World Maritime University
The Maritime Commons: Digital Repository of the World Maritime University

World Maritime University Dissertations | Dissertations

8-22-2015

Optimization of East Med service of ZIM

Yuntao Xie

Follow this and additional works at: https://commons.wmu.se/all_dissertations

Part of the Business Analytics Commons, Marketing Commons, and the Transportation Commons

Recommended Citation
Xie, Yuntao, "Optimization of East Med service of ZIM" (2015). *World Maritime University Dissertations*. 1581.
https://commons.wmu.se/all_dissertations/1581

This Dissertation is brought to you courtesy of Maritime Commons. Open Access items may be downloaded for non-commercial, fair use academic purposes. No items may be hosted on another server or web site without express written permission from the World Maritime University. For more information, please contact library@wmu.se.

WORLD MARITIME UNIVERSITY

Shanghai, China

Optimization of East Med Service of ZIM

By

Xie YunTao

China

A research paper submitted to the World Maritime University in partial Fulfilment of the requirements for the award of the degree of

MASTER OF SCIENCE

(INTERNATIONAL TRANSPORT AND LOGISTICS)

2015

Xie Yuntao, 2015

FORMAT OF THE DECLARATON

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

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

(Signature): Xie Yuntao

(Date): 2015 7 1

ABSTRACT

The thesis is a case study of liner route optimization, and a route optimization problem can be divided into several sub-problems: ports of call, the sequence of ports of call, ship size selection and slot allocation. Because of ports of call selection and calling sequence is fixed in this particular case, the key problem of the case is the ship deployment and slot allocation.

There is no doubt that the fluctuations of freight and demand forms a conflict with the requirement of liner service stability, so it is necessary for ship lines to adjust strategy in time. Taking ZIM for example, the adjustment of its ship size selection and slot allocation determines its revenue, voyage cost and service level. This research based on ZIM's operation on East Med Service, study the reasonable ship deployment and slot allocation so as to gain more profits and keep competitive position in the future. Finally, the author worked out the example simulation with decision making techniques, and found the optimal solution to East Med Service.

Key Words: Liner route optimization; East Med Service; Ship deployment; Slot allocation; Decision Making Techniques

CATALOG

LIST OF TABLE

LIST OF CHART

1. Introduction

1.1. Background and project aim

1.1.1. Background

Since the 1970s, the container liner shipping transportation has been growing at a high pace rate with the increase in Asian production. However after global economic crisis in 2008, the increase of import and export of developed countries began to slow down, as a result, shipping industry which is the derivative industry of global trade became terrible depressed. Dry bulk market, container liner transport market and ship building market face a series of crisis, so many ship companies, ship yards went bankrupt. Several years later, the trade volume of the world started to increase, and the market becomes bigger and bigger. Nowadays, after a period of recovery, ship companies start to expand their capacity again, for instance, Greek massively build new ships, Maersk constructs dozens of Triple E Class container ships and China shipping also built their own 19,000 TEU container. Newbuilding activity in 2014 was focused on either the very large or small boxships. Of the total 0.89m TEU ordered last year, 0.55m TEU was accounted for by the 12,000+ TEU sector. The orderbook remains focused on the delivery of very large boxships with a high delivery of these expected in 2015. However, supply is expected to grow less fast than trade in 2016. Meanwhile, the 0.32m TEU on the sub-3,000 TEU orderbook is equivalent to just 7.9% of fleet capacity in the size range. The contraction of the sub-4,000 TEU fleet in recent years may eventually lead to a deficit of capacity in this sector. As a result, although trade flow is continuously increasing, the capacity is increasing much more dramatically. All those facts show the ship market, especially container liner transport, starts to get well, and competition also becomes severe.

Shipping lines have to explore more cargo resources and increase profits while they control their operating cost strictly in order to get rid of bad performance due to the depressed market. And the most part of container transport cost is assets assignment, which involves ship size deployment and containers assignment. Precisely because shipping lines require paying a large amount of money to purchase or charter vessels and containers, it is crucial to arrange assets in a proper way.

1.1.2. Proposed Problem

This paper studied the ship size deployment and slot allocation of ZIM Integrated shipping in the East Med service. And to a mature route, as the changing of the market conditions, the most effective assignment of assets should be changed. So it is important for a ship line to determine the most effective assignment of ship in a particular route according to the demand situation.

Slot allocation is a key element for the management of container shipping line. As the supply of each calling port which means cargo quantity here is imbalanced and fluctuated, some container shipping routes may accumulate quit a few empty containers at some calling ports, while the other calling ports perhaps face with the shortage of empty containers. Thus whether the company can gain the maximum profits depends on reasonable slot allocation of each calling ports to some extent. Here I take ZIM Integrated Shipping for example whose one of the main business is on East Med Service, how to adjust their assets and keep a competitive position has become the priority it should to solve.

1.1.3. Research Project Aims

This paper prepares to study East Med service, which is one of the important trade lanes for all global carriers and is also supposed to be one of the long-established service loops for ZIM Integrated Shipping. Since the global economic crisis in 2008, ZIM also faced a lot of challenges. Recently ZIM decided to quit its North Europe/ Far East service and gave up its market share of that line due to the debt. I consider that company needs to find some potential problems of its remaining lines in order to get rid of the situation of ZIM with unsatisfactory performance. And here I pick EAST MED/ BLACK SEA EXPRESS SERVICE which is the one of the important shipping line of ZIM for the next analysis. Due to the fluctuation of cargo demand of liner service, shipping lines often require adjusting their transportation capacity every year. Therefore, how to optimize the East Med service to keep and maximize the interest under current market situation has been an essential issue for ZIM Integrated Shipping.

1.2. Literature review

1.2.1. World research statues:

Based on the traditional model for minimize the cost and maximize the capacity, ZHAO Gang analyzed and improved the vessel allocation model. ZHAO considered it is not reasonable that the traditional model does not reflect he shipping liner schedule and the shipping line requires giving more transportation capacity in order to attract more shippers. As a result, ZHAO developed a new model to solve those problems and also gave the iterative method to solve it.

ZENG Qingcheng, YANG Zhongzhen, CHEN Chao considered that the operating efficiency of container shipping lines depends on proper resource allocation of container shipping. With taking container leasing costs and storage costs into consideration, they use non-linear programming model to analyze the best slot allocation and the most suitable ship size on one route, and it is one kind of pure academic theory. Based on ZENG, YANG, CHEN's study, YANG Qin presented a computational analysis of the optimization of Middle Asia route. Compared with pure academic theory, YANG's research gave some specific data of company A, and in that case, the calling port and the rank of calling port is fixed, then YANG use lingo to programme and calculate the most suitable ship size and the best slot allocation of company A. Based on the actual situation of company C, SHEN Xuechao proposed AHP model for the analysis of China/Persian Gulf service and developed optimal alternative offers for Company C.

CHEN Chao, ZHANG Zhe, ZENG Qingcheng proposed an optimal design of container shipping networks under fluctuating demands, in this particular paper, shipping routing, empty container repositioning, ship- slot allocating and ship size were considered based on fluctuating demands for a year, and developed a bi-level genetic algorithm to provide more realistic solutions to the optimal model. LIU Ying also used genetic algorithm to solve the route optimization problem, what were studied in his paper is to gain the schedule design of container liner and optimizing ship route though the analysis of the related content. Based on the CHEN Chao, ZHANG Zhe, ZENG Qingcheng's theory, SUN Guodong introduced the concept of season fluctuation into the optimal container liner service, carried on the principal components analysis through the SPSS statistics software to the season fluctuation's influencing factors, used 0-1 integer programming, the TSP way choice theory, and a series of mathematical theory to solve the optimal problem, it is a effective way to apply pure theory into practice.

CHEN Kang proposed a user equilibrium traffic assignment method for container liner shipping networks to solve the problem of the traffic assignment for the liner shipping network, and CHEN developed a genetic algorithm based on the space-time transformation and the frank-wolf algorithm to solve an optimal model.

CHEN Yan discussed on the line optimization with its marketing, service and vessel allocation by introducing such models as discriminating pricing model, superior ration model and the vessel allocation model.

Through analyzing the supply and demand of container transport market, JIN Xindao found that the container shipping market is stochastic, then presented a Stochastic Programming model of container liner shipping network and gave a example of this model to illustrate how it worked for shipping line optimization.

SHOU Yongyi, LAI Changtao, LU Rufu applied ant colony optimization into liner shipping optimal problems, and they found the proposed model is feasible through the calculation. It is effective for ant colony optimization to solve such multi-objective problems as ship scheduling problem.

Rana and Vicksonl discussed optimal problem of the fixed fleet in one particular route, they researched how to design routes and analyze the optimization of the calling port in order to maximize the benefits of shipping lines. Yang，Zhongzhen, Chen, Kang, Notteboom, Theo introduced an optimization model for container liner services that optimizes the shipping route and the container slot allocation on vessels by considering the interactions between the container shipping scheme and the transport demand in the ports. Kris Braekers, An Caris, Gerrit k. Janssens presented a decision support model to determine optimal shipping routes for roundtrip services between a major seaport and several hinterland ports located along a single waterway. Nguyen Khoi Tran studied the port selection in liner shipping, author set up a model to deal with the order of selected ports and loading/unloading ports for each shipment in order to minimize total cost. Based on multi-trip vehicle routing model, Fagerholt considered a real liner shipping problem to optimize the weekly routes for a given fleet. Ting and Tzeng developed a slot allocation model to maximize the freight contribution. Li etal. developed a model for the empty container allocation problem. Shintani considered the selection of the order of calling port and the empty contain allocation problem to optimize the container liner routes. Powell B. and Perakis A.N. developed two models, the first one transform Rana's mathematic model to a linear model in order to optimize the most suitable assignment of ship size; the second one involved the 0-1 variable mixed integer programming model so that it could solve the order of calling ports.

Ronen, Christiansen study the slot allocation of particular ships in a specific shipping route networks. The author considered that if the vessels still remain spare slot, ship companies will accept shippers’ orders in order that they could lower the rate of empty slot and increase profits. However ship companies also fail to achieve more profits brought by other shippers in the process of the voyage. Therefore the chaotic management may cause it difficult to optimize slot allocation.

Baird presented a multi-objective model about shipping line schedule and design in order to lower the transport and storage cost. Initially the author designed a foundation about transport cost and storage cost, then he solve the model with relevant information to get the most optimal ship size and schedule.

YANG Qiuping, XIE Xinlian, SU Chen presented a model of ship routing and fleet planning, which take maximum total operation profits as its objective function in order to improve practicability of studying ship resource optimization deployment. The authors designed a simplex algorithm to solve the linear programming model and numerical test are carried out to illustrate validity of the model.

Lim considered that the price of vessel, freight rate, operation cost, vessel deadweight and the distance of shipping line route would determine the ship size assignment.

Willmington, Jansson and Shneerson considered that large vessels would decrease the transport cost of each container, however small vessels could decrease the cost in the yard of the port of each container.

