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Analysis of the efficiency of current liner shipping alliance between Asia and Europe

by

Ruixiao Liu

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Abstract

In this paper, the efficiency of the shipping networks of the two shipping alliances: 2M and CKYHE, that operates in the market of Asia-Europe is analyzed in the perspective of revenue maximization. According to the current research, there is no previous research regarding this topic.

In order to address the above stated research purpose of this paper current status of the liner shipping market and alliances operate in the market of Asia-Europe are introduced. A mathematical model of supply and demand is then built in which Asian ports are treated as supplier and European ports are treated as customer. The model is to achieve the optimal capacity allocation between the two regions. The data inputs include the total shipping capacity, the freight rate and demand between each pair of ports. Data estimations are made regarding the shipping capacity for the 2M alliance and demand between each pair of ports.

After getting the optimal way of attributing the total transportation capacity for the origin-destination situation, same number of routes as the actual situation are derived and compared with the actual shipping network in the aspects of number of routes visit certain port and ports connectivity in the network. The comparisons are taken in both alliance level and individual level. The results of the comparison suggest that the actual shipping network of the two alliances are not efficiency to achieve revenue maximization in the alliance level. In addition, there is conflict of interest between the alliance as a whole and individual companies because there is high level of difference between the optimal shipping network in the individual level and alliance level. The results also suggest that the shipping network of the 2M alliance is of high level of consistence with the revenue maximization for individual company while the CKYHE alliance is not.

Sensitivity analysis is taken next because there are issues including the alliance strategies regarding the shipping network which is not consistence with the model and limitation of demand are not taken into consideration in the previous discussion. The data input in the model is thus changed according to the issues. The results suggest that there is still high level of difference between the result of the sensitivity analysis and the actual situation. This suggests that the current shipping networks of the two alliances are not efficiency of achieving revenue maximization.

The suggestions for the shipping networks derived from the model include that the two alliances shall attribute more capacity to the Colombo port in Sri Lanka because the high freight rate regarding this port. For the 2M alliance, more shipping capacity shall be attributed to the Japanese ports and the Gdansk port in Poland. For the CKYHE alliance, more shipping capacity shall be attributed to the South Korean ports, the Hong Kong port in China, the Algeciras port in Spain, and the Antwerp port in Belgium.

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Chapter 1 Introduction

1.1 Background

As IHS put in its report of Valuation of the Liner Shipping Industry, liner shipping “is the service of transporting goods by means of high capacity, ocean-going ships that transit regular routes on fixed schedules.” (IHS, 2009) As one of the basic maritime transportation service modes together with tramp and industrial operation, liner shipping bears the majority of seaborne trade in term of value and facilitates a significant portion of the merchandise trade of the world. In the 2007, the percentage of seaborne trade value transported by liner shipping is 60%, which amount to $7.7 trillion. (Laporte, 2007)

By reviewing the size of container ships in the liner shipping industry, it can be observed that the size of the ships is increasing significantly. The early container ship that built in 1956 is with the capacity between 500 and 800 TEU. While the Triple-E that built in 2013 is with the capacity of 18000 TEU. (Kremer, 2013) This situation is due to two reasons. Firstly, the worldwide trade has increased for the past twenty years, according to the WTO, the average of increase of export is about 5%. (WTO, 2014) The level of trade increase is even higher between Asia and Europe. In the year 2013, the EU trade with Asia reached €1.25 trillion, which is two times higher than that of ten years ago. (Constâncio, 2014) The increase of trade value acquires higher capacity of transportation. Secondly, the increase requirement of transport capacity lead shipping company pursuing economics of scale, the increase of ship size leads to the decrease of cost of transportation per unit cargo.

Since the trade amount between Asia and Europe is at high level and the distance between the two regions is big, liner-shipping companies tend to apply big ships to transfer cargos. However, the chase of building large ships currently leads to the situation of overcapacity in the industry. To overcome such situation, lower down various operational and financial risks and expend market to different regions, liner-shipping companies involve alliance. Some researches show that alliances among liner-shipping companies lead individual companies serve more ports and expand their network, while the total number of ports served remain the same.(Brian Slack, 2010)

The liner shipping alliance starts at the beginning of the year 1996 and the main cooperate operation including slot rent, port operation, inland transportation, container interchange, and equipments sharing, etc. Before the form of shipping alliance comes into practice, the form of cooperation among liner shipping companies is liner conference. The cooperation among liner shipping companies in the liner conference including setting common freight rates, condition of transportation and freight pool. Comparing with shipping alliance, the liner conference has negative effect on the market because it limits new entrances in the market. The shipping alliance is more flexible and reasonable compare with liner conference. This form of cooperation among liner shipping companies can improve the operational performance and reduce cost more efficiently. (Renato Midoro, A critical evaluation of strategic alliances in liner shipping, 2000)

There are three modes of horizontal alliances among liner-shipping companies. The first mode is strategic or global alliances. Under such alliance, shipping companies share the employment and utilization of ships over particular routes together with sailing schedules and itineraries, joint terminals and container coordination on a global scale. However, liner shipping companies involve in strategic alliance have their market separately, the marketing, price setting and management of profit or loss are also taken independently. The aim of the strategic alliance is integrate the transport capacity. The second mode is financial alliance. Liner shipping companies involve in such alliance have the same aim to keep the market stability. Such alliance includes freight rate settlement and capital alliance. Liner shipping companies share certain capital investments such as dock and ships, and set standard freight rates. The third mode is logistics alliance, in which liner-shipping companies involve the closest relationship of all the three modes. Such alliance includes share of container and logistics information among companies involved in the alliance.(lib, 2015)

Of all the three alliance modes, the strategic alliance is the most currently and applied most regularly in the shipping industry because under such alliance liner shipping companies can maintain certain level of independency while share risks and improve operation performance. However, certain level of defaults also exists in such alliance such as companies under one alliance lack synergy because they usually bear different strategies and the profit and loss do not share between members involved in one alliance, the situation can result in conflict among members and the shipping companies under one alliance become competitor against each other.

