodities. As for the flow of freight, most of the time, it goes from north to east and then from south to north. Since both domestic and foreign container transportation have distinctive regional characteristics, the round-trip cargo volume also shows significant differences from the Southeast Asia route where Company A is located.

Container liner transportation, as a mode of transportation that quickly occupies international commerce, is in a booming stage, and its rapid development reflects customers' demand for transportation safety, quality, speed and cost. The content of this subsection provides a good basis for the design of the following routes and also ensures that the optimal design of the routes is more feasible. The main features are shown in the following figure:

(1) Stable schedule

The certainty of time, price, route and location is characteristic of container liner shipping route, and timing is one of the most critical factors in liner shipping operation, which can not only ensure the cargo side does a good job of pre-loading work but also ensure the stability of schedule from the perspective of sea transportation managers to carry out supervision and management work efficiently and following the law, to improve transportation efficiency and service quality. In addition, the liner company can adjust the schedule in time according to the market changes to meet customers' demands and provide them with better services.

(2)Accurate ship schedule

When compared with other types of ships, container ships can carry out cargo transportation more efficiently and conveniently. In addition, since containers have good packing and sealing properties, the cargo delivered will be fine even under bad weather conditions. In addition, container ships operate very fast in the port, and the chance of delay is relatively small, so they can effectively ensure the accuracy of the shipping schedule. In addition, container ships can also shorten the turnaround time of goods in the port, thus saving a lot of time and costs and also reducing the losses arising from delays.

(3) Fewer ports of call

Due to the large volume and high speed of container ships, they can get more benefits and more benefits in the shipping market. These ships have strong convenience and economic value due to the large volume of cargo they ship and the small number of ports of call. To avoid delay in the schedule, when there are more ships' ports of call, the ships have higher requirements for the ships, which causes higher fixed costs of the ships and has a greater impact on the operating income of the ships.

(4) regional

The prominent regional nature of the container as the core of the ship, ports, freight stations, and other infrastructure has been widely distributed in the world, making the liner container cargo flow have significant geographical characteristics. As far as China's inland river and coastal traffic is concerned, both the Yangtze River and coastal areas are rich in cargo resources. As for the flow of freight, most of the time is from north to east and then from south to north. Since both domestic and foreign container transportation have distinctive regional characteristics, the round-trip cargo volume also shows significant differences from M's Southeast Asia route.

(5) Facilitate the development of international multimodal transport

As one of the highly competitive new transportation modes, container transportation gives full play to the advantages of commodity packaging during transportation. After merging the packaging unit and shipping unit, compared with other forms of shipping and loading, container loading has significant superiority. Based on the efficient conversion operation of various modes of transportation, the company is committed to ensuring fast, reliable and safe freight transportation and continuously improving shipping efficiency to support the development of international multimodal transportation.

2.2.2 Influencing factors of liner route optimization

In many cases, time, organizational culture, social environment and others all have some influence on the pre-planning of a project. From the perspective of a liner company, the only real environment in the real world is the relative state of motion. Compared with the traditional liner enterprises, the new ones always maintain a very competitive development, no matter whether the expenses of fixed costs or shipping revenues are increasing, and the shipping technology is also advancing continuously. The importance of shipping enterprises combined with the actual situation of environmental analysis, on the one hand, can provide insight into the current stage of development; on the other hand, it can predict the future trend and affect the strategic planning of other transportation work and liner enterprises from time to time. Therefore, in the process of designing and optimizing container routes, liner enterprises need to measure various factors comprehensively:

The first is the market factor. As container shipping gradually becomes the mainstream of the international shipping market, the change of market elements has an increasingly obvious impact on the planning of container routes, and the cargo volume is the most direct manifestation. In general, liner enterprises to improve cargo loading to make reasonable arrangements for container ship call orders based on the imbalance between import and export cargo will a careful consideration, and cargo volume indicators have an important role in route optimization.

The second is the seaport factor. Since different terminal facilities will have different effects on transportation efficiency, better terminal facilities will have a greater impact on the cost of transportation companies. Under certain circumstances, in some terminals with poor infrastructure, large ships stay in the harbour, their loading and unloading efficiency is lower, and the time required is longer, which greatly impacts the normal operation of the maritime transport market. In addition, the terminals' clearing, refuelling, and working hours, as well as the level of service at the terminals, the flow of goods, and the geographical location impact the whole transport system.

The third is the environmental factor. The customer's delivery and arrival time will impact the ship's schedule. The cargo arrives at the port using road transport, meaning it needs to travel a long way. There will be many unpredictable objective factors that impact the transport work, the most important of which are: traffic factors, weather and environmental factors, which are closely related to the development of the shipping schedule and the optimization of the sailing route.

The fourth is the management element. Management in the general sense refers to the process that under specific shipping market conditions, the management personnel of shipping enterprises adopt various methods such as control, organization, planning and leadership to coordinate the resources owned by the enterprises, to promote the realization of organizational goals. In terms of operational elements, the main ones include fleet size, decision support system, and organizational structure of the shipping company. The decision support system is efficient enough to provide the company with the best route, schedule and loading options. The fleet's composition and overall size will directly impact the fleet's ability to respond flexibly to local disruptions.

The fifth is the shipping factor. Parameters related to operating costs, such as ship service life, sailing speed, shipload and draft, all impact route optimization. Regarding shipload and draught factors, each terminal will set the maximum draught line to limit the ships entering the port. When the line is higher than the port limit, the ships will not be able to enter the port, thus causing some interference to the determination of ship sailing routes.

2.2.3 Container liner route optimization content

Route path selection includes the following four types.

(1)Point to point route

Point to point route is the most fundamental and simple basic route, i.e. the ship travels between two terminals. The detailed operation is shown in the following diagram.

Figure 2 Point to point route

(2) Hub and spoke route

In this mode, ships travel between two different transportation areas. Unlike the point-to-point transportation mode, this mode is based on the premise that a core port is identified and ships are berthed between the core ports. The detailed operation mode is shown in the figure below.

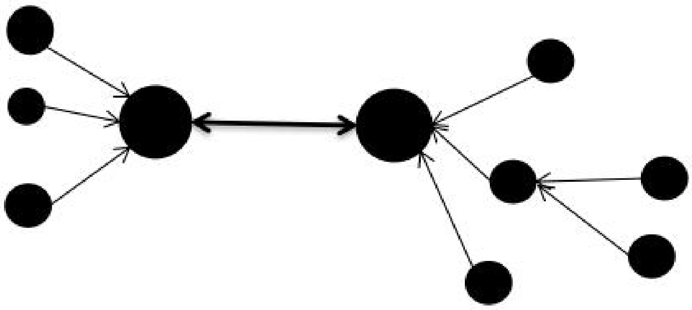

Figure 3 Hub and spoke route

(3) Pendulum route

A pendulum course means sailing in one direction from a certain starting point and returning to the starting point when you reach the end. Then a course that sails from that starting point in another direction, reaches another end point and then returns to the starting point. The course trajectory is similar to the pendulum motion trajectory.

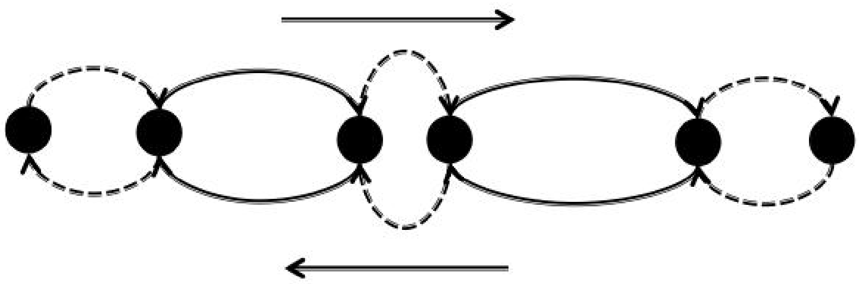

Figure 4 Pendulum route

（4）Circumferential route

That is, the container ship in a number of terminals for directional round-trip transportation, and the pendulum type is different, its only need to stay in each port once, can be improved in the route of the imbalance in cargo flow. Detailed operation is shown in the figure below.