Damas considered that factors involving the depth of harbour basin and shipping lane, function of vessels and other physical and technique constraints would contribute to larger scale of vessels.

1.2.2. Existed Problem

Those literatures are about shipping line route optimization, which involve number and order of shipping line route ports of call, slot allocation, ship size assignment and container assignment study. According to different author, the emphasis of each paper is different, qualitative model and quantitative model both exist.

However, although there are a lot of methods and ranges of this field, those researches are too qualitative and not specific enough for one particular route of one particular shipping company. For instance, analytic hierarchy process in Study on Optimization of China/Persian Gulf Service of Company C is too controversial. And it is difficult for many researches to apply into practice for some particular shipping company.

1.3. Main context

Chapter 1 is the introduction of this paper, and it analyzes the background and objective of this paper. Then based on other research about container liner routes, I also gave a literature review.

Chapter 2 will focus on the actual condition of East med service, including market, operating conditions.

Chapter 3 will present some optimal characteristics of container liner routes optimization.

Chapter 4 will present a particular model for East Med Service optimization according to the situation of ZIM Integrated Shipping, then analyze and solve this programme.

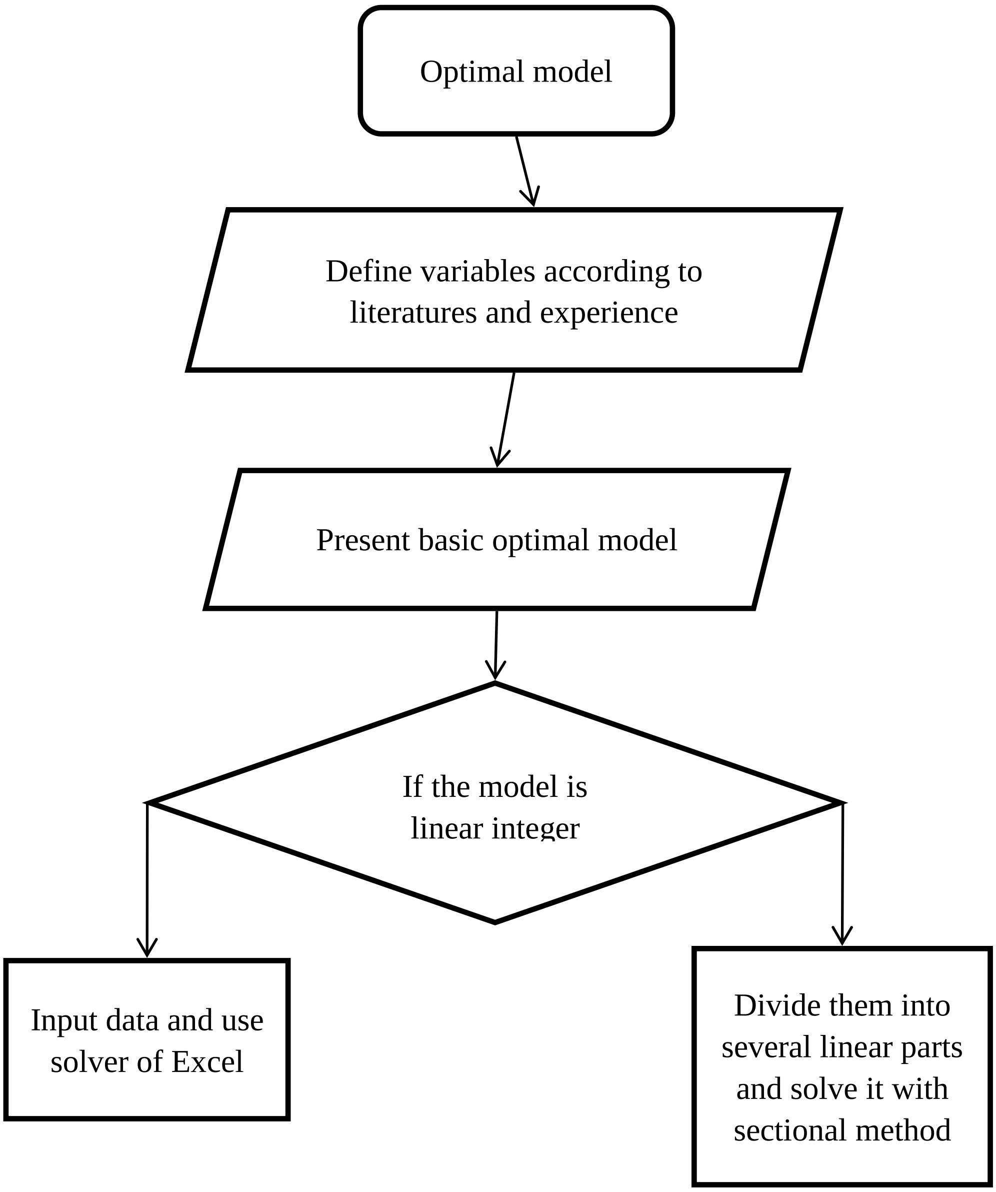
Chapter 5 will get the outcomes of the model according to the data of ZIM Integrated Shipping.

Chapter 6 will give the conclusion and the advice for late research.

1.4. Research methodology

The author intends to use case study method, which is to find information in relevant cases and literatures in order to acknowledge what the author is going to study according to specific research aim. In this paper, firstly, finding some direction from cases and literatures, then I will describe the problem and define some parameters, next, presenting a suitable model for ZIM, finally, working out the model with practical data. The case would be studied based on the fact of East Med Service and data of ZIM. According to several scholars' cases, a route optimization problem can be divided into several sub-problems: ports of call, the sequence of ports of call, ship size selection and slot allocation, so this thesis will choose some angles to optimize the East Med Service.

The specific process is as followed,


Optimal model
Define variables according to literatures and experience
Present basic optimal model
If the model is linear integer
Input data and use solver of Excel
Divide them into several linear parts and solve it with sectional method

2. Condition of East Mediterranean

2.1. East Med Situation Introduction

2.1.1. Main ports of the service

Pusan (Busan): Pusan is the largest port city in South Korea and the world's fifth busiest seaport by cargo tonnage. And it is located on the southeastern-most tip of the Korea peninsula. Since 1978, Busan has opened three container terminals including Jaseungdae, Shinsundae, and Gamman. And it can handle up to 13.2 million TEU shipping containers per year. What Pusan exports mainly include industrial machinery, aquatic products, electronic products, petrochemicals and textile and so on.

Ningbo: Ningbo is a seaport in the northeast of Zhejiang province, CN. The port is deepwater and capable of handling 300,000 tonne vessels. What Ningbo exports mainly include mine, textile, aquatic products, canned food, wool, carpets and tea and so on.

Shanghai: The port of Shanghai faces the East China Sea to the east, and Hangzhou Bay to the south. It includes the confluences of the Yangtze River, Huangpu River, and Qiantang River. What Shanghai exports mainly include steel, food, coal, oil, fertilizer, wood, toys concrete, mine and so on.

Da Chan Bay: Da Chan Bay is one part of the port of Shenzhen, which is one of the busiest and fastest growing ports in the world. It is located in the southern region of the Pearl River Delta in China's Guangdong province.

Port Klang (Kelang): Port Kelang is the largerst port of Malaysia, and was the 12th busiest container port in the world in 2012. Cargo includes wood, plywood, palm oil, rubber, steel, paper, sugar, wheat, fertilizer and so on.

Istanbul Ambarli: Istanbul is the largest seaport of Turkey. It is located on southwest coast of Istanbul Strait, and closed to northeast of Marmara. Cargo mainly includes coal, iron, copper, wood, industrial products, wool, cotton, fruit and carpet and so on.

Novorossiysk: Novorossiysk is the largest oil exporting port of Russia. It is located on the top of Novorossiysk Bay and closed to northeast of Black Sea. Cargo mainly includes crude oil, concrete, food, wood and frozen food and so on.

Odessa: Odessa is the largest port of Ukraine. It is located on the southwest coast of Odessa Bay and closed to northwest of Black Sea. Cargo mainly includes grain, sugar, wood, wool and so on.

Nhava Sheva: Nhava Sheva, also known as Jawaharlal Nehru Port, is the largest container port in India. Located south of Mumbai in Maharashtra, the port on the Arabian Sea is accessed via Thane Creek. The Nhava Sheva International Container Terminal (NSICT) is leased to a consortium led by P & O, now a part of DP World. Cargo mainly includes textile, cotton and so on.

2.1.2. Trade scale overview of East Med Service

According to Clarkson's forecast, Global container trade (demand) is projected to expand by 6.8% in 2015, and 6.8% in 2016, having grown by an estimated 6.0% in 2014. And container capable supply (supply) is projected to expand by 5.8% in 2015, to reach 21.6m TEU, with containership deliveries expected to reach 1.5m TEU this year. In 2016, global container capable supply growth is expected to slow to 3.7%. As a result, Clarkson forecasted that having narrowly outpaced total supply growth in 2014, global demand is expected to continue growing faster than supply in 2015 and 2016. However, problems of oversupply remain and, with a high proportion of expected deliveries in the very large containership sizes, supply management will be key in determining the market environment on the individual trade lanes. "Cascading" dynamics and overall fundamentals may provide some eventual support for the charter market.

Table 2.1 Container trade

	end year					forecast		current & forecast, end				*Trend*
	2010	2011	2012	2013	2014	2015	2016	Q4 14	Q1 15	Q2 15	Q3 15	%
ESTIMATED GLOBAL CONTAINER TRADE m teu												
Mainlane East-West	45.6	47.3	47.1	49.1	51.3	54.1	57.3	13.0	12.7	13.5	14.2	*3.9%*
	11%	*4%*	*-1%*	*4%*	*5%*	*5%*	*6%*					
Transpacific e/b	13.1	13.2	13.3	13.8	14.7	15.7	16.8	3.8	3.6	3.8	4.4	*4.9%*
Transpacific w/b	7.2	7.6	7.6	7.9	7.7	8.0	8.4	2.1	2.0	2.0	1.9	*1.9%*
Far East-Europe e/b	5.8	6.2	6.5	6.9	6.9	7.2	7.5	1.7	1.7	1.8	1.8	*3.8%*
Far East-Europe w/b	13.8	14.2	13.6	14.3	15.4	16.4	17.5	3.7	3.8	4.1	4.3	*4.3%*
Transatlantic e/b	2.7	2.8	2.6	2.7	2.7	2.7	2.8	0.6	0.7	0.7	0.7	*4.3%*
Transatlantic w/b	3.0	3.3	3.5	3.6	3.9	4.1	4.2	1.0	1.0	1.0	1.1	*5.2%*
Other East-West	16.9	18.8	19.5	20.1	21.5	23.1	24.8	5.4	5.4	5.8	6.0	*5.7%*
	16%	*11%*	*4%*	*3%*	*7%*	*7%*	*8%*					
North-South	24.9	27.2	27.6	28.9	30.5	32.4	34.4	7.9	7.2	8.1	8.7	*4.8%*
	15%	*10%*	*1%*	*5%*	*6%*	*6%*	*6%*					
Intra-Regional	51.9	56.0	59.7	63.1	67.6	72.8	78.3	16.8	17.7	18.2	18.8	*6.9%*
	14%	*8%*	*7%*	*6%*	*7%*	*8%*	*8%*					
TOTAL TRADE	**139.3**	**149.3**	**153.8**	**161.2**	**171.0**	**182.4**	**194.8**	**42.9**	**44.5**	**43.2**	**43.0**	**5.5%**
annual growth	13.8%	7.2%	3.0%	4.9%	6.0%	6.7%	6.8%					
est. peak leg growth	*15.2%*	*7.2%*	*2.8%*	*4.9%*	*6.8%*	*7.1%*	*7.2%*					
est. TEU-mile trade, bn	765	815	830	866	918	978	1,044					
est TEU mile trade growth	*13.7%*	*6.5%*	*1.9%*	*4.4%*	*6.0%*	*6.5%*	*6.7%*					