For the liner-shipping network between Asia and Europe, four strategic alliances occupy over 90% of the market. The four alliances including the 2M alliance (Maersk Line and Mediterranean Shipping Co), the G6 alliance (American President Lines, Hapag Lloyd, Hyundai Merchant Marine, Mitsui, Nippon and OOCL), CKYHE alliance (COSCO, K-line, Yang Ming Line, HANJIN and Evergreen), and the O3 alliance (CMA CGM, China Shipping Container Lines Co. and United Arab Shipping Co). The alliance of the CKYHE is built in the year 2014 and the alliance is working on trades between Asia and Europe, including the Mediterranean region. (Liang, 2014) The CKYHE alliance used to be the CKYH alliance, in which Evergreen is not included. The CKYH alliance is formed firstly in the year 1996. The 2M alliance is also formed in the year 2014. The shipping network of the alliance covers Africa, Asia-Europe, the trans-Atlantic, Central America, Europe-Middle East, Asia-Middle East, intra-Asia, intra-Europe, Oceania, South America and the trans-Pacific. (Egan, 2014)

The figures below show the market share of liner shipping alliances in the East-West and Euro-East Asia market. (Strategic Alliance in Container Liner Shipping After P3 Failure, 2014)

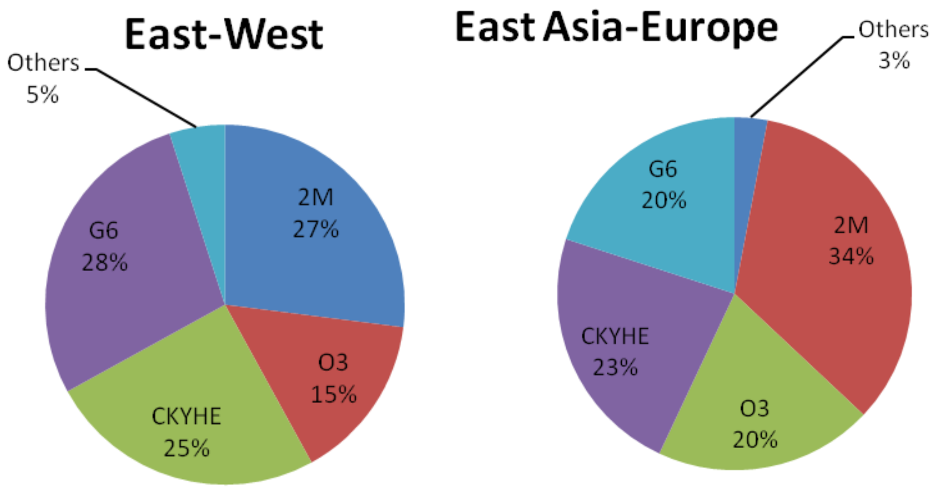

Figure 1 Market share of liner shipping alliance in East-West market
Figure 2 Market share of liner shipping alliance in East Asia-Europe market
Source: (Strategic Alliance in Container Liner Shipping After P3 Failure, 2014)

The two figures above suggest that the level of concentration in the liner shipping market in East-West, as well as in the East Asia-Europe, is high. About 80% of the market is occupied by G6, 2M and CKYHE in the East-West market. It can also be concluded that the alliances in terms of market occupation are successful in the regions shown above since the market is occupied majority by the four alliances. Other liner shipping companies occupy little market share.

1.2 Problem Statement

Following the above background introduction, the purpose of this thesis is to evaluate the efficiency of the alliances among liner shipping companies of the market in the regions of Asia and Europe. Based on the background part, two alliances are going to be analyzed in the research, which are the CKYHE alliance and the 2M alliance because these two alliances occupies most of the market share in both the East-West market and East Asia-Europe market. In the East-West market, the total market share of the two alliances is 52% while in the East Asia-Europe market, the number is 57%. Such high level of market share can be treated as sufficient to be analyzed and determine the efficiency of the alliances in the market.

The efficiency of alliance can be defined in two folds. Firstly, the level of efficiency is the level of profit difference of the actual situation and the theoretical outcome. Secondly, whether the member companies involved in the alliance achieve a higher profit than taking out their own operation individually also reflect the efficiency of the alliance .Therefore, the main research question can be generated as:

Is the two alliance: 2M and CKYHE achieve efficiency in the market of the shipping line between Asia and Europe in terms of profit generation?

The scope of this research is as follows: It is focus on the reasonableness behind the formation of the shipping network of the two alliances in terms of revenue generation in the market of Asia and Europe. This means a theoretical model shall be built to generate optimal solutions. Then compare and analyze the difference between the actual situation and the optimal solution shall be taken out to determine whether the current alliance situation is of theoretical reasonable.

In order to be able to answer the main research question, several sub research questions and issues have to be addressed. First of all, the current situation including the current shipping network of the two alliances and their operational situation shall be provided. Secondly, the optimal solutions which show the theoretical shipping network under the objective of profit maximization shall be derived to be the benchmark to the actual situation. The optimal solutions shall contain the optimal shipping network both in the alliance level and in the individual level.

Therefore, the following sub research questions will be addressed in this thesis:

1. What is the current liner-shipping network of the two alliances existing in the regions of Asia and Europe?
2. What is the optimal solution of shipping network for each companies involved in the two alliances if they taking same operation routes separately.
3. What is the optimal solution of shipping network for each of the two alliances separately base on the objective of profit maximization?
4. Are the alliances existing in the market reasonable and what is the potential level of increase of the alliances for the market?

On a final note, this research will provide a view of evaluation of the existing liner shipping networks of the two alliances, 2M and CKYHE in the market of Asia and Europe in term of alliance. The gap between the actual situation and the theoretical results provides a view of potential development of the shipping network.

1.3 Structure

The structure of this thesis is as follows:

The Chapter 2 is the literature review. The sources of the literature include the official websites of the shipping companies involved in the three alliances, research papers, reports and textbooks regarding the liner-shipping network of Asia and Europe, the model building of deriving optimal solution and the method of evaluation of liner-shipping alliance.

In Chapter 3, the methodology is discussed and a mathematical model is going to be built under reasonable assumptions. The reason behind the model building, the way of application the model, the model reliability and limitation of the model are also being presented.

In Chapter 4, the data required for the methodology is being searched, assumed and explained. The data input including the numbered and grouped ports of the two alliances, the revenue between each pair of the grouped ports, demand between two ports, capacity and number of ships involved in the alliances.

In Chapter 5, the results derived from the model are shown and analysis is taken to determine the efficiency of the two alliance by comparing the results of the model with the actual shipping network. The theoretical results are in both alliance level and individual level. In this chapter, the sub-research questions 2 and 3 can be answered.

In Chapter 6, sensitivity analysis regarding the demand between two ports is taken. While the reason of the difference between the theoretical results and the actual situation is being discussed. In this chapter, the sub-research question 2 and 3 can be further answered and the sub-research question 4 can be answered.