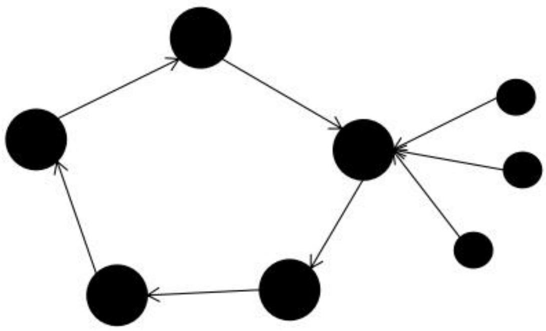

Figure 5 Circumferential route

2.2.4 Container liner route optimization methods

(1) The basic criteria for container route optimization

Liner companies aim at profit maximization, whether its ultimate goal or its starting point, is profit. When a company is neither profitable nor generates income for its managers, it is meaningless. Therefore, the main objective must be to obtain greater profits and further optimize the routes on this basis.

(2) Appropriate ships according to the route

The basic principle of route optimization is to use the right vessel for the right route to ensure the meaning of optimization. For example, if a large container vessel of 10000 TEU only travels on a route of about 5000 TEU, then in the long run, there will be a shortage of 5000 TEU, which causes a huge waste of resources and is against the goal of optimization. In short, when arranging vessels and routes, the economic benefits of routes and companies must be taken into account.

(2)Simultaneous optimization of trunk and feeder lines

From the previous research on container navigation routes, there is often a single study on the trunk line, or a single study on the optimization of the feeder lines, and relatively little research on the simultaneous optimization of the trunk and feeder lines. However, what is instructive and meaningful for practice is the simultaneous optimization of trunk routes and feeder routes, only in this way can the optimized algorithms and models, etc. conform to reality and be operable and effective.

At the same time, since the container liner line is a global maritime market, international maritime transportation can be considered a product based on international trade. The international trade situation is the key factor affecting the maritime transportation market. The optimization process needs to be combined with the actual situation, not detached from the actual situation, into a purely theoretical aspect of the study. Combine theory and practice, test the theory through practice, and revise the theory based on this. In short, only what is realistic is the optimal decision. Therefore, when constructing the model, especially when selecting relevant data, and setting parameters and constraints, it must be combined with the real situation. In the process of designing the algorithm, the characteristics of the container navigation route must be fully considered, and the subsequent calculation will be further improved.

3 Container liner route optimization model

3.1 Shipping cost analysis

When a liner company is planning a shipping task, cost as a decisive factor must be considered in the context of cost analysis, taking into account profitability as well as cost efficiency. As a purely economic analysis, costs can be used as a guideline for decision making and their basic type and structural composition must be defined. In general, shipping costs consist of capital costs, voyage costs and operating costs.

1. Shipping Capital Costs

Capital costs are the expenses incurred by a liner company for purchasing operating tools such as ships. Because the ship will incur wear and tear while in use, the value of the tool itself will gradually decrease, and the longer it is used, the lower the value will be and the more serious the depreciation will be. To increase profits, liner companies usually estimate the depreciation cost of operating tools, and the annual depreciation rate is calculated by the following formula:

$$Z=C/Y \quad (1)$$

Z - annual depreciation rate;

C-Capital cost;

Y-expected economic life

2.Shipping operating costs

For the purpose of maintaining normal operations, liner companies must invest capital to ensure the normal and continuous use of operational tools such as ships, such as the repeated use of containers and the seaworthiness of ships. In order to better analyze shipping operating costs, they can be divided into insurance costs, ship repair and maintenance costs, crew costs, management costs and daily consumption costs, as follows:

(1) Insurance cost

The natural environment determines the safety of operation to a certain extent, while the marine environment is unpredictable and unpredictable, and there are great variables whether the fleet can reach the destination port on time. Under the relatively harsh marine environment, the possibility of ship damage and cargo loss is greatly increased. Therefore, it is necessary for liner companies to insure their vessels with relevant insurance companies for the purpose of guaranteeing the safety of navigation, so as to reduce the losses caused by unpredictable risks.

(2) Equipment maintenance cost

In the process of normal operation, the transportation equipment will be damaged to different degrees, and if the ship is out of repair, it is very likely to break down, which will seriously delay the daily operation plan of the liner company and cause certain economic losses. Therefore, it is very necessary to maintain and overhaul the ships on a daily basis. At the same time, the ship administration department will regularly check the operating qualification of the ship, which results in the equipment maintenance cost.

(3) Crew cost

Because of the complexity and unpredictability of the marine environment, it means that the work of crew members is very challenging and their shipping skills are tested all the time. Nowadays, more and more shipping companies gradually realize that an excellent and mature crew team is undoubtedly a hidden wealth, complete the resource reserve work for excellent crew and actively create an excellent crew team. And the formation of crew team should have certain capital investment, mainly including crew's salary, bonus, welfare, insurance premium, etc.

(4) Management cost

The difference between the integrated management of sea transportation and land transportation is that the ship manager has an indispensable role in the normal navigation of shipping and cannot be separated from an advanced scientific operation system. The establishment of ship management organization and ship business department is the premise to ensure the normal operation of shipping plan, which will inevitably generate management cost.

(5) Daily consumption cost

A successful shipping needs the close cooperation of all aspects, such as the burning of gasoline to provide power and the lubricating oil to make the parts cooperate more smoothly, and these daily consumables cost a certain economic cost.

3.Voyage operating costs

As a modern shipping tool, ships need enough fuel to provide constant power to ensure that they can sail continuously in the ocean. For a normal voyage, the liner company has to bear a large amount of economic costs, i.e. vessel's voyage operation costs, which are mainly composed of port making fee, fuel cost, ship's tonnage tax, cargo port service fee, pilotage fee, berthing fee and cargo handling operation fee. Detailed analysis is as follows:

(1) Port charge

The daily construction and maintenance of the port requires a lot of human and financial resources, and the port makes a series of rules for use based on its own economic interests and charges certain fees from the liner company. When charging fees, the port is mainly based on the time of docking ships in port and the volume of transportation. The size of the port is different, and the charges are different, for example, most Southeast Asian ports need to levy wharf sanitation fees, while China's ports will levy tug fees.

(2) Bunker fuel cost

Tight oil resources in today's world have led to a continuous increase in the price of fuel oil, which has invariably increased the transportation cost of liner companies. As the main component of ship operation cost, fuel cost greatly determines the profit rate of liner companies, and an effective management plan can improve their market share and competitiveness. Different locations of fuel purchase, different specifications of fuel and the implementation of international energy policies will all cause differences in fuel costs. To sum up, how to save and use fuel reasonably has become an important issue for liner companies.

(3) Tonnage tax

The tax levied by the national tax bureau on port users based on the purpose that the ship can carry out shipping business normally has two types: 30-day and 60-day, and the rules of levy vary from country to country. However, the expiration of the ship's tonnage tax is handled in the same way in all countries of the world, and the only way to operate normally is to repurchase it. The formula for calculating the ship tonnage tax is as below:

$$T=NT*t \quad (2)$$

T-vessel tonnage tax;

NT-net tonnage of the ship;

t-tax rate

(4) Cargo port charges

For goods in port, ports charge management fees based on the daily maintenance of front waters, and cargo port charges can also be used as one of the profit-making means for ports. The state strictly controls the collection of port charges, which must be in accordance with the relevant provisions of the "Rules of the People's Republic of China on Port Charges". Its calculation formula is:

$$Pc=t1*t \quad (3)$$

Pc-cargo port charges;

t1-tonnage of cargo;

t-tax rate

(5) Pilotage dues

The management authorities generally charge a certain amount of pilotage fee according to the net tonnage class, and set the relevant levy standard by taking into account the influencing factors such as the draught of the ship, the departure rate and the transfer rate. In some ports, pilotage service is compulsory for the purpose of ensuring navigation safety when ships enter or leave the port, resulting in the need for liner companies to pay pilotage dues. The calculation formula is:

$$Po=NT*0.53 \quad (4)$$

Po - pilotage dues;

NT-net tonnage of the vessel

(6) Groundage

Berthing fees, i.e. fees levied when a ship calls at a port for loading and unloading operations, are usually based on factors such as the volume tonnage rate, net tonnage and berthing time of the ship. According to the nature of operation, berthing fees mainly consist of productive berthing fees and non-productive berthing fees, in particular, for the collection of productive berthing fees, the Ministry of

Communications issued strict charging rules in 2015, which have clear rate standards, and different. The formula for calculating the mooring fee is

$$B=NT*t_2*t \quad (5)$$

B-Berthing fee;

NT-net tonnage of the vessel;

t_2 - time;

t-tax rate

(7) Handling Charges

When the transported cargo arrives at the target port, the loading and unloading operations are carried out by manual and machine in most cases, and the handling costs incurred during the operations vary according to the standard rates.