Note : For definitions of Transpacific, Far East - Europe and Transatlantic trades, see Table 2.1.
Other East-West includes trade between North America/Europe/Far East and Middle East/Indian Sub-Continent.
Intra-Regional trade includes all non east-west, north-south trade including south-south trade.
Trend shows average annual growth over 5 years up to and including the forecasts shown.
Estimated global peak leg container trade growth based on estimated peak leg trade growth for east-west and north-south trade, and projected peak leg growth for intra-regional trades based on average estimated imbalance on non-intra-regional trades.
Source : Clarkson Research Services, Container Trades Statistics, FEFC, PIERS, MDS Transmodal, Various

Trade volumes on the peak leg Far East-Europe trade are currently expected to increase by 6.4% in 2015, to reach 16.4m TEU and probably reach 17.5m TEU in 2016. It turns out that market share of East Med Service will expand soon and shipping companies need to adjust their strategy in this area. Statistics is from the table 2.1.

IMF also gave their estimation about this area and claimed that GDP of most of those counties will steadily increase in 2015 and 2016, such as real GDP of Korea is projected to 3.3% in 2015 and 3.5% in 2016, Malaysia is projected to 4.8%. I am also impressed by stronger net exports of Turkey, especially this performance were partly offset by faltering private investment following previous policy tightening, and I believe it will gradually get rid of negative effect and make a better progress in the future.

Although IMF gave China a negative evaluation, I still believe Shanghai port still will perform well in 2015 and 2016 because most of cargos in Yangtze River industrial delta export there and it will positively contribute to East Med Service. Roughly speaking, total import and export value of China in 2014 is about 3,790 billion RMB, which declined 2% from a year earlier. However the export value is about 1,530 billion RMB, which increased about 15% from a year earlier. In specific, the export value China/America is with year-on-year growth of more than 21%, China/ASEAN is with year-on-year growth of more than 38%, China/India is with year-on-year growth of more than 35%, and China/EU is even with year-on-year growth of more than 13%. And it can be a positive factor for the export forecast in 2015 and 2016. Of course the negative factors also exist. There is no doubt that Russia and other CIS economies were affected by deepening geopolitical tensions surrounding eastern Ukraine and related sanctions and counter-sanctions, so importing activities in Novorossiysk would become depressed, and the statistics has shown that export value from China to Russia declined 26% from one year earlier.

In general, I hold an optimistic opinion on the performance of East Med Service, which benefited from increasing Far East- Euro trade.

2.2. ZIM Service Condition Analysis

ZIM’s East Med/Black Sea Express Service (EMX) was cooperated with OOCL starting September 2013. And EMX provides first-class service between China, Korea and Malaysia to Russian and CIS countries, with an exclusive direct call to Novorossiysk at with the fastest transit time in the market, direct Odessa call and excellent port coverage. ZIM’s long-standing EMX service, upgraded in 2012 to include additional exclusive calls at best-in-market transit times, proved to be very popular with customers.

EMX overview:

Total vessel: 10 (including 2 OOCL’s vessels)

Service Fluency: Weekly

Capacity: About 4300 TEU

Schedule: 70 days/ voyage

Average speed: 14 k’s

So here we can see that ZIM has made its own shipping line design, and actually the vessels also keep navigating, but it does not mean that ZIM has to choose its own vessels (cooperation with OOCL’s vessels is a good beginning) with the liberalization of ship charter market. According to Clarkson's container report in 2015, although the idle boxship fleet is relatively low, representing 1.3% of the fleet at start 2015, the majority of this capacity is charter owned; this has maintained downward pressure on charter market earnings.

ZIM Integrated Shipping has its own ready-made route of East Med service, and its vessels also have been serving for a certain period, but company is still able to choose to charter other available vessels to match its East Med service in order to gain the maximum benefits. And because the selection of calling ports and the order of calling ports has been argued and established at the process of design this particular route , and the cooperation with ports of call is complicated and fixed, it extremely unlikely to modify. Thus this paper will focus on ensuring the selection of ship size and the assignment of slot and assets in East Med service for the maximum benefits of company.

3. Container Liner Route Optimal Characteristics

3.1. Characteristic of Liner Shipping Transport

1) Time fixed

Liner shipping transport typically needs to have a weekly service at its ports of call. Container ships equipment is relatively advanced, with fast speed and less effect of bad weather. And container ships loading and discharging is highly specialized, so it will positively contribute to reliable schedule.

2) Price fixed

Liner shipping transport is highly standardized, so freight is designed with XXX dollars per TEU and does not differ from particular cargo. As a result, freight does not change a lot in one period when it has been confirmed.

3) Location fixed

Stability of cargo flow is why liner shipping transport can run, therefore shipping line needs to speed a lot of time and cost building good relationship with shippers. Meanwhile, once shipping line has selected some ports of call, they have to spend a large amount of money chartering or building terminal facilities, so it is not easy to change service location.

4) Vessel fixed

Shipping line is obliged to arrange fixed vessels in order to promise the stability of liner service.

3.2. Characteristic of Liner Service Networks

1) Low operating cost

Containerships operation typically benefits from the economies of scale, and large containerships are capable of leading to lower cost of each TEU. As major operators have launched newer and bigger ships in the water, they have significantly reduced the slot costs in the container trades to which these ships are assigned. Meanwhile, technology development also provides better equipments with less cost of bunker, that is a positive factor contributed to low operating cost.

2) High requirement of assets assignment

As liner shipping transport pays attention to reliable schedule and strict time control in ports of call, shipping line has to study the fleet size, demand of containers assignment and facilities and situation in the terminal in order to realize reasonable assets deployments before the shipping line service starts to operate.

3) Fast transit times

In a narrow approach, the transit time can be defined as the number of sailing days on a port-to-port basis. As the focus in this paper is on the liner service, we primarily use the narrow definition. Offering short transit times is a competitive factor in liner shipping, in particular when the goods involved are time sensitive.

4) Both tight and reliable voyage schedules

The container transport system is structured by time-tight schedules. Shipping lines have developed a strong focus on designing liner services with a high degree of schedule reliability. In view of delivering an impeccable service to their customers, shipping lines are keen to meet the timings as announced official schedules.

5) Equilibrium principle

Container shipping line resources include ships and containers, whose number and ratio are determined by the cargo transport demand, number of calling ports and the turnaround time of containers on land. Containers are an important resource in container shipping lines, while the deployment of containers influences the stability and efficiency of the container shipping line. Because of trade imbalances and fluctuations of cargo quantities, a container shipping line may accumulate a large number of empty containers at some port, while other ports may face a shortage of empty containers. Normal operation of shipping line may require empty container repositioning or increase in the number of containers in order to keep the efficiency and processing fluency of shipping line.

3.3. Concept of Shipping Line Optimization

Shipping line optimization is that shipping company makes the best decision of shipping line design in order to minimize the cost of operation or maximize the profit. Shipping line design includes selection of calling ports, order arrangement of port of call, navigation speed, ship size, schedule and slot allocation and etc..

So the shipping line optimization classification is as followed:

1) Selection of ports of call, which means to choose some particular ports of call in one target area. Limiting the number of port calls will shorten round voyage time and increases the number of round trips per year, thereby minimizing the number of required for that specific liner service. For instance, there are a lot of ports of call on the Mediterranean coastal, but considering the gather of cargo and harbor facilities, it is impossible to select every port as base ports of the shipping line, in specific, Haifa and Hadera is very close, so we just need to select Haifa. It is one kind of Knapsack Problem when shipping company chooses their advantage base port.

2) Order arrangement of port of call, which means how to arrange order of port of call in order to lower the operation cost and make management less complicated. For example, it is still argued which port should be called in advance when one

shipping line confirmed to choose Odessa and Novorossiysk as its base port. It is one kind of travelling salesman problem.

3) The fleet size, vessel size and fleet mix. Once shipping company solved above two problems, it needs to arrange appropriate vessels to operate. Traditionally, As economies of vessels are more significant on longer distances, the biggest vessels are deployed on the longest route, that means vessels are required to be technical feasible and economic feasible, simply speaking, they should be big enough to fulfill the cargo requirement of shipping line. However large vessels also could lead to low utilization of capacity and cause higher cost once market goes depressed, and it also has proved problematic because of recent acceleration of demand, and because congestion has been rising at key ports. So shipping company needs to adjust their plan through both practical (market investigation) and academic (model solution) method.

4) Service frequency and slot allocation. Service frequency is one important standard of shipping line service, for now, in deep-sea liner shipping, shippers typically demand a weekly call at each and every port of call in the rotation. Slot allocation is to delivery some proportion of slot to each port of call, including full container slot and empty container slot.

4. The selection of optimal model for East Med Service

4.1. Problem description

According to the analysis in above chapter, we can find that once a shipping liner route was designed, the ports of call in this service would be unaltered in a long period. As a result, this paper intends to optimize the ship size assignment and slot allocation in East Med Service of ZIM. For now ZIM has arranged 10 vessels in this service, which including 8 owed and 2 chartered ships. And capacity of most those vessels is 4253 TEU (chartered are 4526 TEU).

4.1.1. The principle of ship size assignment

(1) The selection of ship size should be based on the distance of the service. Traditionally, the biggest vessels are deployed on the longest route, although this theory is still not be proved academically, it is reasonable in practice.

(2) The ship size assignment should be based on the number of ports of call. It would determine reasonable ratio of stowage.

(3) The ship size assignment should be based on the schedule of the service. It is just concerned speed of vessels, so selection of vessels should be qualified with requirement of the frequency in the service in order to promise the steady operation.

4.1.2. The principle of slot allocation

(1) Cargo supply in hinterland of ports of call would affect slot allocation, so shipping lines investigate their market share and remain enough storage space in case of suffer from cargo rejection.

(2) Slot allocation should meet equilibrium principle, which means shipping line needs to adjust both full container and empty container allocation.

4.2. Parameter design

Shipping companies usually do not change number and order of ports of call in order to keep the service level of their shipping line. So ZIM has its fixed ports of call, order of ports of call and weekly frequency in East Med Service. And according to cargo flow of each port and market freight situation, we can find what effect shipping line route optimization is:

(1) Amount of cargo flow in ports of call, which determines period of loading and discharging, and as a result, it will effect service of shipping line.