In Chapter 7, conclusions and future research directions are made. The conclusions include the efficiency of each of the two alliances and the suggestions of potential alliance structure change. Limitations and inefficiency of the thesis are also analyzed in this chapter. Following this, the thesis ends with the references and appendices.

Chapter 2 Literature review

2.1 Alliance type

Alliance in the liner-shipping industry suggests there is cooperation relationship among the parties in the industry. There are two kinds of alliances existing in the liner-shipping industry mentioned in the research of Eddy van de Voorde and Thierry Vanelslander, which are horizontal alliance and vertical alliance. The vertical alliance, which is more commonly referred as vertical integration, is the alliance relationship between members in a supply chain. In the liner-shipping case, the most common vertical alliance exists between the liner-shipping company and the feeder company.(Eddy van de Voorde, 2008)The horizontal alliance is the cooperation among liner-shipping companies taking out business in the same market. Some of the views suggest that vertical alliance is of higher successful rate compare with horizontal alliance. This is because "vertical alliances deepen the relationship of the firm with suppliers through the exchange of know-how and commercial intelligence and suppliers become actively involved in product design and distribution arrangements", while competition and conflicts of interest occur in horizontal alliance regularly(Sarkissian).

In the case of horizontal alliance, there are different types of cooperation existing in the liner-shipping industry. Except the three types of alliances mentioned in the introduction part, other collaborative agreements including ship sharing agreements and slot sharing agreements are also horizontal alliances existing in the liner-shipping industry. Fixed ship capacity of certain routes is going to be exchanged between partners under slot exchange agreement while ship sharing agreement require partners under the agreement to fulfill demand on specific trade routes by ship sharing and performing joint optimization. Under these two agreements, profit, operating costs and demand information are sharing among partners. (Heaver, 2005)

The combination of vertical alliance and horizontal alliance exists among liner-shipping industry to gain performance advantages. Such alliance referred as liner-shipping network involves intermodal service providers, container management services providers and container terminal operators. The members under the alliance share resources and develop mutually beneficial strategies.(Lun, 2009) Meanwhile, such cooperation can be beneficiary in aspects of cost reduction in areas including intermodel feeder services, expand service coverage and economies of scale. (Photis M. Panayides, 2011). However, such kind of cooperation involves various parties with different business can lead to conflict of interest and synergy inefficiency.

Of all the alliances types stated above, most of the liner-shipping companies especially that involved in the global trading, choose strategic alliance over other types. This is because other types of alliances require higher level of commitment from each partner. The cooperation including the terms of financial and information, etc. While the strategic alliance asks for an operational level of commitment as stated in the introduction part. Liner-shipping companies involved in global trading are from different countries in which the policy, currency and economic situation are different. In this case, it is difficult for companies commit a close cooperation relationship. However, the strategic alliance among liner-shipping companies can provide the partners to access new market, to apply cutting-edge equipment with shared risk and cost and to gain competitive advantages while remain certain level of independency thus reduce the level of conflict of interest. (Koay, 1994)

Even in the situation of strategic alliance, cooperation details can be different. The Porter's value chain concept distinguishes the type of resources contributed by the partners in an alliance. The alliance parties can contribute similar resource to pursue economies of scale and economies of scope, or they can contribute complementary resources to overcome their weaknesses, build on their respective strengths, achieve competitive advantages.(Photis M. Panayides, 2011)

The literature "Slot Allocation Planning for an Alliance Service with Ship Fleet Sharing" mentions the way partners of an shipping alliance share ships. In most of the case, the partners of an alliance share the capacity of a certain route base on the percentage of the total shipping capacity they contributed in the alliance. Partners can also transact their slots with each other if there is shortage and redundant capacity exist between two partners. (Hua-An Lu C.-W. C.-Y., 2009)

2.2 The reason of strategic alliance among liner-shipping companies

By reviewing the literature, four reasons can be summarized of liner-shipping companies involve in strategic alliance.

Firstly, liner-shipping companies involve in strategic alliances to expand their markets. This reason is commonly mentioned in the literatures regarding the motive of liner-shipping companies involve in strategic alliance. All these literatures treated expanding market as one of the most important motive for companies to join alliances. In the research taken by Hua-An Lu, extend service coverage is identified as the most important reason for a liner-shipping company involves in an alliance by applying the Delphi method. The value attribute to this reason is 2.7 out of 3 and recognized by 80% of the professionals involved in the method. (Hua-An Lu, 2006). In addition, Erin Anderson and Hubert Gatignon mentioned in their literature that strategic alliance is a method to reduce transaction cost to enter a foreign market.(Erin Anderson, 1986)The transaction cost is derived from the need to acquire and process information, negotiation and bargaining of contracts, etc. (Photis M. Panayides, 2011)

Secondly, liner-shipping companies involve in strategic alliance to avoid exposing to certain risk. In the literature "An Evaluation of Strategic Alliances in Liner Shipping-An Empirical Study of CKYH", share the risks of providing new liner services is the second important reason that a liner-shipping company involves in an alliance.(Hua-An Lu, 2006). The risks for a liner-shipping company include the investment risk of purchasing capital intensive ships, the uncertainty of the new market and the obsolete of technology.

Thirdly, liner-shipping companies involve in strategic alliance to seek resource usage efficiency and get access to other companies' resources. ERIC W. K. TSANG identifies that the firm as a collection of resources. (TSANG, 1998)The literature "A Resource-Based Theory of Strategic Alliances" mentions that "firms need to seek a strategic fit between their internal characteristics (strengths and weaknesses) and their external environment (opportunities and threats)" and strategic alliance with partners bears complementary quality is one of the methods to overcome the weakness and reduce threats for the company to apply its resources in an efficiency way. (Das, 2000)

Fourthly, liner-shipping companies involve in alliance to seek for economic rent. The definition of rent is mentioned in Robert D. Tolli's research as the return in excess of the company's opportunity cost. Therefore, the rent seeking can also be transferred as profit maximization seeking. (TOLLI, 1982)

2.3 Definition of efficiency of alliance

The literature "The Dynamics of Learning Alliances: Competition, Cooperation, and Relative Scope" identifies that the benefits derived from strategic alliance can be separated as common benefits and private benefits. Private benefits are benefits for particular member of the alliance while common benefits are for the alliance as a whole. The decision for a liner-shipping company to join an alliance is determined by the ratio of the private benefit for the company to the common benefit for the alliance.(TARUN KHANNA, 1998) Therefore, in this thesis, the efficiency of alliance is evaluated in two aspects: the common benefits and the private benefits.