In general, the above shipping costs constitute the total costs incurred in the process of container liner transportation on Company M's Southeast Asia route. The special costs incurred because of the variability of the geographic location of the port terminals contribute to the proper operation of container shipping tasks. In the following, for the established route optimization model, the basic composition of the objective function, the necessary constraints and the practical significance of the parameters will be described in detail, based on the perspective of cost analysis, with the objective of minimizing the total cost of container liner transportation.

4.Analysis of liner shipping cost components

Southeast Asia liner services, as part of the international container shipping network, are also composed of the same shipping costs. Because of the special geographic location in Southeast Asia, special costs are incurred, such as imperfect infrastructure equipment for loading and unloading operations, harsh natural environment, resulting in longer berthing time for container ships and increased possibility of schedule delays.

To sum up, when calling at Southeast Asian ports, it is necessary to bear additional shipping costs and provide more quality services to stabilize ship schedules. The riskiness of criminal acts such as piracy in Southeast Asian waters is higher, so liner companies will increase the insured amount when insuring their transportation tasks.

For the optimization model to be constructed in this paper, the purpose is to minimize the total cost of container liner transportation. In order to ensure the correctness and operability of this mathematical model, an analysis needs to be carried out on the constitutive conditions of the model, the main contents of which are the constraints and the composition of the actual parameters to prove its accuracy. At the same time, in order to combine the optimization model with the actual problems of maritime transportation, as well as to be able to propose an effective reference for the decision making of liner companies, it is also necessary to take into account the actual demand fluctuations of the shipping market, which is extremely necessary.

3.2 Optimization model construction

3.2.1 Related hypotheses

This paper studies regional routes and optimize existing routes for liner companies from the perspective of Company M. The aim is to minimize operating costs with stable transport demand and arrive at the best routes, while verifying the effectiveness of the model and algorithm.

Based on the better construction of container liner transportation optimization model to ensure its convenience and authenticity, and combined with the characteristics of container liner transportation, the following assumptions are made:

(1) The container ships' departure ports are all Ningbo Zhoushan Port, and after arriving at the destination port, they discharge the product and then complete the loading task and finally return to Ningbo Zhoushan Port, and the return schedule settings are all one-weekly, i.e. single-weekly schedule;

(2) Each daily average fuel consumption cost of container ships is provided by historical data;

(3) Excluding the disturbance of external environment, the container ship performs the navigation task under relatively ideal conditions and determines factors such as route structure and navigation speed;

(4) The volume of freight within a fixed cycle design between ports is also fixed, and the problem of route design for container line liner transportation can be decomposed into route optimization within each shift;

(5) In addition to the shipping costs analyzed above, i.e., fixed costs of container ships, fuel costs, port charges and single voyage loading and unloading costs, no consideration is given to other types of shipping costs;

(6) The loading and unloading equipment of each port of call can be completed according to the established plan.

3.2.2 Build the optimization model

（1）Model Symbol Description

m:the number of ports of call of container ships;

n:the number of container ships involved in the transport;

k:the code of the container ship involved in the transport;

i、j:code name of the loading port / discharging port on the route;

C_{ij}:the average daily fixed cost from port i to port j (no other ports are called in between);

V:(0,1,2,...,i,...,j,...,m):the set of alternative ports;

q_i:the total import cargo demand at port i;

Q_{ij}:the export cargo from port i to port j;

S_m:the maximum loading capacity of container transport vessel m;

R_{ij}:The actual quantity of cargoes shipped and discharged from port i to port j;

L_{ij}:the actual sailing distance from port i to port j(no other ports are called in between). In particular, i, j = 0 corresponding to the starting port;

V_1:the speed of container transporting vessel;

P_i:the speed of loading and unloading cargo at port i;

T_i: the time of entering and leaving the port and stopping at port i;

C: average daily fixed usage cost of container transporting vessel;

a_1: average daily consumption of heavy fuel oil of container ship;

a_2: daily average consumption of light oil of container ships;

a_3: average daily consumption of light oil by container ships during the operating hours at ports of call;

b: actual price of heavy oil;

h: actual price of light oil;

d: net tonnage of the container transporting vessel;

p: port charge generated per unit deadweight ton of container transporting vessel;

M: a sufficiently large number

W_i: the rate of unloading charges at port i;

$$x_{ijk} = \begin{cases} 1, \text{ which means when container ship k passes through port j from port i} \\ \text{(no other ports are called in between)} \\ 0, \text{ other} \end{cases}$$

$$x_{ik} = \begin{cases} 1, \text{ which means when container ship k passes through port i} \\ 0, \text{ other} \end{cases}$$

（2）Establish objective function

The objective function constructed in this paper is to minimize the total transportation cost of container liner shipping routes. The objective function can be represented by the following function:

$$\min \sum_{k=1}^{n} \sum_{i=0}^{m} \sum_{j=0}^{m} c_{ij} x_{ijk} \quad (6)$$

The goal of route optimization is to use the least amount of transportation costs to accomplish the most number of shipping tasks and to ensure maximum cost efficiency. The cost of route operation mainly refers to the cost of transportation, while the completed transportation tasks are the ones that allow the transfer of goods in space. In summary, based on the shipping company's perspective, if you want to establish an advantage in the competitive shipping market, is to compete for the most market share through the rational allocation of the fleet's resources, the model's can achieve maximum effectiveness. The goal of route optimization is to use the least transportation cost to accomplish the most number of shipping tasks to ensure the maximum cost efficiency. The cost of route operation mainly refers to the transportation cost, while the completed transportation tasks are the ones that can achieve the transfer of goods in space. In summary, based on the shipping company's perspective, if you want to establish an advantage in the competitive shipping market, is to compete for the most market share through the rational allocation of the fleet's resources, the model's can achieve maximum effectiveness.

（3）Model Constraints

1. Number of transport vessels constraint

$$\sum_{i=1}^{m}\sum_{k=1}^{n} x_{ijk} = 1, \forall j = 1, \ldots, m \quad (7)$$

$$\sum_{j=1}^{m}\sum_{k=1}^{n} x_{ijk} = 1, \forall i = 1, \ldots, m \quad (8)$$

Corresponding to the second hypothesis, the above equations all indicate a single container ship calling the target port.

2. Container capacity constraint

$$Q_{ij} \leq S_m , \forall i, j = 1, \ldots, m \quad (9)$$

At any times, the cargo onboard should not exceed the container capacity.

3. Loading constraints of transport vessel

$$\text{If } Q_{ij} > 0,\ \sum_{k=1}^{n} x_{ik} x_{jk} \geq 1$$

$$Q_{ij} - M\sum_{k=1}^{n} x_{ik} x_{jk} < 0, \quad i = 1,2, \ldots m; \ j = 1,2, \ldots, m \quad (10)$$

The above formula indicates that if there is a transport task from port i to port j, there must be a vessel k to call at port i and this vessel must call at port j later, but it is not necessary to call at port j directly after leaving from port i.

4.The setting constraint of central port

$$\sum_{j=1}^{m} x_{0jk} = 1 \quad k = 1,2 \cdots n \quad (11)$$

$$\sum_{j=1}^{m} x_{j0k} = 1 \quad k = 1,2 \cdots n \quad (12)$$

Corresponding to the first assumption condition, the above equation indicates that the departure port of each container ship is Ningbo Zhoushan Port, and after arriving at the destination port, it completes the loading task and finally returns to Ningbo Zhoushan Port.

4. Departure constraint of transport vessel

$$\sum_{i=0}^{m} x_{i0k} - \sum_{j=0}^{m} x_{0jk} = 0, i, j = 1, \ldots, m; \ k = 1, \ldots, n \quad (13)$$

The above equation indicates that after unloading operations have been performed after calling at the target port, the vessel must also depart from that port.

5. Voyage time constraint

$$\sum_{i=0}^{m}\sum_{j=0}^{m}[(L_{ij}\times V_1+T_i+T_j)\div 24]\le 7 \quad (14)$$

The voyage time should better not exceed one week.