(2) Direction of cargo flow in ports of call, which determines slot allocation in each calling port.

(3) Flow of export and import containers, which determines number of chartered container leasing depot.

(4) Capacity of ships, which determines period of loading and discharging, cost of operation, rate of full containers.

(5) Number of chartered containers, which is one of the elements of cost of the service

(6) Unit cost of chartered containers, which is one of the elements of cost of the service

(7) Volume of containers in container yard, which is one of the elements of cost of the service

(8) Unit cost of container in container yard, which is one of the elements of cost of the service

(9) Unit cost of transporting for full and empty containers, which is one of the elements of cost of the service

(10) Unit cost of loading and discharging for full and empty containers, which is one of the elements of cost of the service

(11) depth and width of shipping lane, which determines the limitation of ship size selection

4.3. Suitable optimal model for East Med Service

Based what described in literatures, we can consider the optimization is to maximize the profit, so the question can be described as earnings-cost. And I found Suitable optimal model for East Med Service should solve both ship size arrangement and slot allocation, and according to the third model, here presenting one model for ZIM as followed

Parameters descriptions:

x— — represented full container

y— — represented empty container

R_{ij}^{x}— — Freight for one full container from port i to port j

C_{ij}^{x}— — charge/discharge fee for one full container from port i to port j

R_{ij}^{y}— — Freight for one empty container from port i to port j

C_{ij}^{y}— — charge/discharge fee for one empty container from port i to port j

x_{ij}— — full container flow from port i to port j

y_{ij}— — empty container flow from port i to port j

T— — time coefficient of chartered comtainers and inventory in terminal ，normally more than 3

C_i^l— — unit cost of chartered container

C_i^s— — unit cost of storage in terminal

v— — vessel number of one voyage, normally one vessel per week

CAP_k— — apacity of k size vessel

$f(CAP_k)$— — operation cost per voyage

$$\max\left\{\sum_i\sum_j^n(x_{ij}+y_{ij}),\sum_i\sum_j^n(x_{ji}+y_{ji})\right\}$$ — — quantity of work in terminal

μ— — cost of each container per voyage, XXX usd/day

$\sum_i\sum_j^n(x_{ij}+y_{ij})-\sum_i\sum_j^n(x_{ji}+y_{ji})$ — — Number of chartered and inventory containers

$Q_{ii}=\max\{\sum_i\sum_j^n(x_{ij}+y_{ij}),\sum_i\sum_j^n(x_{ji}+y_{ji})\}\forall i\in n$ — — Quantity of work in terminal

$\mu\sum_i\left\{\max\{\sum_i\sum_j^n(x_{ij}+y_{ij}),\sum_i\sum_j^n(x_{ji}+y_{ji})\}\right\}$— —Container deployment cost per voyage

Presented Model:

$\max p=\sum_i^n\sum_j^n\{(R_{ij}^x-C_{ij}^x)\times x_{ij}+(R_{ij}^y-C_{ij}^y)\times y_{ij}\}-T\sum_{i=1}^n C_i^l\times(\sum_i\sum_j^n(x_{ij}+$

$y_{ij}) - \sum_i \sum_j^n (x_{ji} + y_{ji})) - T \sum_{i=1}^n C_i^s \times (\sum_i \sum_j^n (x_{ij} + y_{ij}) - \sum_i \sum_j^n (x_{ji} + y_{ji})) -$

$\{\mu \sum_i max\{\sum_i \sum_j^n (x_{ij} + y_{ij}), \sum_i \sum_j^n (x_{ji} + y_{ji})\} + f(CAP_k)\}$ (4.1)

Constraints:

(1) Supply and demand constraint

$$x_{ij} \leq d_{ij} \quad \forall i, j \in n \quad (4.2)$$

(2) Capacity constraint

$$\sum_{i \in n} \sum_{j \in n}^{n} (x_{ji} + y_{ji}) \leq CAP_K \quad (4.3)$$

(3) Variables constraint

$$x_{ij}, d_{ij}, CAP_K \in n \quad (4.4)$$

Then the next problem is to define $f(CAP_k)$

Next I intend to define $f(CAP_k) = C_F + C_{IFO} + C_{MGO}$ (4.5)

C_F—— depreciation or charter hire

C_{IFO}——IFO cost

C_{MGO}——MGO cost

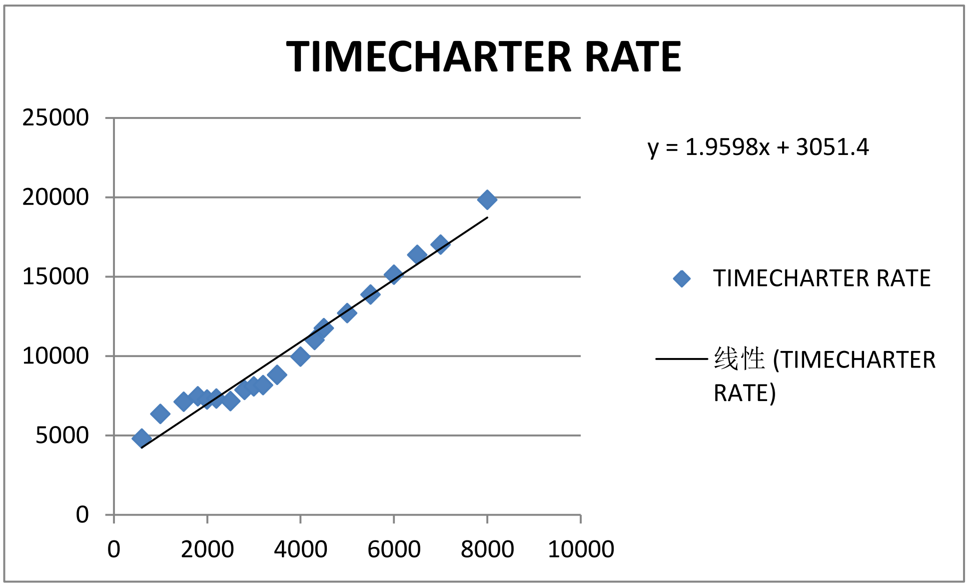
Table 4.1 Month timecharter rate

US$/day end	725 teu geared	1,000 teu geared	1,700 teu geared	2,000 teu gearless	2,500 teu geared	2,750 teu gearless	3,500 teu gearless	4,400 teu gearless	Index 1993=100
2002	5,900	6,600	9,250	9,000	11,850	12,750	15,000		59
2003	7,100	9,800	17,500	20,000	30,000	30,000	30,000	35,000	94
2004	13,250	19,000	32,000	34,000	38,000	40,000	44,000	50,000	163
2005	10,250	12,750	18,250	19,000	22,000	22,750	28,000	34,000	116
2006	8,900	11,500	14,300	17,000	20,000	20,000	24,000	28,000	91
2007	8,900	12,500	17,750	21,000	27,750	30,000	33,000	38,000	114
2008	4,000	4,600	5,900	6,500	7,600	8,500	10,500	13,500	47
2009	3,425	4,000	4,200	4,300	4,500	4,550	5,500	6,500	32
2010	5,500	8,500	9,250	11,000	12,500	13,500	18,000	26,000	59
2011	4,250	5,000	6,250	6,250	6,800	7,000	6,250	8,000	42
2012	4,250	5,400	6,250	6,200	6,750	6,250	6,600	8,800	42
2013	5,100	6,600	7,500	6,500	7,750	7,000	7,250	7,150	47
2014	4,900	6,350	7,350	7,250	7,150	7,850	8,800	11,000	47
Jan-12	4,250	5,000	6,250	6,250	6,800	7,000	6,250	8,000	40
Feb-12	4,250	5,200	6,250	6,250	6,950	7,000	6,250	8,250	41
Mar-12	4,300	5,400	6,400	6,500	7,000	7,100	7,500	8,500	42
Apr-12	4,500	5,500	6,500	6,700	7,500	7,100	8,000	10,000	43
May-12	4,500	5,600	6,500	6,700	7,500	7,250	8,150	12,500	45
Jun-12	4,400	5,500	6,500	6,700	7,250	7,000	7,750	12,500	45
Jul-12	4,400	5,500	6,400	6,500	7,000	7,000	7,500	11,650	44
Aug-12	4,400	5,500	6,200	6,400	6,900	6,750	7,500	11,000	44
Sep-12	4,600	5,400	6,200	6,400	6,500	6,700	7,250	10,000	44
Oct-12	4,500	5,300	6,100	6,200	6,500	6,500	7,000	9,500	43
Nov-12	4,250	5,200	6,100	6,200	6,250	6,000	6,500	8,900	42
Dec-12	4,250	5,200	6,100	6,100	6,400	5,500	6,500	8,500	42
Jan-13	4,250	5,400	6,250	6,200	6,750	6,250	6,600	8,800	42
Feb-13	4,250	5,750	6,500	6,350	6,900	6,350	6,600	9,000	43
Mar-13	4,250	5,750	6,500	6,300	7,100	6,300	6,500	9,000	43
Apr-13	4,750	6,250	6,700	6,300	7,750	6,600	6,800	9,150	45
May-13	4,900	6,500	6,950	6,400	8,000	6,750	7,000	9,150	46
Jun-13	4,950	6,500	7,250	6,600	8,100	6,900	7,250	9,000	47
Jul-13	4,950	6,500	7,300	6,750	8,000	7,100	7,250	8,900	47
Aug-13	5,100	6,800	7,500	6,800	7,800	7,100	7,250	9,000	48
Sep-13	5,100	6,700	7,700	6,600	7,500	7,000	7,500	8,850	47
Oct-13	5,200	6,700	7,700	6,500	7,750	7,200	7,500	8,500	48
Nov-13	5,200	6,500	7,450	6,500	7,750	7,200	7,000	7,500	47
Dec-13	5,200	6,500	7,350	6,500	7,700	7,200	7,000	7,500	47
Jan-14	5,100	6,600	7,500	6,500	7,750	7,000	7,250	7,150	47
Feb-14	5,000	6,600	7,250	7,000	7,600	6,900	7,350	7,250	47
Mar-14	5,000	6,600	7,250	7,100	7,400	6,800	7,350	7,500	47
Apr-14	5,000	6,600	7,400	7,100	7,400	7,250	7,850	7,750	47
May-14	5,000	6,350	7,400	7,100	7,250	7,100	7,750	8,500	47
Jun-14	5,000	6,350	7,500	7,000	7,250	7,250	7,800	8,750	47
Jul-14	4,950	6,250	7,350	7,100	7,350	7,450	7,850	8,750	47
Aug-14	4,950	6,300	7,250	7,200	7,350	7,600	7,850	8,950	47
Sep-14	4,950	6,300	7,350	6,800	7,000	8,000	7,900	10,500	47
Oct-14	4,900	6,300	7,000	6,550	6,900	7,750	7,900	10,000	47
Nov-14	5,000	6,250	7,250	6,850	7,000	8,000	8,000	10,000	47
Dec-14	4,900	6,250	7,250	6,900	7,250	8,000	8,100	10,150	47