As profit seeking institutions, the maximization of profit is the fundamental purpose for each liner-shipping choose to involve in the alliance and the level of achievement of it shall be the measurement of private benefits. (Agarwal, 2007)

The maximization of profit in the above statement is of various meanings.(Michael C. Jensen, 2001) Firstly, maximization of profit as the main purpose of companies when making strategic decisions, balance shall be made between short-term profit maximization and long-term profit maximization because it is common in the situation that the company's short-term interest is conflict with its long-term interest. There is potential profit that require time to realize when making strategic decisions. In the case of liner-shipping company alliance, the decision to involve in an alliance with the purpose to expand a new market may generates losses for the company in the short-term but in the long run, the company can get profit from providing better quality of service and further occupation of the market.

Secondly, maximization of profit requires the balance between divisions of the company and the company as a whole. In the case of liner-shipping alliance, the decision of whether involving in an alliance may let the company as a whole realize its profit maximization, while for the division involved in the alliance, for instance, the Asia-Euro line division, the profit maximization may not achievable. (Agarwal, 2007)For instance, the strategic alliance of a liner-shipping company in the Asia-Euro line may maximize the profit of Asia-Euro division due to the decrease of operational cost, but this may generate loss of profit of other divisions because of the shortage of ships, lack of maintenance etc.

Thirdly, the specific terms of alliance, including the partners' share of certain routes and ships, and the level of business the company involved in the alliance also determine the achievement of profit maximization. Since these are changing all the time, it is difficult to determine whether a company achieves profit maximization of involving in the alliance.

As most of the literatures related to liner-shipping alliance put achieving economies of scale as one of the most important purposes to involve in an alliance,(Koay, 1994) one of the standard to evaluate the efficiency of alliance shall be the level of economies of scales achieved by the alliance as a whole.

Meanwhile, there are other standards to evaluate the efficiency of the operation of liner-shipping company or liner-shipping alliances. In the literature "Evaluating efficiency of international container shipping lines: A bootstrap DEA approach", the efficiency is defined as the level of output compare with the input required, which can be referred as product rate. (E s t e r Gu t i é r r e z, 2014) While in the literature "An Evaluation of Strategic Alliances in Liner Shipping-An Empirical Study of CKYH", the author identifies that the CKYH is chosen as the subject of research is because firstly, none of the members of this alliance has left since its formation. Secondly, "the entire capacity of this alliance ranks at number two with 10.3% of supplied slots in the world". This suggests that the market occupancy of the alliance is high. Thirdly, the number of members of the alliance is more than two but it still operates in a more stable way than others. The three statements above can be treated as standards of evaluate alliances. (Hua-An Lu, 2006)

2.4 Evaluation of liner-shipping alliance

Since the purpose of this thesis is to determine the efficiency of liner-shipping alliance in the market of East Asia and Europe in term of profit maximization realization, the previous literature regarding the evaluation of liner-shipping alliances are searched. It is suggested that the research related to the financial aspect of the liner-shipping alliance is limited. Most of the literature regarding the evaluation of liner-shipping alliances focus on the stability of the alliance.

There is reason that the stability of alliance becomes the most important concern to define the successfulness of an alliance. As we mentioned previously, the reason for liner-shipping companies to involve in alliance can be summarized as achieving profit maximization by cooperation to overcome weakness and avoid threats. Tarun Khanna's research suggests that the decision of a company to join an alliance depends on the percentage of interest it can achieve of all the interest derived from the synergy. (TARUN KHANNA, 1998). In his research, he identified that the alliance cannot be stable either under the situation that all the partners of an alliance pursue only the common interest or the partners pursue only private interest. There shall be a balance, which is difficult to get, between the private interest and common interest that keeps the alliance stable. However, the situation is always dynamic due to the changing economic and political environment and the individual's strategic changing. This makes the balance impossible to be realized.

Many of the literatures regarding the evaluation of stability of strategic alliance suggest that individual companies focus on pursuing their own interest is the most important reason that result in the instability situation in alliances. The pursuing of individual interest rather than common interest result in intra-alliance competition. (Killing, 1988) In addition, the number of partners in an alliance, the nature and amount of each individual's contribution, the trust building and the complexity of the operation of the liner-shipping network all contribute to the instability of the alliance.(Renato Midoro, 2010).

Since explore new market is one of the reasons that a liner-shipping companies involves in the alliance, the company probable drop out of the alliance after getting into the market and choose merge and acquisition as more efficient tools to get market share and maximize its profit. (DONG-WOOK SONG, 2010). The research shows that alliance is not the only way for liner-shipping company to achieve the purposes stated under the reason of companies join alliances, and there is also deviation of the theoretical situation of an alliance from the actual situation. The game theory is applied in the research to explain the deviation and identifies that the focus on pursuing individual interest results the deviation.

By evaluating currently one of the most successful liner-shipping alliances, CKYH, the author presents the following successful reasons, which are Mutual trust between all partners, The number and size of partners, Partner compatibility (in particular of company's culture), A reasonable and practicable cooperating rule for following up, Good understanding by all parties of competition and marketplace and Mutual agreement on co-operation objectives. (Hua-An Lu, 2006)

From the statement above, it is suggested that even though most of the literatures regarding the evaluation of the strategic alliance among liner-shipping company focus on the stability issue, there is close connection between the stability of an alliance and the financial efficiency, which is the achievement of the profit maximization. This is because shipping companies are profit-seeking organizations, which means that all the decisions the companies made are aim to achieving profit maximization. A shipping alliance with high level of stability suggests that the partners of the alliance make the decision to stay in the alliance. Therefore, the alliance with high level of stability suggests that the alliance bears high level of financial efficiency. All the partners involve in the strategic alliance achieve high level of profit maximization individually and there are high level of common profit maximization achievement somehow ensure the stability of the alliance.

2.5 The research method

The literatures related to maritime network design, routing and scheduling, either for liner ships or other type of ships, similar methods are used. The mathematical methods usually include an objective function either minimize cost or maximize profit. Certain constraints are set under different situation. The different aspects of such models including the complexity of the problem, for instance, some of the model is used to deal with shipping network in small area with settled demand while others are applied in the situation of long-distance network with uncertain demand and freight rate. In addition, the set of data inputs are different in literatures to deal with different situations, for instance, in some models the cost of operating a ship is an estimated figure while in others the cost consist of different aspects involve in shipping operation. The results give the optimal network and ship scheduling.