3.2.3 Calculation specification of objective function

The amount of the international shipping cost reflects the profitability of liner enterprises to a certain extent, so minimizing the cost of expenses incurred during the operation of the route as the purpose of optimization is also the main problem analyzed when constructing the optimization model. And the shipping cost mainly consists of fixed cost of container ship, fuel consumption cost of container ship, port make fee, loading and unloading cost.

(1)Fixed cost of container ships

In the specific region and time period, the fixed cost generation remains constant with the change of transportation quantity. The metric formula for calculating fixed cost is as follows:

$$\sum_{i=0}^{m}\sum_{j=0}^{m}\sum_{k=1}^{n}[\frac{L_{ij}X_{ijk}}{v_1\times 24}+(\frac{q_i}{p_i\times 24}+T_i)\times x_{ijk}]\times C \quad (15)$$

(2) Fuel Costs

The choice of different fuel resupply options usually results in relatively large cost cost differences. The metric formula for calculating the fuel cost is as follows:

$$\sum_{i=0}^{m}\sum_{j=0}^{m}\sum_{k=1}^{n}[\frac{L_{ij}X_{ijk}}{v_1\times 24}\times a_1\times b+\frac{L_{ij}X_{ijk}}{v_1\times 24}\times a_2\times h+(\frac{q_i}{p_i\times 24}+T_i)\times x_{ijk}\times a_3\times h] \quad (16)$$

(3) Port charges

The port charges are mainly composed of pilotage fees, tug fees, ship tonnage tax, etc. The formula for calculating the port charges is as follows

$$\sum_{i=1}^{n}(D \times p \times x_i) \quad (17)$$

(4) Handling charges for single voyage

After the ship arrives at the destination port, the container transport ship for handling operations, resulting in the cost of loading and unloading cargoes. The formula of single voyage handling charges is as follows:

$$\sum_{i=1}^{n}(q_i \times x_i \times w_i) \quad (18)$$

Combining the fixed cost of container ships, the bunker charges of container ships, the port charges and the handling charges, the total cost of shipping is calculated by the following formula:

$$\sum_{k=1}^{n}\sum_{i=i}^{m}\sum_{j=1}^{m} c_{ij}x_{ijk} = \sum_{i=0}^{m}\sum_{j=0}^{m}\sum_{k=1}^{n}[\frac{L_{ij}X_{ijk}}{v_1 \times 24} + (\frac{q_i}{p_i \times 24} + T_i) \times x_{ijk}] \times C + \sum_{i=0}^{m}\sum_{j=0}^{m}\sum_{k=1}^{n}[\frac{L_{ij}X_{ijk}}{v_1 \times 24} \times a_1 \times b + \frac{L_{ij}X_{ijk}}{v_1 \times 24} \times a_2 \times h + (\frac{q_i}{p_i \times 24} + T_i) \times x_{ijk} \times a_3 \times h] + \sum_{i=1}^{n}\sum_{k=1}^{n}(D \times p \times x_{ik}) + \sum_{i=1}^{m}\sum_{k=1}^{n}(q_i \times x_{ik} \times w_i) \quad (19)$$

4 Current situation of liner routes in Southeast Asia of M Shipping Company

4.1 M company profile

M SHIPPING COMPANY, the world's second-largest container fleet liner transportation and shipping agency, is an international shipping company which was founded in 1904. With a global service network, it also has a high market share and first-class competitiveness in China, occupying the leading position in China's shipping industry and capable of providing extensive and comprehensive shipping services. Advanced information systems and standard operating procedures are adopted to ensure the smooth implementation of transportation services. Through business exchanges with customers at home and abroad, M shipping company has made sincere efforts and dedication to the shipping industry. With hundreds of offices in more than 100 countries, M company serves the world's shipping industry, terminal operations, logistics, oil and gas exploration and production, etc.

The top three global liner companies in terms of shipping capacity are Mediterranean Shipping, M Shipping Company and CMA CGM Group. The total shipping capacity of these three companies accounts for 46.7% of the market share, among which M Company accounts for 16.0%. The specific ranking and shipping capacity is shown in the figure below.

Table 1 Ranking table of global shipping companies

	Operator	Teu	Share
1	Mediterranean Shg Co	4,673,148	17.80%
2	M Shipping company	4,207,312	16.00%
3	CMA CGM Group	3,387,140	12.90%
4	COSCO Group	2,866,465	10.90%
5	Hapag-Lloyd	1,795,177	6.80%

Data source: Alphaliner

4.2 Southeast Asia liner route status analysis of M Company

President Xi made a series of visits to Central Asia and Southeast Asia in September and October 2013, based on which he proposed the strategic concepts of "One Belt, One Road" and "21st Century Maritime Silk Road". Under the promotion of the Belt and Road Initiative, the economic and trade relations between China and

Southeast Asian countries are getting closer and closer, and the shipping industry is the main guarantee of this relationship. The "Belt and Road" strategic vision connects China with a vast region of Southeast Asia, covering 11 countries with a total population of over 1.8 billion and an economy of over 20 trillion dollars. It accomplishes a significant amount of trade activity by sea and promotes economic cooperation between China and Southeast Asian countries.

In addition, the Belt and Road Initiative provides more investment opportunities and development opportunities for countries along the route. This provides a wide market space for China and Southeast Asia routes. For Southeast Asian countries, the emergence of large container ships can not only provide them with broader trade channels but also more sources of goods, thus promoting the better integration of developing countries in Southeast Asia into the development process of globalization. In this process, China has gradually become a solid force to promote the trade development of Southeast Asian countries.

Taking Southeast Asia as an example, as shown in the table below, the overall container traffic of Company M's Southeast Asia route showed an upward trend, with slight ups and downs after 2014, while 2016 showed a stable upward trend, and the total container trade in Asia also showed an upward trend. Now Southeast Asia market has become its main strategic maritime target.

Figure 6 South East Asian lines Container cargo traffic volume

Data source:Containerization

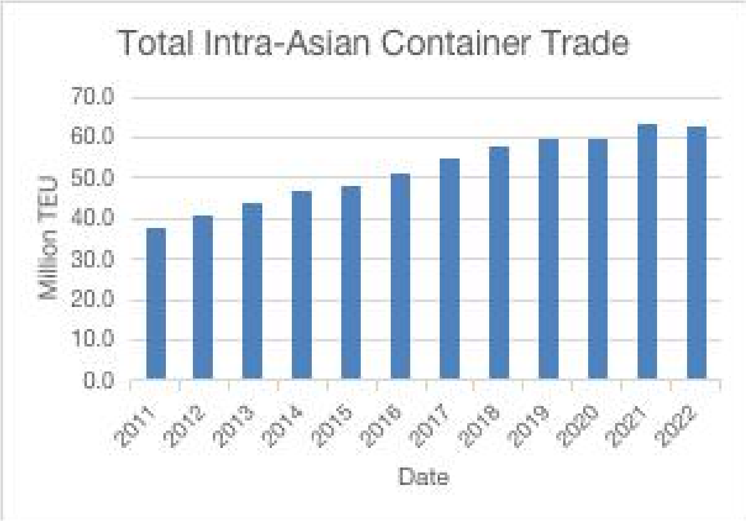

Figure 7 Total Intra-Asian Container Trade

Data source:Clarkson

Taking Southeast Asia as an example, as shown in the table above, the overall container traffic of Company M's Southeast Asia route showed an upward trend, with slight ups and downs after 2014, while 2016 showed a stable upward trend, and the total container trade in Asia also showed an upward trend. Now Southeast Asia market has become its main strategic maritime target.

M has opened several circular routes according to the demand plan, involving Haiphong, Ho Chi Minh, Laem Chabang, Racha, Bangkok, Malacca, Manila, Samba-wan, Singapore, Klang, Kaohsiung, Jakarta and other Southeast Asian ports, and the demand for container cargo transportation between ports of each route can be derived from the actual survey.

For the convenience of analysis, four simplified routes with Ningbo-Zhoushan port as the port of origin and destination are selected in this paper.

1.The operation design of the first route is Ningbo-Zhoushan / Singapore / Ho Chi Minh /Laem Chabang / Ningbo - Zhoushan.

2.The operation design of the second route is: Ningbo-Zhoushan /Nansha New Port/Bangkok/ Lem chabang /Ningbo-Zhoushan.

3.The operation design of the third route is: Ningbo-Zhoushan /Sembawang /Jakarta /Ningbo-Zhoushan.

4.The operation design of the fourth route is: Ningbo-Zhoushan /Yogyakarta / Jakarta/ surabaya /Ningbo-Zhoushan.