Source : Clarkson Research Services

Here I used excel to get the chart,

Chart 4.1 Timecharter rate chart



So $C_C = 1.9598CAP_k + 3051.4$ (4.6)

Table 4.2 Top 100: operated fleets

Alphaliner - Top 100 : Operated fleets as per 07 January 2015											
		TOTAL		Owned		Chartered			Orderbook		
Rnk	Operator	TEU	Ships	TEU	Ships	TEU	Ships	% Chart	TEU	Ships	% existing
1	APM-Maersk	2,912,918	605	1,589,730	250	1,323,188	355	45.4%	178,082	12	6.1%
2	Mediterranean Shg Co	2,539,354	497	1,070,014	192	1,469,340	305	57.9%	637,900	51	25.1%
3	CMA CGM Group	1,648,867	447	545,625	84	1,103,242	363	66.9%	352,519	36	21.4%
4	Hapag-Lloyd	980,354	186	523,078	80	457,276	106	46.6%	46,500	5	4.7%
5	Evergreen Line	953,946	197	539,170	111	414,776	86	43.5%	165,524	13	17.4%
6	COSCO Container L.	825,405	163	484,371	97	341,034	66	41.3%	119,500	10	14.5%
7	CSCL	673,578	135	508,114	75	165,464	60	24.6%	56,940	3	8.5%
8	Hanjin Shipping	608,459	98	278,102	38	330,357	60	54.3%	56,140	6	9.2%
9	MOL	602,134	112	194,708	31	407,426	81	67.7%	60,060	6	10.0%
10	APL	562,346	94	386,003	50	176,343	44	31.4%			
11	OOCL	540,465	99	339,306	48	201,159	51	37.2%	26,664	3	4.9%
12	Hamburg Süd Group	533,365	111	254,872	41	278,493	70	52.2%	48,928	5	9.2%
13	NYK Line	501,424	107	282,158	49	219,266	58	43.7%	112,000	8	22.3%
14	Yang Ming Marine Trar	401,920	87	190,757	40	211,163	47	52.5%	225,186	18	56.0%
15	PIL (Pacific Int. Line)	377,955	161	277,846	118	100,109	43	26.5%	23,334	6	6.2%
16	Hyundai M.M.	377,705	57	159,326	21	218,379	36	57.8%	60,000	6	15.9%
17	K Line	366,445	71	132,152	22	234,293	49	63.9%	138,700	10	37.9%
18	UASC	362,492	54	228,150	28	134,342	26	37.1%	247,737	15	68.3%
19	Zim	331,968	80	54,329	14	277,639	66	83.6%			
20	Wan Hai Lines	200,388	86	170,837	71	29,551	15	14.7%			
21	X-Press Feeders Grour	112,448	78	19,060	12	93,388	66	83.0%			
22	HDS Lines	88,608	22	6,864	3	81,744	19	92.3%			
23	SITC	84,125	71	34,693	32	49,432	39	58.8%	18,080	10	21.5%
24	KMTC	82,622	49	34,035	24	48,587	25	58.8%	8,672	4	10.5%
25	NileDutch	76,576	28	8,321	3	68,255	25	89.1%	7,020	2	9.2%
26	TS Lines	75,347	37	3,156	2	72,191	35	95.8%			
27	Arkas Line / EMES	56,126	38	45,186	30	10,940	8	19.5%	10,000	4	17.8%
28	Quanzhou An Sheng S	53,305	45	48,614	36	4,691	9	8.8%	9,600	4	18.0%
29	Simatech	50,706	20	8,701	6	42,005	14	82.8%	8,700	2	17.2%
30	RCL (Regional Contain	48,636	32	22,734	20	25,902	12	53.3%			
31	UniFeeder	45,509	42			45,509	42	100.0%			
32	Sinotrans	43,555	31	20,631	16	22,924	15	52.6%			
33	Grimaldi (Napoli)	38,249	37	37,614	36	635	1	1.7%	21,700	8	56.7%
34	Swire Shipping	35,434	27	31,378	22	4,056	5	11.4%	6,468	4	18.3%
35	CCNI	34,845	12			34,845	12	100.0%	36,120	4	103.7%
36	Schöller Group	34,560	19	6,042	3	28,518	16	82.5%			
37	Zhonggu Shipping	34,269	40	24,146	16	10,123	24	29.5%	25,000	10	73.0%
38	Heung-A Shipping	34,235	29	11,198	16	23,037	13	67.3%	7,400	5	21.6%
39	Matson	32,666	20	31,118	17	1,548	3	4.7%	7,200	2	22.0%
40	Linea Messina	32,645	14	14,600	5	18,045	9	55.3%	8,760	3	26.8%
41	Seaboard Marine	32,461	26	1,444	2	31,017	24	95.6%			
42	Samudera	32,342	36	10,628	17	21,714	19	67.1%			
43	OEL / Shreyas (Transw	31,636	22	19,387	14	12,249	8	38.7%			
44	Sinokor	30,035	31	15,845	18	14,190	13	47.2%			
45	Meratus	29,317	50	28,658	45	659	5	2.2%	1,056	2	3.6%
46	Salam Pasific	29,170	45	27,882	43	1,288	2	4.4%			
47	S.C. India	28,928	9	17,766	6	11,162	3	38.6%			
48	Nam Sung	26,095	30	19,974	23	6,121	7	23.5%	2,000	2	7.7%
49	Tanto Intim Line	25,852	45	25,852	45						
50	FESCO	23,928	22	12,288	15	11,640	7	48.6%			
51	Horizon Lines	23,398	11	18,394	8	5,004	3	21.4%			

I would throughout the duration of define $f(CAP_k)$ only give charter rate as one part of cost, precisely because ZIM's fleet has just 14 owned vessels or less in the future. That means we shall charter vessels to adjust liner route.

Table 4.3 Average Bunker price 2015 (source: BMS United Bunker (HK) Limited)

Indications*	USD PMT		
Ports	**380cst**	**180cst**	**MGO**
South East Asia			
Singapore	364	381	590
Port Klang	370	394	620
Bangkok	437	444	689
East Asia			
Hong Kong	386	403	601
Busan	395	416	601
Dalian	415	458	747
Shanghai	406	452	737
Tai Chung	414	424	740
South Asia			
Mumbai	415	-	727
Colombo	420	432	670
Middle East & Africa			
Fujairah	378	404	732
Durban	-	458	788
Europe & Mediterranean			
Antwerp	338	385	582
Piraeus	356	382	635
South America			
Buenos Aires	453	-	-

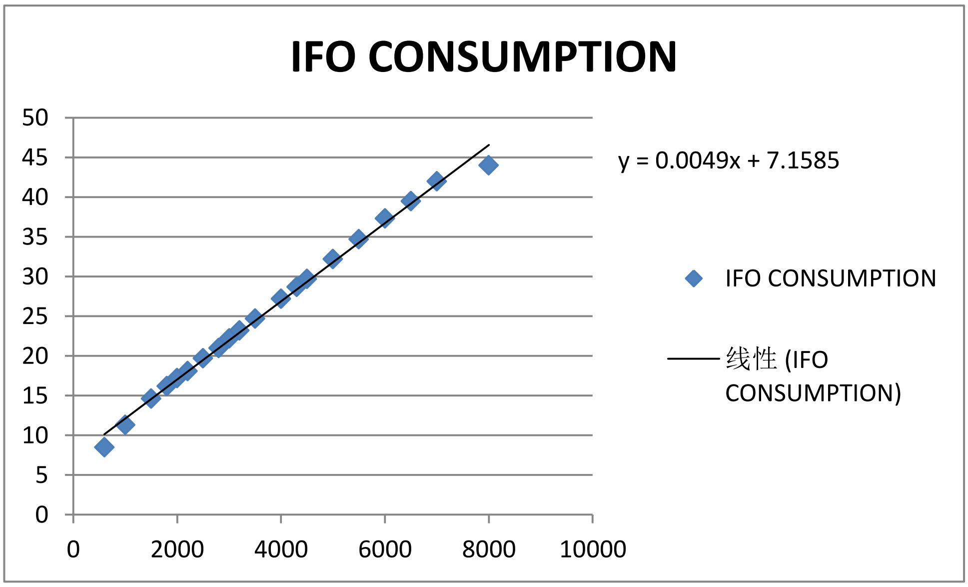
Table 4.4 Fuel oil consumption

BODY FORM, FUEL OIL CONSUMPTION AND COST CPRRESPONDING RELATIONSHIPS (14 knot)		
VESSEL SIZE AND CAPACITY	**IFO CONSUMPTION(T/D)**	**MGO CONSUMPTION(T/D)**
600	8.5	11.5
1000	11.3	12.5

1500	14.6	13.7
1800	16.2	13.8
2000	17.2	13.9
2200	18.1	14
2500	19.7	14.1
2800	21	14.2
3000	22.2	14.3
3200	23.2	14.3
3500	24.7	14.4
4000	27.2	14.6
4300	28.7	14.7
4500	29.7	14.8
5000	32.2	15
5500	34.7	15.1
6000	37.3	15.3
6500	39.5	15.5
7000	42	15.7
8000	44	16
SOURCE：ZIM		

Then I used EXCEL to find the relationship between them:

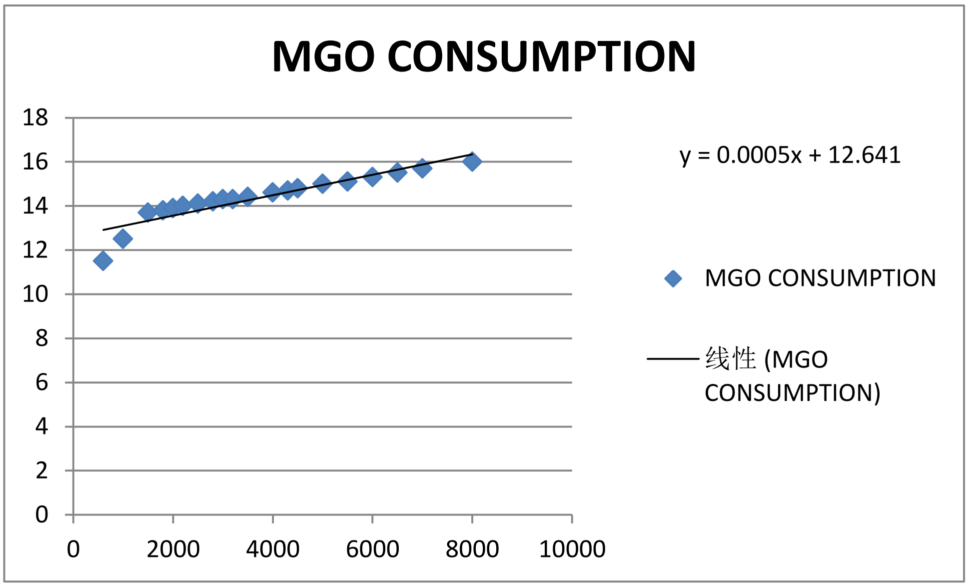
Chart 4.2 Fuel oil consumption chart



So here I define IFO $= 0.0049CAP_k + 7.1585$ (4.7), and it turns out $C_{IFO} = 2.1CAP_k + 3071$ (4.8)