In the literature “Inventory Constrained Maritime Routing and Scheduling for Multi-Commodity Liquid Bulk”, the objective function is to get the minimum cost of operating ships of liquid bulk. While the assumptions involved in the literature including heterogeneous ship fleet, and most importantly, the ship can only transport one kind of cargos due to the nature of the cargos. Thus, there is constraint of the amount of cargos transported. The results of applying the model shall including the optimal routing schedule that specifies the amount of each product to carry “from which port to which port, at what time, and on which ship, subject to the conditions that all ports must have sufficient product for consumption, and the stock levels of the products cannot exceed the inventory capacity of that port.” (Hwang, 2005)

The author of the literature “The Container Shipping Network Design under Changing Demand and Freight Rates” builds the model including three stages to deal with the changing demand and freight rates issues, because the changing data input is the main problem of most of such models. The objective function is to maximize profit. The demand data input is based on randomly assumptions. While the output of the model involves in the literature including optimal set of ports to be called, the optimal order of calling sequence, the optimal size of ships, and the optimal series of ship-slot allocations on shipboard at each calling ports. (Chao, 2009)

The literature:"Designing optimal routes in a liner shipping problem" describes a different method to generate optimal network to realize minimum cost. The first step is to generate all the feasible routes between the settled ports, the routes are generated under certain constraints including the limitation of ship capacity and the time constraints of the routes that limits the number of ports a route can visits. The costs of each candidate route are calculated and are input for the second step. In the second step, all the routes are taken into consideration under the objective function to minimize the total cost of all the ships involved in the network. The constraints set in the second step include that all the ports must be visited and each of the ships must have an allocated route. (FAGERHOLT, 2006)

As identified previously, the levels of profit maximization in both individual level and common level are applied as the evaluation standard to determine the efficiency of alliances in the Asia-Europe market, the mathematical analysis method is to be applied to generate the theoretical outcome. The book “Handbooks in Operations Research and Management Science: Transpiration” provides the mathematical model that can be applied in this thesis in a reasonable way.

In Chapter 4,3.3.1 traditional liner operations, a mathematical model is built to determine the optimal routes for each ships employed by the shipping companies. The method focuses on the problem that a liner shipping company is going to operate several routes differently among a set of ports ordered along a straight line. The ships under such method are heterogeneous and the aim of the method is get the optimal routes network to realize the profit maximization.

The routes are set under the following rules: (1) the ports are numbered and each route has two end ports. (2) A route starts in one port and travels outbound to ports with higher numbers in as sequent way until the destination port, and then it turns around and starts it inbound travel to ports with lower numbers in a sequent way until the original port. The ships do not have to visit each port between the numbers and they also do not have to visit the same ports on the outbound and inbound legs of the route. (3) “Each container is loaded in its loading port and stays on board the ship while the ship either sails a part of the outbound or inbound route before it is unloaded in its unloading port”. The mathematical description of the problem sets the objective function and the constraints including the limitation of demand, the limitation of capacity of ships, and the routes are organized in a sequent way. (Laporte, 2007)

The data input and variables set for the model are described in the table below:

Table 1 Model data input

Concept	Mathematical expression	Range	Index
[1] No. of ports	N		i, j, k, i', j'…..
[2] Ports in the line numbered after i	N_i^+	i+1, i+2,……N	
[3] Ports in the line numbered before i	N_i^-	1,2……..i-1	
[4] Ports in the line numbered after j	N_j^+	j+1, j+2,……N	
[5] Ports in the line numbered before j	N_j^+	1, 2,……j-1	
[6] Two end ports of a route	i, j	1⩽i⩽h; h<j⩽N	
[7] The last port in Asia	h	1⩽i⩽h<j⩽N	
[8] Set of ships	V		V
[9]The revenue of transporting one container from port i to port j	R_{ij}		
[10] The cost per ship of transporting from port i to j	C_{ijv}		
[11] The capacity of a ship	Q_{ijv}		
[12] The demand of transporting from ito j	D_{ij}		
[13] Transport time between port i and j	T_{ij}		
[14] Shipping frequency	F		

[1] It is assumed that the shipping lines are operated in set of ports ordered more or less on a straight line. The ports involve in the research are numbered from 1 to N in a sequent way.

[2] –[5] Defines the set of ports numbered before i or j, or after i or j.

[6] Each route has start port and end port. The ship starts its outbound trip from port ito j, including the ports between the two ports, but not all the ports between the two ports are necessary to reach. After reaching port j, the ship starts its inbound trip from j to i. The ports reached in the outbound trip are not necessarily the same with that of the inbound trip. The route however shall reach both Asia and Europe.

[7] h is the last port numbered in Asia. In this model, it is assumed that the ports in Asia are numbered lower than those in Europe. Therefore, the ports numbered in the range [1, h] are Asian ports while the ports numbered in the range (h, N] are European ports.

[8] The ships are numbered from 1 to V.

[9] The revenue of transporting each container on the ship is different because the distance moved for each container is different and not all the containers are travelled from port i to j. While this model, we made this assumption that the revenue is the freight rate per container transported from port i to j.

[10] In reality, it is difficult to determine the average cost per container because there are many determines, including the condition of the ships, the fill rate, and the distance a container transported, which is changing all the time, etc. Therefore, the cost in this model is set as the total cost of a ship under the situation that the route is directly from port i to j.

[11] The capacity of a ship is set in number of containers under the situation that it sails directly from port i to j. According to the book "Handbooks in Operations Research and Management Science: Transpiration", "it will be sufficient not to let capacity depend on the sailing leg (i, j), but in rare cases capacity may depend on weather conditions or other factors."(Laporte, 2007) In this case, we treated the containers transported between the ports among i to j but not including i or j as transported from i to j.

[12] The demand is the sum of export volume of each port. Since during the round route, all the containers are fully load and unload among the ports from i to j, it is the same to use export volume of each port as import volume. Therefore, the demand is the transportation demand for each route.

[13] The transport time between port i and j including the time required to loading and unloading containers.

[14] The shipping frequency is an important factor for customer satisfaction. The

frequency is defined as the time interval between two ships leaving from port i to j.