The schedule information of each route is shown in the table below.

Table 2 Schedule of liner route

liner route	1	2	3	4
schedule	Bi-weekly shift	Weekly shift	Bi-weekly shift	Weekly shift

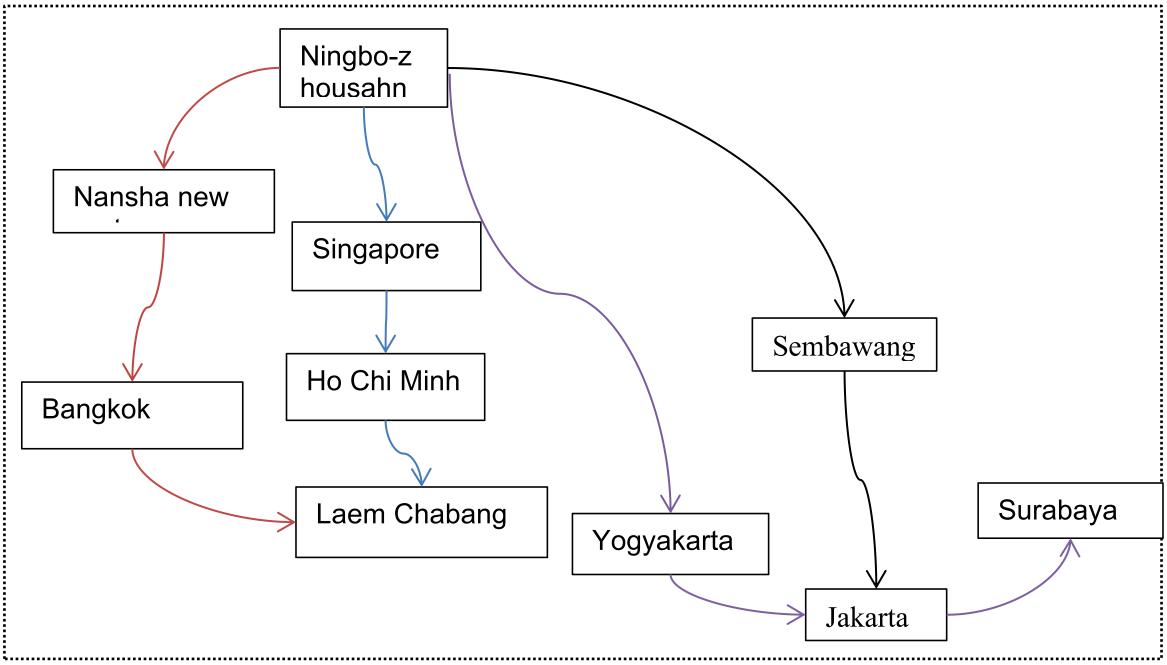

Figure 8 Schematic of company M’ s South East lines

Through the analysis of M's Southeast Asia container liner shipping routes, combined with M's current service level and operation, the following problems are found:

(1)Overlapping ship routes and duplicated port calls

Currently, Company M only considers the transportation demand from the port without considering the sailing distance and transportation cost. Due to the unreasonable route design of double and single week, there is a part of the same route between the liner of different schedules, thus causing the capacity of the liner container fleet to be seriously wasted, thus increasing the transportation cost while the capacity is relatively smooth. Multiple callings of container vessels of different schedules will lead to partial overlapping of routes or the same schedule of vessels calling the same ports, which will not only lead to the waste of capacity but also lead to the increase of frequency of container vessels, thus leading to the increase of operating costs of vessels, and at the same time will lead to the decrease of service quality. For example, the single weekly class and a bi-weekly class of container vessels of Company M have the phenomenon of route overlap and repeated calls to Ho Chi Minh Port, Linchaban Port and Jakarta Port, respectively. Therefore, to avoid the existence of the same liner routes in the transportation network of different schedules, and also to save shipping costs and improve shipping efficiency, it is necessary to make proper planning and integration of the routes of different schedules.

(2) Disconnected external communication and low service level

The operation of shipping enterprises is closely connected with ports. However, in the Southeast Asian maritime freight market, the lack of overall regional collaboration, the unclear functional positioning of each port, the low efficiency of information transmission between liner enterprises and each port, and the lack of resource-sharing ability have led to the imbalance in the development of feeder ports. These thus lead to a shortage of their service capacity, which is challenging to adapt to the needs of the growing international container transportation. The number of shipping companies operating container liner transportation is significant, and most of them lack effective management, and they are working separately and competing with each other, which makes it difficult for the liner companies to get stable cargo sources so that the container cargo sources that should belong to M companies are lost, and the degree of union and complementarity between various shipping enterprises decreases, which leads to the large flow of customer groups, low level of development of logistics industry, and difficulty in optimizing transportation costs.

(3) Unclear market positioning and single development mode

Due to the commitment to pursue market share and economies of scale rather than profit and profitability, the decline in freight rates caused by the entry of other large shipping companies into the regional market will cause difficulties for M companies aiming to pursue profitability and excellent customer service. In addition, with the increasing competition in the international container shipping market, the need for logistics consolidation has increased, and M's current Southeast Asia service is still container-based and highly substitutable. Therefore, to maintain its current dominant position, Company M must reduce its operating profit at the expense of gaining sufficient market share. Company M is not working on side services such as break-bulk transportation, and its competitive advantage is gradually being eroded. This situation, due to the lack of resource sharing and complementary capabilities, makes Company M limited in its future long-term growth.

4.3 Research problem description

When a liner company plans a certain transport task, cost, as a decisive factor, must be considered for cost analysis. Thus the liner route optimization problem can be formulated as follows: It is known that the liner company has a fleet of n ships with the same box load (4500 TEU). And it serves some fixed m ports.

For the optimization model to be constructed in this paper, the aim is to minimize the total cost of container liner transportation. To simplify the model, it is assumed that the total transportation cost includes the fixed cost of the container ship, port charges, bunker cost and handling charges.

it is necessary to analyze the constitutive conditions of the model, whose main elements are the constraints and the composition of the actual parameters to prove its accuracy. The objective function is to minimize the total cost. The known conditions are the set of alternative ports, the cargo demand of the ports, etc. Other relevant parameters are vessel capacity, average daily fuel consumption, light/heavy fuel prices, port handling charges, etc.

To take into account the convenience of the model, there are some preconditions assumed:

The ship's origin and destination are both Ningbo Zhoushan Port; the cargo volume is fixed between ports; no other costs are considered except for the above-mentioned freight rates; the loading and unloading facilities at each port can complete their tasks as planned, and so on.

5 Case study

5.1 Related parameter setting in the model

Other parameter settings are as follows.

(1) Ports of call: Ningbo-Zhoushan, Nansha New port, Bangkok, Laem chabang, Sembawang, Jakarta, HoChiMinh, Singapore, Yogyakarta, Surabaya.

(2) are recorded as "1, 2, 3,...,9", in addition, Ningbo Zhoushan port is recorded as "0";

(2) Schedule setting: single-weekly and bi-weekly

(3) Observation period: one voyage

(4) Each port of call takes the same rate except for the handling fee

(5) Average daily shipping fixed cost: 65,000 yuan

(6) Price of heavy oil: 4500 yuan/ton

(7) Price of light oil: 5600 yuan/ton

Table 3 Related parameter setting in the model

Actual container capacity（TEU)	voyage speed（nm/h）	Daily average heavy oil consumption（mt） a1	Average daily light Oil consumption（mt） a2	Average daily light oil consumption in port operations（mt） a3	Maximum container capacity (TEU)
4500	25	100	12	3	5000

Data resource：Containerization

5.2 Data collection

In this paper, the Southeast Asia liner route of Company M is selected as the optimization object, based on ensuring the normal navigation of container ships, the bunker quantity of ships is determined by the voyage time, bunker consumption rate during the voyage and during the berth and the lay time, the distance information between the designed ports in four Southeast Asia routes of Company M is shown in the following table.