And with the same method, we can find:

Chart 4.3 Fuel oil consumption chart



So here I define $\text{MGO} = 0.0005CAP_k + 12.64$ (4.9), and $C_{MGO} = 0.3685CAP_k + 9315.7$ (4.10)

$f(CAP_k) = 70 \times (C_C + C_{IFO} + C_{MGO}) = 70 \times (1.9598CAP_k + 3051.4 + 2.1CAP_k + 3071 + 0.3685CAP_k + 9315.7) = 309.984CAP_k + 1080667$ (4.11)

Finally

$$\max p = \sum_i^n \sum_j^n \{(R_{ij}^x - C_{ij}^x) \times x_{ij} + (R_{ij}^y - C_{ij}^y) \times y_{ij}\} - T\sum_{i=1}^n C_i^l \times \left(\sum_i \sum_j^n (x_{ij} + y_{ij}) - \sum_i \sum_j^n (x_{ji} + y_{ji})\right) - T\sum_{i=1}^n C_i^s \times \left(\sum_i \sum_j^n (x_{ij} + y_{ij}) - \sum_i \sum_j^n (x_{ji} + y_{ji})\right) - \{\mu \sum_i max\{\sum_i \sum_j^n (x_{ij} + y_{ij}), \sum_i \sum_j^n (x_{ji} + y_{ji})\} + 309.984CAP_k + 1080667\}$$

(4.12)

(1) supply and demand constraint

$$x_{ij} \le d_{ij} \quad \forall i, j \in n \quad (4.13)$$

(2) capacity constraint

$$\sum_{i \in n} \sum_{j \in n}^n (x_{ji} + y_{ji}) \le CAP_K \quad (4.14)$$

(3) variable constraint

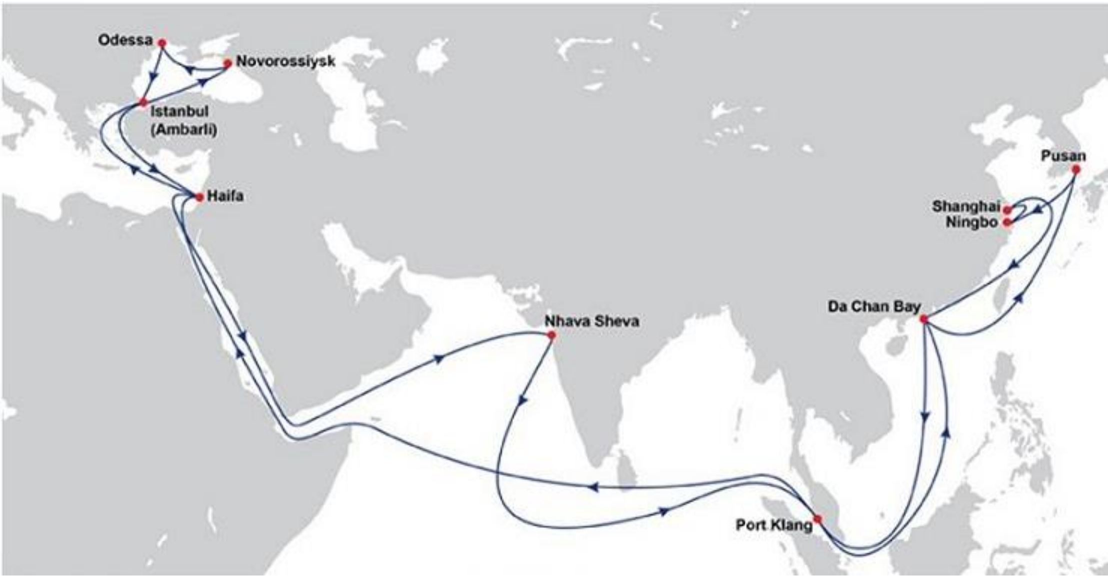
$$x_{ij}, d_{ij}, CAP_K \in n \quad (4.15)$$

5. Case study

5.1. The calling sequence of East Med service

The sequence is: PUSAN---NINGBO---SHANGHAI---DA CHAN BAY---PORT KELANG---HAIFA---ISTANBUL---NOVOROSSLYSK---ODESSA---ISTANBUL---HAIFA---NIHAVA SHEVA---PORT KELANG---DA CHAN BAY---PUSAN

Chart 5.1 The calling sequence of East Med service



Total vessel: 10 (including 2 OOCL's vessels)

Service Fluency: Weekly

Capacity: About 4300 TEU

Schedule: 70 days/ voyage

Average speed: 14 k's

Storage cost in terminal: $5/TEU.day

Chartered container cost in terminal: $5/TEU.day

5.2. Relative parameters

Table 5.1 The average freight of full containers ($)

POL/POD	PUSAN	NINGBO	SHANGHAI	DA CHAN BAY	PORT KELANG	HAIFA	ISTANBUL	NOVOROSSLYSK	ODESSA	NIHAVA SHEVA
PUSAN	0	0	0	0	240	1350	1200	1475	1050	0
NINGBO	0	0	0	0	210	1250	1100	1375	950	0
SHANGHAI	0	0	0	0	210	1250	1100	1375	950	0
DA CHAN BAY	0	0	0	0	185	950	800	1075	650	0
PORT KELANG	315	163	163	163	0	167	325	365	575	0
HAIFA	675	625	625	233	233	0	243	227	225	435
ISTANBUL	600	550	550	300	275	0	0	120	120	243
NOVOROSSLYSK	735	695	695	510	275	223	120	0	120	243
ODESSA	500	350	350	300	275	223	120	0	0	243
NIHAVA SHEVA	710	650	650	320	120	0	0	0	0	0

Table 5.2 The average load and unload charge of full containers ($)

POL/POD	PUSAN	NINGBO	SHANGHAI	DA CHAN BAY	PORT KELANG	HAIFA	ISTANBUL	NOVOROSSLYSK	ODESSA	NIHAVA SHEVA
PUSAN	0	0	0	0	60	75	80	80	80	85
NINGBO	0	0	0	0	60	75	80	80	80	85
SHANGHAI	0	0	0	0	60	75	80	80	80	85
DA CHAN BAY	0	0	0	0	60	75	80	80	80	85
PORT KELANG	80	70	70	100	0	75	80	80	80	0
HAIFA	80	70	70	100	60	0	80	80	80	0
ISTANBUL	80	70	70	100	60	0	0	80	80	85
NOVOROSSLYSK	80	70	70	100	60	75	80	0	80	85
ODESSA	80	70	70	100	60	75	80	0	0	85
NIHAVA SHEVA	80	70	70	100	60	0	0	0	0	0

Table 5.3 The average load and unload charge of empty containers ($)

POL/POD	PUSAN	NINGBO	SHANGHAI	DA CHAN BAY	PORT KELANG	HAIFA	ISTANBUL	NOVOROSSLYSK	ODESSA	NIHAVA SHEVA
PUSAN	0	0	0	0	30	35	40	40	40	45
NINGBO	0	0	0	0	30	35	40	40	40	45
SHANGHAI	0	0	0	0	30	35	40	40	40	45
DA CHAN BAY	0	0	0	0	30	35	40	40	40	45
PORT KELANG	40	35	35	50	0	35	40	40	40	0

HAIFA	40	35	35	50	30	0	40	40	40	0
ISTANBUL	40	35	35	50	30	0	0	40	40	45
NOVOROSSLYSK	40	35	35	50	30	35	40	0	40	45
ODESSA	40	35	35	50	30	35	40	0	0	45
NIHAVA SHEVA	40	35	35	50	30	0	0	0	0	0

Table 5.4 The cargo demand among terminals (TEU)

POL/POD	PUSAN	NINGBO	SHANGHAI	DA CHAN BAY	PORT KELANG	HAIFA	ISTANBUL	NOVOROSSLYSK	ODESSA	NIHAVA SHEVA
PUSAN	0	0	0	0	235	285	289	185	270	0
NINGBO	0	0	0	0	223	265	225	155	270	0
SHANGHAI	0	0	0	0	220	293	363	196	355	0
DA CHAN BAY	0	0	0	0	220	257	268	143	312	0
PORT KELANG	65	52	60	55	0	175	192	90	193	0
HAIFA	85	58	95	51	48	0	142	106	95	175
ISTANBUL	80	82	91	71	39	0	0	55	31	217
NOVOROSSLYSK	45	45	70	45	40	12	3	0	11	145
ODESSA	58	52	73	54	41	8	15	0	0	157
NIHAVA SHEVA	95	81	124	86	53	0	0	0	0	0

5.3. Solution illustration

Here I intend to work out the model with Decision Making Technique (Professor Yuan Qun gave us this lecture before).

I prepare 5 candidate ship size, which is 4300TEU, 4700TEU, 5100TEU, 5600TEU and 6000 TEU.

Input data:

Table 5.5 Input data part 1

POL/POD	PUSAN	NINGBO	SHANGHAI	DA CHAN BAY	PORT KELANG	HAIFA	ISTANBUL	NOVOROSSLYSK	ODESSA	NHAVA SHEVA	WEST	EAST
PUSAN	0	0	0	0	235	285	289	185	270	0	1264	
NINGBO	0	0	0	0	223	265	225	155	270	0	1138	
SHANGHAI	0	0	0	0	220	293	363	196	355	0	1427	
DA CHAN BAY	0	0	0	0	220	257	268	143	312	0	1200	
PORT KELANG	65	52	60	55	0	175	192	90	193	0	650	232
HAIFA	85	58	95	51	48	0	142	106	95	175	343	512
ISTANBUL	80	82	91	71	39	0	0	55	31	217	86	580
NOVOROSSLYSK	45	45	70	45	40	12	3	0	11	145	11	405
ODESSA	58	52	73	54	41	8	15	0	0	157	6119	458
NHAVA SHEVA	95	81	124	86	53	0	0	0	0	0		439
DEMAND												2626

POL/POD	PUSAN	NINGBO	SHANGHAI	DA CHAN BAY	PORT KELANG	HAIFA	ISTANBUL	NOVOROSSLYSK	ODESSA	NHAVA SHEVA
PUSAN	0	0	0	0	30	35	40	40	40	0
NINGBO	0	0	0	0	30	35	40	40	40	0
SHANGHAI	0	0	0	0	30	35	40	40	40	0
DA CHAN BAY	0	0	0	0	30	35	40	40	40	0
PORT KELANG	40	35	35	50	0	35	40	40	40	0
HAIFA	40	35	35	50	30	0	40	40	40	45
ISTANBUL	40	35	35	50	30	0	0	40	40	45
NOVOROSSLYSK	40	35	35	50	30	35	40	0	40	45
ODESSA	40	35	35	50	30	35	40	0	0	45
NHAVA SHEVA	40	35	35	50	30	0	0	0	0	0
L/D EMPTY CONTAINER										

The blue part represented cargo flow goes west, and the pink part represented cargo flow goes back.