Table 2 Model variables

Concept	Mathematical expression
[15] Number of containers transported from port i to j	e_{ijv}
[16] If the ship transport container directly from i to j	x_{ijv} (binary variable)
[17] Number of ship voyages ship v manages in the planning horizon	w_v
[18] Ship v is allocated to a route that starts in port i and turns around in port j.	y_{ijv} (binary variable)

[15] The first variable is the number of containers transported between each pair of port in the certain route that the end ports are i and j.

[16] A binary variable is set to determine whether the route for the ship is directly from i to j, which suggests that the ship only visits two ports. If the ship only visits two ports, the value of this variable is 1, if not, the value is 0.

[17] Wv determines the number of voyage a ship can manage during a year.

[18] A binary variable is set to determine whether ship v is allocated in the route between the port i and j. If ship v is allocated in the route i-j, the value of this variable is 1, if not, the value is 0.

After setting the data input and the variables, the objective function of maximizing profit can be shown as:

$$max \sum_{v \in V} \sum_{i \in N} \sum_{j \in N} w_v (R_{ij} e_{ijv} - C_{ijv} x_{ijv})$$

The following constraints are set:

(1) $x_{ijv}(\sum_{i' \in N_{i+1}^-} \sum_{j' \in N_{j-1}^+} e_{i'j'v} - Q_{ijv}) \leq 0, \forall v \in V, i \in N_{h+1}^-, j \in \ N_h^+$

(2) $x_{ijv}(\sum_{i' \in N_{i-1}^+} \sum_{j' \in N_{j+1}^-} e_{i'j'v} - Q_{ijv}) \leq 0, \qquad \forall v \in V, i \in N_{h-1}^+, j \in \ N_h^-$

The two constraints above limits the number of container transported by ship v to the capacity of the ship v.The constraint (1) limits the inbound trip while the constraint (2) limits the outbound trip.

(3) $w_v e_{ijv} \leq D_{ij} \sum_{j' \in N_i^+ \setminus N_j^+} x_{ij'v}, \qquad \forall v \in V, i \in N_{h+1}^-, j \in \ N_h^+$

(4) $w_v e_{ijv} \leq D_{ij} \sum_{j\prime \in N_i^- \backslash N_j^-} x_{ij\prime v}$, $\forall v \in V, i \in N_{h-1}^+, j \in N_h^-$

(5) $w_v e_{ijv} \leq D_{ij} \sum_{i\prime \in N_j^- \backslash N_i^-} x_{i\prime jv}$, $\forall v \in V, i \in N_{h+1}^-, j \in N_h^+$

(6) $w_v e_{ijv} \leq D_{ij} \sum_{i\prime \in N_j^+ \backslash N_i^+} x_{i\prime jv}$, $\forall v \in V, i \in N_{h-1}^+, j \in N_h^-$

The four constraints above define a route shall be start at port i and end at port j either directly or via ports numbered between i and j. The constraints (3) and (5) limits the outbound trip while the constraints (4) and (6) limits the inbound trip.

(7) $\sum_{v \in V} w_v e_{ijv} \leq D_{ij}$, $\forall v \in V, i \in N_{h+1}^-, j \in N_h^+$

Constraint (7) suggests that the total containers transported in one ship shall not exceed the demand of route i-j.

(8) $w_v (\sum_{i \in N} \sum_{j \in N} T_{ij} x_{ijv}) \leq 365, \forall v \in V$

The analyzing period under this method is one year. It is assumed that all the ships can operate for the whole year and maintenance is ignored in this situation. The constraints (8) limits the shipping operating time to the time of a year.

(9) $\sum_{i \in N \backslash \{N\}} \sum_{j \in N_i^+} y_{ijv} \leq 1$, $\forall v \in V$

The constraint above ensures each route can only have one pair of ports.

(10) $y_{ijv} \left(\sum_{j' \in N_i^+ \backslash N_j^+} x_{ij'v} - 1 \right) = 0$, $\forall v \in V, i \in N_{h+1}^-, j \in N_h^+$

(11) $y_{ijv} \left(\sum_{j' \in N_i^+ \backslash N_j^+} x_{j'iv} - 1 \right) = 0$, $\forall v \in V, i \in N_{h+1}^-, j \in N_h^+$

The constraints (10) ensures that the ship starts in port i needs to leave port i to a port not farther away from port j and constraint (11) ensures the ship arrives in i from a port not father away from j. The constraints above ensures the routes are similar with straight lines rather than intersect.

(12) $y_{ijv} \left(\sum_{i' \in N_k^- \backslash N_i^-} x_{i'kv} - \sum_{j' \in N_k^+ \backslash N_j^+} x_{kj'v} \right) = 0$,

$\forall v \in V, i \in N_{h+1}^-, j \in N_h^+, k \in N_i^+ \backslash N_{j-1}^+$

(13) $y_{ijv} \left(\sum_{i' \in N_k^+ \backslash N_j^+} x_{i'kv} - \sum_{j' \in N_k^- \backslash N_i^-} x_{kj'v} \right) = 0$,

$\forall v \in V, i \in N_{h+1}^-, j \in N_h^+, k \in N_i^+ \backslash N_{j-1}^+$

The above constraints make sure that the port k, which is a port between i and j, shall be reached for the same number of times as it be leaved from, both on the outbound route and on the inbound route. The constraint (12) ensures that if port k is the last port of the outbound route, the ships leaves port k and goes directly to port j. The constraint (13) ensures that if port k is the first port of the inbound route, the ship leaves port j and goes directly to port k.

(14) $w_v \sum y_{ijv} \geq 365/f,\qquad \forall v \in V, i \in N_{h+1}^{-}, j \in N_h^{+}$

The constraint above limits the ship frequency of the network. Since one of the reason that liner-shipping company involved in alliance is to improve the quality of service for customers. The shipping frequency ensures this point.

(15) $x_{ijv} \in \{0,1\},\qquad \forall v \in V, i \in N_{h+1}^{-}, j \in N_h^{+}$

Constraint (15) ensures the variable x_{ijv} is a binary variable as stated previously. The value of this variable is thus either 0 or 1.

(16) $e_{ijv} \geq 0,\qquad \forall v \in V, i \in N_{h+1}^{-}, j \in N_h^{+}$

Constraint (16) puts practical meaning of the variable by ensuring the amount of containers transported between port i and j is above zero.

(17) $w_v \geq 0 \; and \; integer,\qquad \forall v \in V$

Constraint (17) express the definition of the variable we set in Chapter 3.1, the variable $w_v$is the number of voyages that a ship operates in the time unit, thus the value of this variable shall be above zero and integer.