Table 4 The distance between every ports on the first route/ nautical mile

L_{ij}	Ningbo-Zhoushan	Singapore	HoChiMinh	Laem chabang
Ningbo-Zhoushan	0	2640	1945	2753
Singapore	2640	0	774	850
HoChiMinh	1945	774	0	804
LaemChabang	2753	850	804	0

Data resource: McDistance

Table 5 The distance between every ports on the second route/ nautical mile

Port	Ningbo-Zhoushan	Nansha New Port	Bangkok	Laem chabang
Ningbo-Zhoushan	0	996	2820	2753
Nansha New Port	996	0	1917	1850
Bangkok	2820	1917	0	67
Laem chabang	2753	1850	67	0

Data resource: McDistance

Table 6 The distance between every ports on the third route/ nautical mile

Port	Ningbo-Zhoushan	Sembawang	Jakarta
Ningbo-Zhoushan	0	2618	3287
Sembawang	2618	0	587
Jakarta	3287	587	0

Data resource: McDistance

Table 7 The distance between every ports on the fourth route/ nautical mile

Ningbo-Zhoushan	Yogyakarta	Jakarta	Surabaya
0	3149	3287	3693
3149	0	138	544
3287	138	0	406
3693	544	406	0

Data resource: McDistance

Table 8 Operational indicators for each port

	Port	Total import demand (TEU)	P_i : Port efficiency(TEU/h)	T_i : waiting time(hours)	W_i :Handling rate (yuan/TEU)	p:Port charge (yuan/TEU)
0	Ningbo-Zhoushan	15670	114	/	52	12
1	Nansha New Port	15500	114	3	52	12
2	Bangkok	12025	114	3	52	12
3	Laem chabang	11921	114	3	52	12
4	Sembawang	10013	114	4	52	12
5	Jakarta	11256	114	4	52	12
6	HoChiMinh	8946	114	3	52	12
7	Singapore	11591	114	4	52	12
8	Yogyakarta	5280	114	4	52	12
9	Surabaya	7512	114	2	52	12

Table 9 Demands between the ports

Loading port	Destination	TEU
Nansha New Port	Ningbo-Zhoushan	2045
Bangkok	Ningbo-Zhoushan	1310
Laem chabang	Ningbo-Zhoushan	4537
Sembawang	Ningbo-Zhoushan	1103
Jakarta	Ningbo-Zhoushan	1934
HoChiMinh	Ningbo-Zhoushan	1678
Singapore	Ningbo-Zhoushan	1052
Yogyakarta	Ningbo-Zhoushan	1005
Surabaya	Ningbo-Zhoushan	1106
Ningbo-Zhoushan	Nansha New Port	5000
Bangkok	Nansha New Port	1747
Laem chabang	Nansha New Port	3710
Jakarta	Nansha New Port	2481
HoChiMinh	Nansha New Port	2562
Ningbo-Zhoushan	Bangkok	6879
Nansha New Port	Bangkok	1370
Singapore	Bangkok	2821

Laem chabang	Bangkok	955
Ningbo-Zhoushan	Laem chabang	5446
HoChiMinh	Laem chabang	3936
Bangkok	Laem chabang	2539
Ningbo-Zhoushan	Sembawang	7968
Jakarta	Sembawang	2045
Ningbo-Zhoushan	Jakarta	6364
Sembawang	Jakarta	2375
Yogyakarta	Jakarta	2517
Ningbo-Zhoushan	HoChiMinh	1880
Singapore	HoChiMinh	7066
Ningbo-Zhoushan	Singapore	9767
Nansha New Port	Singapore	1824
Singapore	Yogyakarta	5280
Ningbo-Zhoushan	Surabaya	5632
Jakarta	Surabaya	1880

5.3 Model solution

In this paper, we study the optimization of shipping lines with the aim of minimizing the total cost of container transport.

（1）Genetic Algorithms

Genetic algorithm belongs to intelligent bionic algorithm, the idea originates from biological genetics and the natural law of survival of the fittest, it is an iterative process search algorithm implemented according to the principle of genetic genetics. The starting point is the research problem, the genetic algorithm starts with a population of many individuals, and the new set with the same chromosomes is found through the relevant theories of genetic coding and genetics.

According to Darwin's evolutionary theory, it imitates the genetic and evolutionary process of natural organisms, combines the evolutionary law of superiority and inferiority in genetic theory with the random exchange of chromosomal information, and solves practical problems through encoding, decoding and related transformation of changes. In essence, it naturally mimics the process of biological evolution, the crossover of parental chromosomes and the rate of change of specific selection of the whole collective, and the matching of the new offspring required to obtain a solution to the problem, the offspring, i.e. the results of the subtest. The previous repetition is the initial value for the next repetition. After repeating the cycle several times, it stops until the domain of the solution is stable or satisfies the requirements of the algebra.

The linear programming model in this article is based on fixed shipping costs. In designing a genetic algorithm, the objective problem is encoded with the premise of determining the port of call. A natural iteration forms an initial population of hanging port sequences. The fitness function is calculated and evaluated to judge if it meets the standard for replication. Individuals that meet the standard are selected for replication operations, leading to optimization and the creation of new individuals. The process is repeated until a certain goal is achieved, resulting in the target function of minimizing operating costs for lower-level algorithms.

The specific steps are shown below.

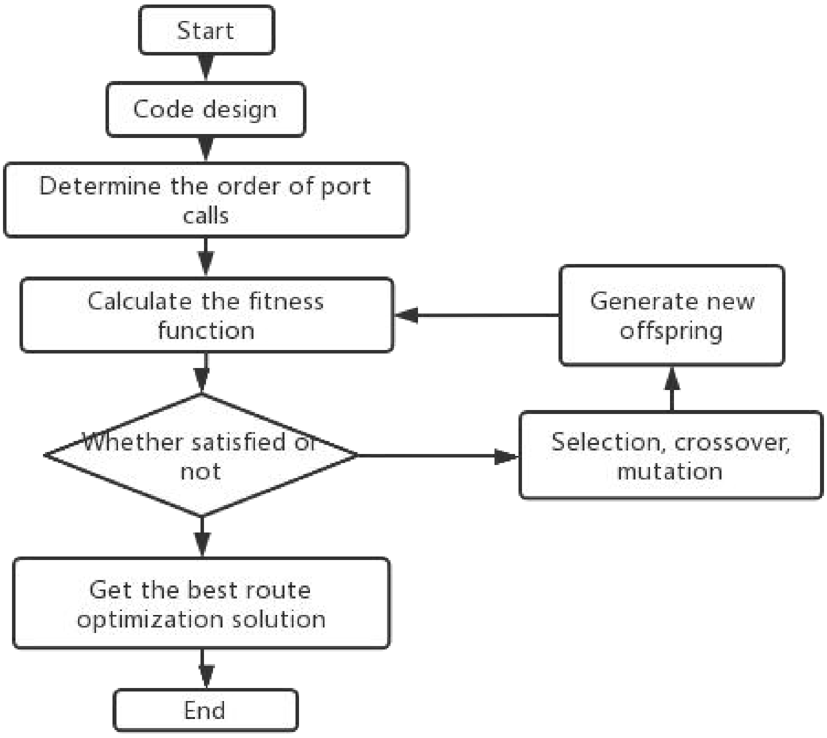

Figure 9 Flow chart of genetic algorithms

(2)Code design

Encoding is a prerequisite for performing genetic algorithm operations, and binary, decimal and Gray codes are generally used to prepare for model solving. In this paper, real number encoding is used for constructing the model, which has the same length of encoding and the same number of variables, and has the characteristics of high flexibility and wide applicability. Assuming that there are n alternative ports, n codes are generated to indicate the selection of the order of ports of call. In addition, Arabic numerals are used to indicate the ports of call of container ships, for example, 0 is used to indicate the starting point and termination point, and a set of codes is 02410, which indicates that the selected port call sequence is 0-2-4-1-0, starting from the starting point and finally returning to the starting point.

(3)Selection, crossover, mutation

Selection: an operation based on the value of fitness, the probability of an individual with strong fitness producing offspring is higher than that of an individual with weak fitness, which invariably corresponds to the law of survival of the fittest in nature, and the probability of an individual being selected for is $p(x_i) = \frac{F(x_i)}{\sum_{i=1}^{N} F(x_i)}, i = 1,2,...,N$.In conjunction with the object of this paper, it is to make a more optimal choice from the currently feasible options for port attachment.