Table 5.6 Input data part 2

POL/POD	PUSAN	NINGBO	SHANGHAI	DA CHAN BAY	PORT KELANG	HAIFA	ISTANBUL	NOVOROSSLYSK	ODESSA	NHAVA SHEVA
PUSAN	0	0	0	0	60	75	80	80	80	0
NINGBO	0	0	0	0	60	75	80	80	80	0
SHANGHAI	0	0	0	0	60	75	80	80	80	0
DA CHAN BAY	0	0	0	0	60	75	80	80	80	0
PORT KELANG	80	70	70	100	0	75	80	80	80	0
HAIFA	80	70	70	100	60	0	80	80	80	85
ISTANBUL	80	70	70	100	60	0	0	80	80	85
NOVOROSSLYSK	80	70	70	100	60	75	80	0	80	85
ODESSA	80	70	70	100	60	75	80	0	0	85
NHAVA SHEVA	80	70	70	100	60	0	0	0	0	0

L/D FULL CONTAINER

POL/POD	PUSAN	NINGBO	SHANGHAI	DA CHAN BAY	PORT KELANG	HAIFA	ISTANBUL	NOVOROSSLYSK	ODESSA	NHAVA SHEVA
PUSAN	0	0	0	0	210	1250	1100	1375	950	0
NINGBO	0	0	0	0	210	1250	1100	1375	950	0
SHANGHAI	0	0	0	0	210	1250	1100	1375	950	0
DA CHAN BAY	0	0	0	0	185	950	800	1075	650	0
PORT KELANG	315	163	163	163	0	167	325	365	575	0
HAIFA	420	267	267	233	233	0	243	227	225	435
ISTANBUL	500	350	350	300	275	0	0	120	120	243
NOVOROSSLYSK	500	350	350	300	275	223	120	0	120	243
ODESSA	500	350	350	300	275	223	120	0	0	243
NHAVA SHEVA	267	125	125	120	120	0	0	0	0	0

FREIGHT

Table 5.7 Input data part 3

POL/POD	PUSAN	NINGBO	SHANGHAI	DA CHAN BAY	PORT KELANG	HAIFA	ISTANBUL	NOVOROSSLYSK	ODESSA	NHAVA SHEVA
PUSAN	0	0	0	0	150	1175	1020	1295	870	0
NINGBO	0	0	0	0	150	1175	1020	1295	870	0
SHANGHAI	0	0	0	0	150	1175	1020	1295	870	0
DA CHAN BAY	0	0	0	0	125	875	720	995	570	0
PORT KELANG	235	93	93	63	0	92	245	285	495	0
HAIFA	340	197	197	133	173	0	163	147	145	350
ISTANBUL	420	280	280	200	215	0	0	40	40	158
NOVOROSSLYSK	420	280	280	200	215	148	40	0	40	158
ODESSA	420	280	280	200	215	148	40	0	0	158
NHAVA SHEVA	187	55	55	20	60	0	0	0	0	0

FREIGHT-L/D FULL CONTAINER

Variables:

Table 5.8 Variables

POL/POD	PUSAN	NINGBO	SHANGHAI	DA CHAN BAY	PORT KELANG	HAIFA	ISTANBUL	NOVOROSSLYSK	ODESSA	NHAVA SHEVA		CAPACITY			OBJECTIVE	-1080667
PUSAN											0	SUMP1	0			
NINGBO											0	P2	0			
SHANGHAI											0	P3	0			
DA CHAN BAY											0	P4	1080667			
PORT KELANG											0	0			X+Y(W)	X+Y(E)
HAIFA											0	0			0	0
ISTANBUL											0	0				
NOVOROSSLYSK											0	0				
ODESSA											0	0				
NHAVA SHEVA												0				
												0				

The green part represented slot allocation of ports of call, total transport cargo and capacity.

X+Y (W)/ (E) represented the sum value of full containers and empty containers (west)/(east).

SUMP1 represented revenue part, and it can be calculated with sum product function.

P2 represented cost of rent containers including inventory charges and rental, and it can be calculated with “voyage period × cost per day × transport containers × ratio of leasing containers”.

P3 represented cost of deployment of containers, and it can be calculated with transport containers × μ × voyage period, here μ is considered as 2 USD/Day

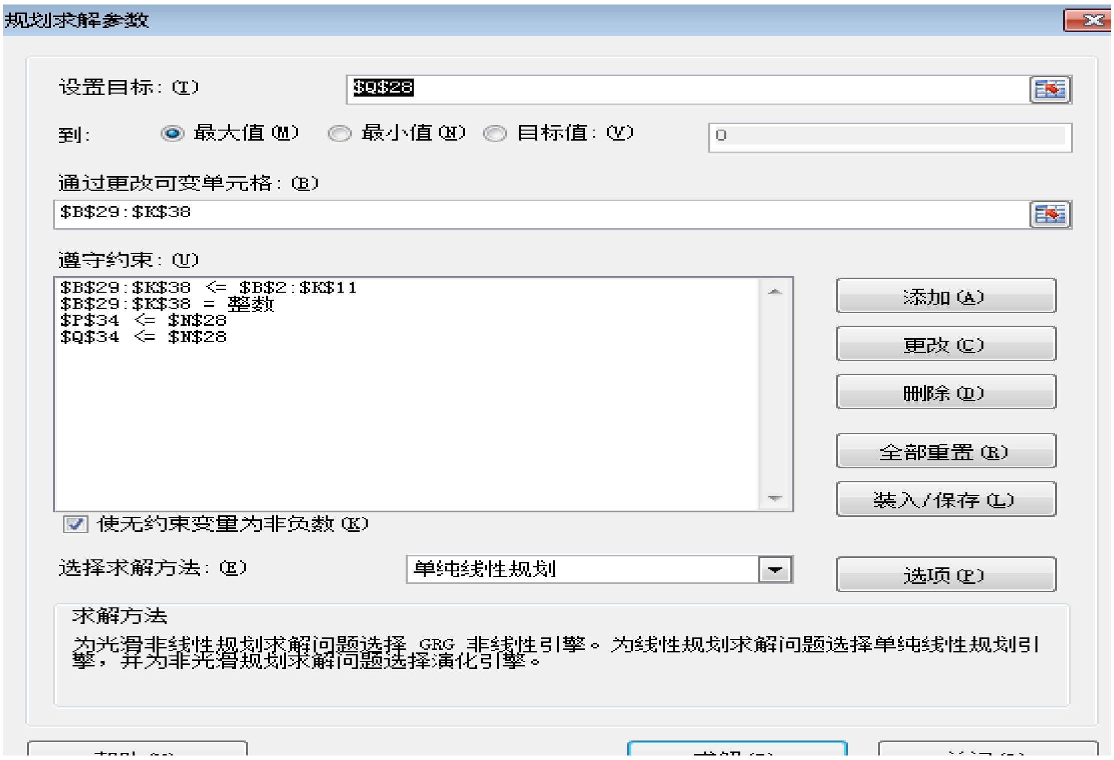
P4 represented

$$f(CAP_k) = 309.984CAP_k + 1080667 \quad (5.1)$$

The red part is the objective and represented Max profit.

Constraints:

Table 5.9 Constraints



The first constraint is to meet supply and demand constraint

The second one is to meet integer constraint.

The third and fourth one is to meet capacity constraint.

The results are as followed,

Table 5.10 RESULT OF 4300TEU CONTAINER SHIPS

POL/POD	PUSAN	NINGBO	SHANGHAI	DA CHAN BAY	PORT KELANG	HAIFA	ISTANBUL	NOVOROSSLYSK	ODESSA	NHAVA SHEVA		CAPACITY	4300		OBJECTIVE	889212.7
PUSAN	0	0	0	0	40	233	235	145	222	0	875	SUMP1	4404516			
NINGBO	0	0	0	0	43	265	225	136	219	0	888	P2	501104.6			
SHANGHAI	0	0	0	0	47	233	321	126	301	0	1028	P3	600600			
DA CHAN BAY	0	0	0	0	46	209	228	133	85	0	701	P4	2413598			
PORT KELANG	61	50	51	55	0	77	29	58	155	0	319	217			X+Y(W)	X+Y(E)
HAIFA	81	52	93	44	48	0	0	0	54	171	54	489			4290	2770
ISTANBUL	49	77	91	70	39	0	0	0	27	201	27	527				
NOVOROSSLYSK	45	45	70	45	40	12	3	0	8	143	8	403				
ODESSA	58	52	73	54	41	8	11	0	0	151	3900	448				
NHAVA SHEVA	94	81	123	86	50	0	0	0	0	0		434				
												2518				

The picture has shown that the max profit is about 0.88 million per voyage when the capacity = 4300.

Table 5.11 RESULT OF 4700 TEU CONTAINER SHIPS

POL/POD	PUSAN	NINGBO	SHANGHAI	DA CHAN BAY	PORT KELANG	HAIFA	ISTANBUL	NOVOROSSLYSK	ODESSA	NHAVA SHEVA		CAPACITY	4700		OBJECTIVE	935341.9
PUSAN	0	0	0	0	62	267	266	165	239	0	999	SUMP1	4655731			
NINGBO	0	0	0	0	25	243	217	135	216	0	836	P2	529837.3			
SHANGHAI	0	0	0	0	61	256	313	175	255	0	1060	P3	652960			
DA CHAN BAY	0	0	0	0	18	221	228	141	261	0	869	P4	2537592			
PORT KELANG	63	52	58	51	0	35	22	41	140	0	238	224			X+Y(W)	X+Y(E)
HAIFA	85	48	95	50	43	0	82	46	36	175	164	496			4664	2801
ISTANBUL	78	75	88	70	37	0	0	41	25	217	66	565				
NOVOROSSLYSK	45	45	66	39	35	12	3	0	8	145	8	390				
ODESSA	56	50	72	51	37	7	15	0	0	157	4240	445				
NHAVA SHEVA	89	80	122	85	50	0	0	0	0	0		426				
												2546				

The picture has shown that the max profit is about 0.935 million per voyage when the capacity = 4700. Compared with above optimization, the profit begins to increase this time, because the bigger vessels can digest cargo demand better.

Table 5.12 RESULT OF 5100 TEU CONTAINER SHIPS

POL/POD	PUSAN	NINGBO	SHANGHAI	DA CHAN BAY	PORT KELANG	HAIFA	ISTANBUL	NOVOROSSLYSK	ODESSA	NHAVA SHEVA		CAPACITY	5100		OBJECTIVE	1200534
PUSAN	0	0	0	0	15	283	284	185	269	0	1036	SUMP1	5137136			
NINGBO	0	0	0	0	18	264	225	155	268	0	930	P2	561380.8			
SHANGHAI	0	0	0	0	22	283	355	188	335	0	1183	P3	713636			
DA CHAN BAY	0	0	0	0	11	257	268	143	302	0	981	P4	2661585			
PORT KELANG	65	52	60	44	0	0	192	77	173	0	442	221			X+Y(W)	X+Y(E)
HAIFA	85	58	95	51	42	0	0	11	15	165	26	496			5097	2812
ISTANBUL	80	82	91	70	37	0	0	25	5	217	30	577				
NOVOROSSLYSK	45	40	68	44	37	12	2	0	6	144	6	392				
ODESSA	55	52	73	50	50	8	10	0	0	157	4634	455				
NHAVA SHEVA	91	75	122	84	43	0	0	0	0	0		415				
												2556				

The picture has shown that the max profit is about 1.2 million per voyage when the capacity = 5100. Compared with above one, the profit has dramatically increased.