(18) $y_{ijv} \in \{0,1\},\qquad \forall v \in V, i \in N_{h+1}^{-}, j \in N_h^{+}$

Constraint (18) ensures the variable y_{ijv} is a binary variable as stated previously. The value of the variable is either 0 or 1.

(19) $\sum_{i \in N \setminus \{N\}} y_{iNv} \geq 1,\qquad \forall v \in V$

(20) $\sum_{j \in N \setminus \{1\}} y_{Njv} \geq 1,\qquad \forall v \in V$

Constraint (19) and (20) ensure all the numbered ports are reached in the network.

Chapter 3 Methodology

3.1 Reason and assumptions behind the model

The model stated in the literature review is suitable to generate a reliable theoretical optimal shipping network that can be compared with the actual situation. However, the model is complicated and due to the limited research condition, it is not suitable for this thesis. The data inputs such as the cost per ship and the situation of each ship of the alliance cannot be achieved and high level of data input estimation involved in the thesis results in unreliable result. Thus, in this thesis, the model will be simplified as a supply-demand model. Firstly, the total supply-demand situation is achieved for both of the alliances and individual liner shipping companies involved in the alliance. Then the shipping networks are built in the next step based on the results of the model.

The model is to generate the optimal shipping network solution for the alliances in both the alliance level and the individual company level. There are certain assumptions set for the model to make it reasonable to be applied to deal the problem.

Firstly, the ships involved in the research are homogeneous. This means the capacity of the ships, the energy consumption efficiency, the speed and the port charge regarding to the type and the size of the ships are the same. In addition, the ship capacity allocated to each routes are the same.

Secondly, the costs of each ship, whatever routes it operates in, are the same. The reason behind this assumption is that all the ships are in the routes between Asia and Europe and the distance between the two regions are of high value that the travelling within the region can be treated as nil. The ship maintenance and cargo handling cost are same based on the first assumption that the ships are homogeneous. The differences exist in the costs of each ship is the port charge and energy cost. This cost is higher in the situation that the ship is allocated in the route that visit more ports. In this situation, the ship consumes more energy and has a higher circulation time. In this case it is assumed that the port charge difference can be ignored. This assumption gives the reason of the objective function setting. The objective function in the model is revenue maximization rather than profit maximization or cost minimization because the cost are constant.

Thirdly, the routes are round routes that including the inbound trip and outbound trip. The ports visited in both trips are the same because this is the practical case.

Fourthly, the transportation within the region is ignored. The capacity of the ships are used to take the Asia-Europe transportation. This suggests that there is no cargo flow between ports belong to N_1or N_2. In practice this is also reasonable because the transportation within the regions (Asia and Europe) are most occupied by inland transportation including railway transportation, while the aim of the alliances are improve the transportation between the two regions. (Rodrigue, 2013)

3.2 The model

The methodology applied in this thesis is mathematic analysis by applying the solver in the excel. The set of the data input can be shown in the table below:

Table 3 The data input of the model

[1] The ports in Asia	N_1 indexed as i
[2] The ports in Europe	N_2 indexed as j
[3] The revenue of transporting one container from port i to j	R_{ij}
[4] The demand of ports in Europe	D_j
[5] The capacity of shipping transport	Q

The set of variables can be shown in the table below:

Table 4 The variables in the model

[6] The number of container transported from port i to j	e_{ij}

The objective function is to maximize revenue and can be shown as the formula below:

$$\max \sum_{i \in N_1, j \in N_2} e_{ij} R_{ij}$$

The constraints including:

(1) $\sum_{i \in N_1} e_{ij} \leq D_j \qquad j \in N_2$

(2) $\sum_{i \in N_1, j \in N_2} e_{ij} \leq Q$

(3) $\sum_{i \in N_1} e_{ij} \geq 2000 \qquad j \in N_2$

(4) $\sum_{j \in N_2} e_{ij} \geq 2000 \qquad i \in N_1$

The constraint (1) suggests that the total amount of cargos transported to port j in Europe shall not exceed its demand. The constraint (2) suggests that the total amount of cargos transported from port i in Asia to port j in Europe shall not exceed the shipping capacity. The constraints (3) and (4) provide that all the ports in the research shall be visited. These two constraints ensure the market size the two alliances get into to make the theoretical results comparable with the actual situation. In this model, it is set that 2000 TEU is the minimum cargo volume to be treated as get into the market.

3.3 Model reasoning and application

The mathematical model stated above is actually a supply-demand model. It is suggested that the Asia port is in the role of supplier while the Europe is in the role of customer. Even though round trips are going to be determined rather than one-way trip, due to the limitation of complexity of the model, only outbound trips are going to be generated and the inbound trips are automatically generated according to the outbound trip. Same ports are visited in a opposite order.

The reason behind the settlement that the Asia is the supply part and Europe is the customer part is based on the fact that the Asia export is much more than that of Europe. This effect give the Asia the role of supplier while Europe the role of customer. Therefore, the problem is simulated as the supply-demand problem. The figures below shows the trade relationship between Asia and Europe in the year 2011. The number in the figure is the value of export measured by $billion. It is suggested that the trade between Asia and Europe has a net value of $283 billion (922-639). The amount is about 45% of the export value from Europe to Asia. This suggests that there is high value of trade unbalance between the two regions and it is reasonable to treat Asia as supplier while Europe as customer when analyzing the shipping-routes.