Crossover: as the main operation in the genetic algorithm, it is the process of getting the population of offspring before the offspring can inherit the characteristics of their parents. In this paper, we adopt the two-point crossover method, for two randomly generated crossover points, and swap the elements between the two crossover points. The following diagram shows the two-point crossover:

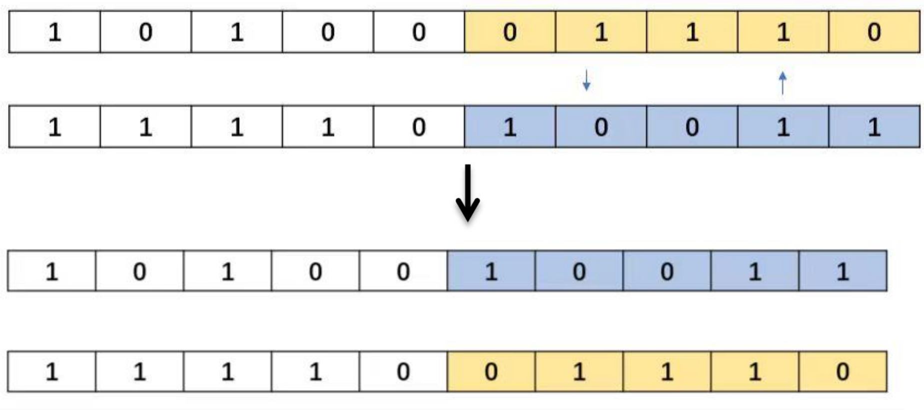

Figure 10 Genetic algorithm two-point crossover operation diagram

Mutation: The possibility of mutation in genetic algorithms is low, and the probability of mutation is usually between 0.1% and 0.6% in the case of randomly selected individuals that change the gene locus in their structure. In this paper, the algorithm uses inversion mutation, and its steps are mainly: firstly, the existing individuals in the gene cluster are judged to be mutated or not with a probability of 0.1%~0.6%, and new individuals are obtained by inversion mutation of randomly selected gene regions, which ensures that the genetic algorithm has local random search ability and can accelerate convergence to the optimal solution, which is conducive to obtaining more excellent individuals.

(4)Fitness function

Genetic algorithm in the evolutionary operation only based on the fitness function to search, its selection has a direct impact on the convergence speed of genetic algorithm and the necessity of the optimal solution, the evaluation of the merit of the individual is also dependent on the value of the fitness of the individual, according to the size of the fitness of the individual for the superiority of the inferiority. By constructing a mapping relationship between the cost objective function of route optimization and the fitness of an individual, the solution to the optimization problem of this paper can be achieved in the process of population evolution. This paper is based on a linear programming non-negative function for minimizing the cost of maritime operations, which follows the mapping relationship that the smaller the value of the objective function, the higher the fitness and non-negative, so the objective function is treated as follows:

$$F_x = \begin{cases} \frac{1}{f(x)}, & f(x) \neq 0 \\ 0, & f(x) = 0 \end{cases} \quad (20)$$

In the above formula, f(x) denotes the objective function and F(x) denotes the fitness function.

5.4 Analysis of numerical results

This paper solves the problem and optimizes the determination of the order of the alternative ports of call through genetic algorithm. Based on the practical requirements, the algorithm parameters are set as follows: initial population = 100, cross rate = 0.9, variation rate = 0.1; maximum number of iterations = 1000; chromosome length (i.e., the number of ports of call) = 10.

```
%% 遗传算法参数
NP = 10;                    % 种群大小
maxgen = 10;              % 最大进化代数
Pc = 0.9;                   % 交叉概率
Pm = 0.1;                   % 变异概率
Gap = 0.9;                  % 代沟(Generation gap)
```

The single-weekly and bi-weekly container ships of Company M have the phenomenon of route overlap and duplicate calls to the ports of Laem Chabang and

Jakarta, respectively. Each time the port of call is discharged, the ports of call with overlapping routes should be adjusted to the single-weekly route when optimising the route. Furthermore, the port of Jakarta will be cancelled in the single weekly service to avoid the problem of repeated calls as much as possible.

In summary, the minimum cost of the objective function of the established linear programming model is 24.135 million yuan, and the cost of the optimized Southeast Asia route of Company M is reduced by 349 thousand yuan.

Table 10 The comparision of pre-optimized routes and optmized routes

	Pre-optimized routes	Optimized routes	Cost after optimization
Bi-weekly	Ningbo-Zhoushan / Singapore / Ho Chi Minh /Laem Chabang / Ningbo - Zhoushan	Ningbo-Zhoushan /Ho Chi Minh /Laem Chabang/ Bangkok/ Yogyakarta/ Jakarta /Ningbo-Zhoushan	24.135million
	Ningbo-Zhoushan /Sembawang/Jakarta /Ningbo-Zhoushan.		
weekly	Ningbo-Zhoushan /Nansha New Port/Bangkok/ Lem chabang /Ningbo-Zhoushan	Ningbo-Zhoushan /Singapore/Sembawang /Nansha New Port/ Ningbo-Zhoushan	
	Ningbo-Zhoushan /Yogyakarta / Jakarta/ surabaya /Ningbo-Zhoushan		

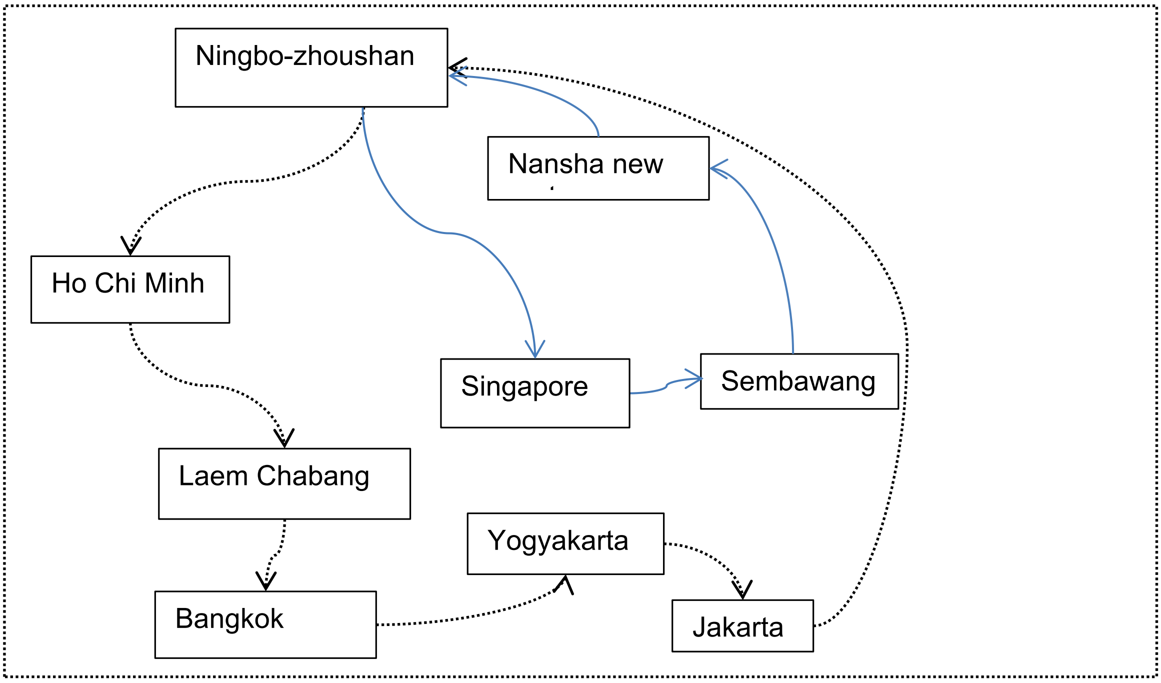

Figure 11 Schematic diagram of routes after optimization

Optimal path: 0>6>3>2>8>5>0>7>4>1>0

Route 1: the total export volume is 49,428, and the path is 0>6>3>2>8>5>0;

Route 2: the total export volume is 37,104, and the path is 0>7>4>1>0;

The total cost: 24135223.4

6. Conclusion and Recommendations

Based on collecting information about container liner transportation of the Southeast Asia route of Company M, this paper analyzes the current situation of container liner transportation of the Southeast Asia route of Company M in detail, builds the shipping network optimization model by drawing on the existing research results of route optimization, and studies this problem from the perspective of combining qualitative and quantitative. On the one hand, the problem is analyzed qualitatively by analyzing the current situation and shortcomings of container liner transportation of the Southeast Asia route of Company M. On the other hand, the problem is studied from both qualitative and quantitative perspectives.

On the other hand, the problem is studied quantitatively by constructing the shipping network optimization model and designing the optimization algorithm.