Table 5.13 RESULT OF 5600 TEU CONTAINER SHIPS

POL/POD	PUSAN	NINGBO	SHANGHAI	DA CHAN BAY	PORT KELANG	HAIFA	ISTANBUL	NOVOROSSLYSK	ODESSA	NHAVA SHEVA		CAPACITY	5600		OBJECTIVE	956744.1
PUSAN	0	0	0	0	117	265	288	185	270	0	1125	SUMP1	5145692			
NINGBO	0	0	0	0	105	260	225	155	268	0	1013	P2	591128.5			
SHANGHAI	0	0	0	0	115	273	353	189	346	0	1276	P3	781242			
DA CHAN BAY	0	0	0	0	46	227	244	142	312	0	971	P4	2816577			
PORT KELANG	63	52	60	0	0	46	192	88	193	0	519	175			X+Y(W)	X+Y(E)
HAIFA	80	55	93	51	48	0	0	66	68	175	134	502			5580	2748
ISTANBUL	78	71	81	66	39	0	0	19	11	217	30	552				
NOVOROSSLYSK	44	45	70	45	40	12	1	0	5	140	5	397				
ODESSA	55	46	73	54	41	8	10	0	0	156	5073	443				
NHAVA SHEVA	95	79	124	81	50	0	0	0	0	0		429				
												2498				

The picture has shown that the max profit is about 0.95 million per voyage when the capacity = 5600.

Here we can find the profit has already reached the peak and it began to go down when the capacity increased to 5600 TEU. So it is not necessary to do test of 6000 TEU container ships.

As a result, the adjusting slot allocation is as followed,

Table 5.14 SLOT ALLOCATION

POL/POD	PUSAN	NINGBO	SHANGHAI	DA CHAN BAY	PORT KELANG	HAIFA	ISTANBUL	NOVOROSSLYSK	ODESSA	NIHAVA SHEVA
PUSAN	0	0	0	0	15	283	284	185	269	0
NINGBO	0	0	0	0	18	264	225	155	268	0
SHANGHAI	0	0	0	0	22	283	355	188	335	0
DA CHAN BAY	0	0	0	0	11	257	268	143	302	0
PORT KELANG	65	52	60	44	0	0	192	77	173	0
HAIFA	85	58	95	51	42	0	0	11	15	165
ISTANBUL	80	82	91	70	37	0	0	25	5	217
NOVOROSSLYSK	45	40	68	44	37	12	2	0	6	144
ODESSA	55	52	73	50	50	8	10	0	0	157
NIHAVA SHEVA	91	75	122	84	43	0	0	0	0	0

According to the outcome, I found that the 5100 TEU is the best ship size for East Med Service. That means ZIM would give up some less-interests business in such as Port Kelang when it optimizes liner route, but it also meet the market demand in almost all of key ports of call. Considering the highly depression in shipping market, I think it is totally acceptable for shipping lines to sacrifice some market shares in order to maximize the profit and keep operating in a good condition.

6. Conclusion

6.1. Thesis conclusion

This thesis pays attention to study optimization of East Med Service of ZIM. Traditionally, problem of liner route optimization can be split into selection of ports of call, sequence of ports of call, selection of ship size and slot allocation. However according to the practical situation of ZIM, it is not easy to change selection of ports of call and sequence of ports of call, so here I cut into the optimal issue in the rest two angles.

Trough looking for existing liner route optimization research, I choose the suitable parameters and model to solve the problem. And we can acknowledge from the analysis that here is a linear integer programming problem, so it can be solved with Microsoft Office Excel and the methods in Decision Making Technique. Finally, I draw a conclusion from the analysis and calculation outcome,

(1) East Med Service is an important link among Far East, Middle East and East Europe. It deserves each shipping line's attention.

(2) As some powerful shipping lines are constructing their larger vessels such as Maersk's Triple E, China Shipping's 19000 TEU container ships, those comparatively small ships will be out of operation and available to charter market or second-hand market. According to the outcomes, 5000 TEU is enough to meet the requirement and interest of ZIM, so it can realize the optimization of East Med Service because of charterer's and vessel buyer's strong position for now.

(3) Thesis solves the optimization of slot allocation, and it is helpful for practical operation.

6.2. Research prospect

Thesis used Microsoft Office Excel and Decision Making Technique method to work out slot allocation optimization and suitable selection of ship size. The outcome not only solves the problem of ZIM's liner route adjustment, but it also provides the basic method of optimization of liner routes. Precisely because the model is linear integer programme, normal domestic computer can work it out.

Of course the model is not perfect and there are still somewhere need to be improved in the future due to author's limited ability,

(1) The formula of cost need refresh in time, because the price of bunkers, timecharter rate, and price of secondhand vessels is always volatile.

(2) Thesis did not analyze the sequence and selection of ports of call, and the model need be adjusted once the optimization problem is refer to them.

(3) Microsoft Office Excel Solver is limited for using, because it cannot solve the non-linear programme.

List of Reference:

[1] ZHAO Gang, 2001. ANALYSIS AND IMPROVEMENT ON THE VESSEL ALLOCATION MODEL OF LINER SERVICE. Journal of systems engineering, 1997 Vol.12 No.1.

[2] ZENG Qingcheng, YANG Zhongzhen, CHEN Chao, 2010. Robust Optimization Model for Resource Allocation of Container Shipping Lines. TSINGHUA SCIENCE AND TECHNOLOGY ISSN 1007-0214 15/17 PP586-594.

[3] YANG Qin, 2010. Study on Optimization of Middle-East Line of Company A. Master Dissertation, Dalian Maritime University.

[4] SHEN Xuechao, 2003. Study on Optimization of China/Persian Gulf Service of Company C. Master Dissertation, Shanghai Maritime University.

[5] CHEN Chao, ZHANG Zhe, ZENG Qingcheng, 2011. An optimal design of container shipping networks under fluctuating demands. Journal of Dalian Maritime University, Vol.37 No.4 Nov., 2011.

[6] LIU Ying, 2014. Route optimization of container liner based on the ring mode in short sea service. Master Dissertation, Dalian Maritime University.

[7] SUN Guodong, 2010.The Study About The Container Shipping Route Optimization Based On Seasonal Fluctuations. Master Dissertation, Dalian Maritime University.

[8] CHEN Kang, 2012. Container Ship Routing Model Based on the User Equilibrium Principle. Doctor Dissertation, Dalian Maritime University.

[9] CHEN Yan, 2009. The Shipping Line Optimization In Short Sea Service. Master Dissertation, Fudan University.

[10] JIN Xindao, 2006. The study on shipping line route optimization based on Market Stochastic Situation. Master Dissertation, Shanghai Maritime University.

[11] SHOU Yongyi, LAI Changtao, LU Rufu, 2011. Multi-objective optimization model and ant colony optimization of liner ship scheduling. Journal of Traffic and Transportation Engineering, Vol.11 No.4 Aug.2011.

[12] Rana, K., Vicksonl, R.G., 1988. A model and solution algorithm for optimal routing of a time- chartered containership. Transportation Science 22(2), 83-95.

[13] Rana, K., Vicksonl, R.G., 1991. Routing container ships using Lagrangean relaxation and decomposition. Transportation Science 25 (3), 201-214.

[14] Yang，Zhongzhen, Chen, Kang, Notteboom, Theo, 2012. Optimal design of container liner services: Interactions with the transport demand in ports. Maritime Economics ＆ Logistiocs, 2012, Vol.14 (4), pp.409-434.

[15] Kris Braekers, An Caris, Gerrit k. Janssens, 2012. Optimal shipping routes and vessel size for intermodal barge transport with empty container repositioning. Computers in Industry,2012.

[16] Nguyen Khoi Tran, 2011. Studying port selection on liner routes: An approach from logistics perspective. Research in Transportation Economics, 2011, Vol.32 (1), pp.39-53.

[17] Fagerholt K. Designing optimal routes in a linear shipping problem. Maritime Policy and Management, 2002, 3(4):259-268.

[18] Ting S, Tzeng G. An optimal containership slot allocation for liner shipping revenue management. Maritime Policy and Management, 2006,31(3): 199-211.

[19] Li J A, Heung S, Wu Y, et al, 2007. Allocation of empty containers between multi-ports. European Journal of Operational Research, 2007, 182(1): 400-412.

[20] Shintani K, Imai A, Nishimura E, et al. The container shipping network design problem with empty container repositioning. Transportation Research Part E, 2007, 43(1): 39-59.

[21] Jaramillo, D.L, Perakis A.N., 1991. Fleet deployment optimization for liner shipping. Part 2: Implementation and results. Maritime Policy and Management 18 (4), 235-262.

[22] Perakis, A.N. Jaramillo, D.L, 1991. Fleet deployment optimization for liner shipping. Part 1: Background, problem formulation and solution approaches. Maritime Policy and Management 18 (3), 183-200.

[23] Ronen, Christiansen. A multi-start local search heuristic for ship scheduling—a computational study[J]. Computer ＆ Operation, 2007, 34 (3): 900-917.

[24] Baird A. Optimizing the container transshipment hub location[J]. Journal of transport geography, 2006, 14, 195-214.

[25] YANG Qiuping, XIE Xinlian, SU Chen. Model of ship routing and fleet planning and its algorithm. Navigation of China, Vol.32 No.1, Mar.2009.

[26] Lim SM. Economies of ship size: A new evaluation [J]. Maritime Policy and Management, 1994, 21(2): 149-166.

[27] Lim SM. Economies of scale in container shipping [J]. Maritime Policy and Management, 1998, 25: 361-373.

[28] Willmington R. The bigger the better [J]. Containerisation International, 2002, 35:52-53.

[29] Jansson J, Shneerson D. Liner shipping economics [M]. London: Chapman and Hall, 1987.

[30] Damas P. Do mega-ships sav money [J]. American Shipper, 2001, 44:68-69.

[31] Damas P. Big ships big problem [J]. American Shipper, 2001, 43: 12-22.

[32] Yuan Qun. Decision-Making Techniques International Transprot and Logistics.

[33] Prof. Notteboom Itl05MAL-MARITIME LOGISTICS, ITL2015,October 2014.

[34] http://en.wikipedia.org/wiki/Busan#Shopping_and_commerce

[35] http://article.bridgat.com/guide/trans/port/port.html

[36] http://www.imf.org/external/index.htm