6.1 Conclusion

The work done in this paper for the optimization of the container liner transportation network of the Southeast Asia route of Company M can be summarized in the following aspects:

(1) First, it summarizes the theories related to container liner shipping routes, the development status of container liner shipping, liner schedules, and shipping routes, and analyzes the necessity of shipping network optimization and the main contents to be optimized through qualitative analysis.

(2) Secondly, the basic situation of the Southeast Asia shipping market of M Company is introduced. On this basis, the current situation of container transportation of the Southeast Asia route of M Company is analyzed with Ningbo Zhoushan Port as the central port, which provides guidance significance for further optimization research below. Subsequently, for the above analysis and research, the

problems of the Southeast Asia liner shipping routes of Company M with different schedules are described, which guides the following route optimization and the establishment of an optimization model.

(3) The operating cost of container liner transportation in Southeast Asia is introduced to provide the basis for establishing the objective function. Then the routes of different schedules are integrated, and the optimization model of the container liner transportation network based on the minimum cost objective function is constructed. A genetic algorithm solves the problem of obtaining the optimal route setting of container liner transportation of Company M in Southeast Asia with different schedules. The minimum cost of the model output objective function is 24.484 million yuan, and after route optimization, the operating cost is reduced by 349,000 yuan, and the operating cost is 24.135 million yuan.

(4) Combining the above with the overall situation of the container liner shipping service level of the Southeast Asia route of Company M, a series of methods and countermeasures must be taken in a targeted manner in order to improve the market competitiveness of Company M. For example continuously, rational planning of liner schedules and routes, strengthening communication and cooperation with the outside world, and rational planning of market positioning.

Although this paper has analyzed and researched the container liner transportation of the Southeast Asia route of Company M as much as possible, optimized and integrated its transportation network in different schedules, and finally made some development suggestions due to the limited ability of the authors, there are some shortcomings in this paper:

(1) Due to the limitation of the literature search, there is no detailed analysis and comparison of the current situation of Southeast Asia container line transportation of other liner companies.

(2) When constructing the model, the treatment of variables is somewhat limited, and only spot oil prices are used in this paper due to the volatility of oil prices.

(3) The improvement measures proposed in this paper are only analyzed theoretically and still need to be put into practice, limiting the practical basis of this study. For this reason, in the future, we can try to collect the current situation of the development of foreign container transport by checking the Internet information,

actively learning from its advanced experience, and apply the results of the study to reality, and carrying out further optimization by comparing the actual costs before and after optimization, to achieve the purpose of optimizing the container liner transport network of Southeast Asia route of Company M.

(4) The model in this paper takes the minimization of container liner transportation cost as the objective function and does not consider the profit factor of carrying different containers. In future research, we can consider profit maximization as the objective function so that the model can consider more revenue factors when selecting the ports of call of each container shipping route and make the slot assignment of the route more reasonable.

6.2 Liner transport development recommendations for M Shipping Company

From the previous analysis, it can be seen that the total volume of container transportation of Southeast Asia route of Company M in the next few years is on a rising trend year by year, and although the overall development momentum is relatively good, there are still many shortcomings, for example, the formulation of liner schedules, market positioning and the selection of ports of call are on the low side, especially the selection of routes seriously restricts the level of feeder liner transportation of Company M. Therefore, in order to improve the overall situation of container liner shipping service level of Southeast Asia route of Company M, a series of methods and countermeasures must be taken in a targeted manner in order to continuously improve the market competitiveness of Company M. In the relatively competitive container transportation market, the four aspects of how to solve the problem of reasonable planning of liner schedules and routes, how to strengthen cooperation with ports and other liner companies, how to plan market positioning and how to improve the service level of Company M should be analyzed, and effective countermeasures should be proposed in the light of the actual situation of Company M.

(1) Rational planning of liner schedules and shipping routes

The liner schedule and the planning and design of transport routes are the determining factors of the efficiency of container transport, so when planning the schedule, it is necessary to combine the actual situation of the port of call, the development trend of the shipping market, the natural environment and national policies and other factors also have more or less influence on the optimization of routes.

First, M Company should use existing transportation resources and use them best through ship scheduling. To avoid duplication of routes, in other words, to make full use of the capacity to maximise efficiency and to stop the phenomenon of the same routes occurring in different schedules. Economic integration continues to deepen, resulting in an unpredictable shipping market; the competition is extremely fierce, and the emergence of new ports of call may interfere with the original route. Therefore, we should fully consider the overall impact of the new port of call on the route, consider the operating cost, transportation efficiency, and service level, and choose the best route to meet the shipping requirements better. In addition, pay special attention to the economic cost troubles brought by opening new routes or leasing large capacity and large volume ships.

Secondly, the natural environment seriously affects the container liner company, so the schedule planning should be combined with the environmental conditions at sea as reasonably as possible and avoid the sea area with a higher danger coefficient in advance. At the same time, if the ship travels against the wind, it will slow down the speed to a certain extent and lead to a delay in the schedule, so it should avoid the seasonal gale affecting the schedule and route planning.

(2) Strengthen outside communication and cooperation to improve the overall service level

First of all, the company should strengthen its cooperation with ports.

More and more liner companies are investing in the construction of terminals to customize their exceptional services to improve the service level or avoid being constrained in every way. Liner companies mainly cooperate with port groups through sole proprietorship development or acquisition of terminals. The government plans the land and shoreline grant, then puts forward the conditions for public bidding, and the liner companies fund the bidding to develop, build and operate the specific terminals. Enterprises and ports jointly own shares in the operation of terminals, with port authorities taking equity in kind and liner companies usually investing in equity, with both having decision-making power. This move can increase the closeness between ports and liner companies and realize the interactive chain of container transportation to improve the comprehensive competitiveness of M companies, stabilize the market source of cargo, and improve the structure of shipping networks.

Liner companies need to enhance market competitiveness and improve overall service levels. Based on dividing the container transportation market in advance, for the difference of customer groups, planning transport services with a different focus and fighting for richer cargo sources through their excellent strength. The liner company should take the actual import and export volume of containers as the basis and plan the unique route with the port, which is more suitable for the actual situation. The liner company can make specific arrangements on port selection, ship quantity and specification according to the requirements of different ports to improve the liner company's revenue and expand the classified cargo source.

Secondly, to strengthen the cooperation with other shipping companies.

According to the international container liner shipping market cycle law, the peak time is much shorter than the trough time. If the operation efficiency in the peak time is high enough, the profit can be guaranteed for the whole year; on the contrary, the possibility of economic loss in the trough time of the market is higher. Liner companies must obey such a cyclical law and strive to make prudent decisions on large amounts of risky investments after reaching a specific scale of operation, observing the objective law; in other words, the proportion of cost investments should be manageable.

Usually today's international transport operators usually will control the fixed capital investment in ships and infrastructure to ensure the efficiency of operation. The alliance is a crucial way to show the operation rules of container liner shipping under continuous practical exploration; the shipping industry has formed the consensus that the alliance is the way to go, mainly through pick-up, space charter, mutual space charter, and expected ship dispatch to Realize.

Finally, reasonable market positioning and diversification are needed.

We will gradually diversify into related industries by improving the competitiveness of the liner shipping system and market and utilizing the existing resources of liner companies. First, take the existing business as the focus, expand upstream and downstream, and focus on building a sustainable and profitable container liner integrated service chain. Seeking more opportunities in the market, improving the service system, enhancing the efficiency of the transportation network and maximising the satisfaction of the ever-changing long-term logistics needs will further enhance the core competitiveness of the company, and the sustainable development of the company will be the crucial issue in M's future strategic planning.

When a liner company enters a new business area, it will actively strengthen its initial competitive advantage. The newly opened business area and existing business resources may lead to resource sharing; in other words, the liner company's existing business and resources have competitive advantages, bringing some competitive advantages to the unknown business area that needs to be tapped or the new business area will increase the competitive advantages of the company's existing business area. The ultimate goal of differentiation is not to reduce the original resource capacity of the liner shipping business but to increase its overall competitiveness and impact.

Company M still has favourable growth opportunities in its currently fully active business areas and should focus on developing its active resources and capabilities in its existing business areas to achieve growth and expand profitability. In conclusion, Company M should continue to focus on its container transportation business, complemented by other value-added business activities, with its core business contributing to its non-core business and its non-core business contributing to its core business.

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