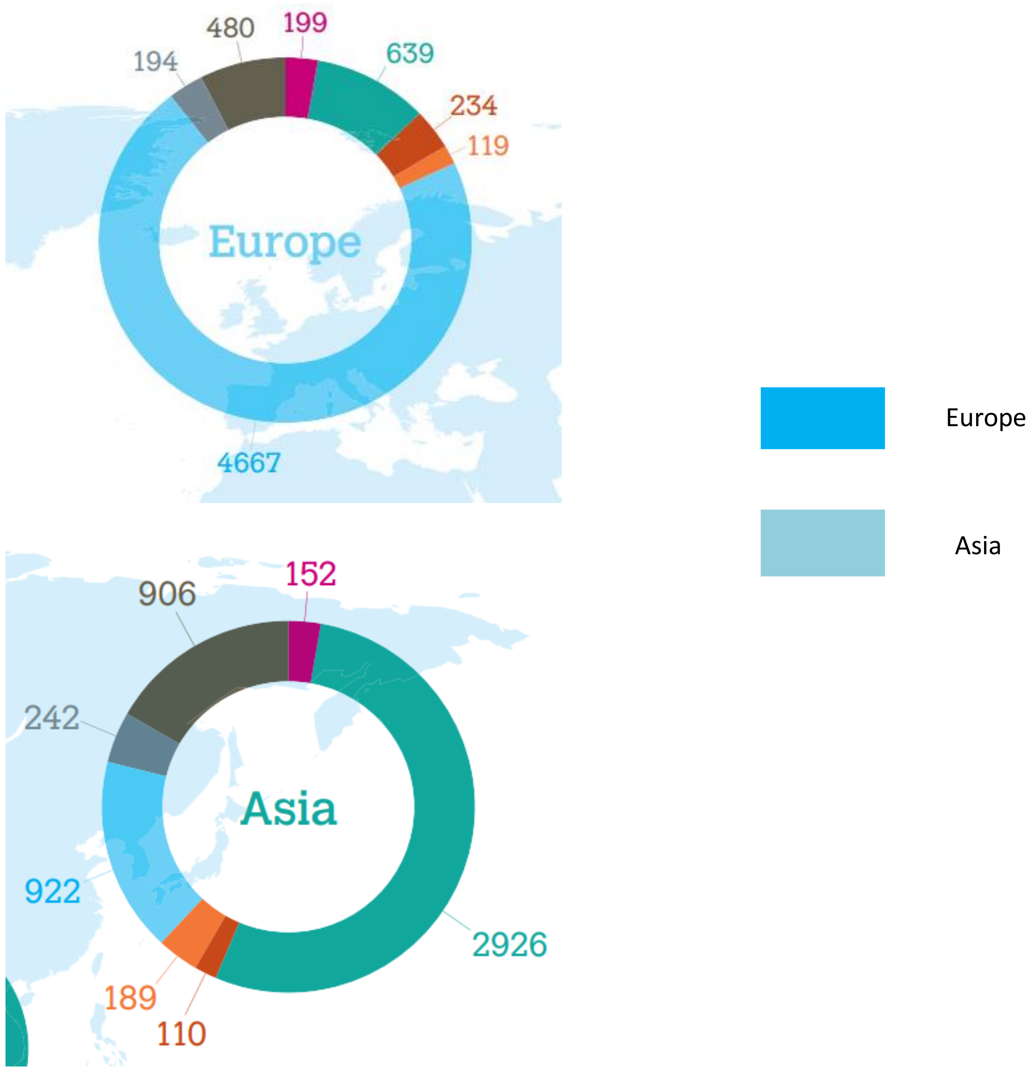

Figure 3 Trade between Asia and Europe

Source: (Organization, 2012)

The model together with other analysis are going to be taken in the following way.

The first step involves three stages. Firstly, the transport capacity of the alliance are put together in the mathematical model to determine the optimal supply-demand situation.

Secondly, the routes are built follow the following principles. First, each of the ports shall be visited the less the better to avoid duplication. Second, the amount of cargos transported in one route shall not exceed its capacity. Third, the sum amount of cargos transported by the routes from one port to another shall be equal to the result in the first stage. The number of routes generated equals to the actual number of routes built in the alliance.

Thirdly, the shipping routes built above are compared with the actual shipping network of the alliance. The comparison including the number of routes visited for each of the port involved in the alliances and the ports connectivity with each other. The difference as well as the reasons are identified and analyzed.

In the second step of the analysis, it is assumed that individual companies in the alliance have the same contribution of shipping capacity. Therefore, the capacity are separated equally among the partners in the alliance. The same process as stated in the first step is taken. The capacity put in the model is calculated as: Total capacity of the alliance divided by the number of partners in the alliance. While in the route generation stage, the number of routes generated is calculated as: Total number of routes divided by the number of partners in the alliance.

The point of limiting the number of routes an individual partner of the alliance operates in is to ensure the shipping frequency, which is the main determinant of the level of service quality of a company, at the same level with that in the alliance. The shipping frequency is determined by the number of ships operates in one route and the time required to finish a round trip. Since the time required of finish round trip is similar among the routes in practice, in the case of 2M alliance, the longest outbound trip takes 45 days while the shortest takes 35 days, it is reasonable to assume the number of ships allocated to each route determines the shipping frequency and service quality. Therefore, to ensure the same number of ships allocated to each route, the number of routes an individual company performs shall be the proportion of the number of ships it contributed to the alliance.

The point of let individual partners in the alliance visits all the ports and the total cargo volume of each of the port is at least 2000 TEU as stated previously are to ensure the individual company has the same market size as in the case of the alliance.

Therefore, it is reasonable to compare the routes generated in an individual level and the alliance level. By comparing the optimal routes generated in the first step with the actual routes and with the optimal routes generated in the second step, the efficiency of the alliance can be determined.

The comparison of the shipping network including two aspects, the number of routes visit for each of the port, and the port connectivity among each other. Under the condition of fully utilized the shipping capacity, the less number of routes visit for the ports, the better. Because more than one route visit a certain port means duplication and the opportunity cost including port charges is higher in this case. The port connectivity shows the opportunity that whether one Asia port, which is a supply port in this model, can provide cargo to one European port and vice versa. The advantage of a shipping network with high level of port connectivity is that the network is more flexible to transportation demand fluctuation. Because the decrease of demand in one port provides the capacity of transporting for other ports in which there is increased demand.

The sensitivity analysis is taking after applying the model stated above. This is because the actual shipping network of the two alliances show certain routing strategies, and there is demand limitation due to the highly competition of the market which does not take into consideration previously. The results of the sensitivity analysis are compared with the actual situation to check whether the actual shipping network is of theoretical reasonable under the renewed situation.

3.4 Reliability and limitation of the model

From the above statement, it is suggested that the model is reliable because it deals the problem in a reasonable way. The assumptions are set under practical situations such as the ports visited in a round trip and the supply-demand relationship between Asia and Europe.

There are also limitations of the model mainly because the model is of theoretical meaning while in practice, the situation is usually much more complicated.

Firstly, there are assumptions involve in the model including the data input and the method, which can distort the results. In practice, the ships are usually not in homogeneous size. In the two alliances that this thesis is going to analyze, the smallest ship is 8500 TEU and the largest ship is 14000 TEU. In addition, the freight rate is changing all the time together with the cost of operating one ship and the demand among ports. There are also different strategies existing in the companies that can generate high level of difference regarding to the cost. Companies that adopt slow steaming strategy bears lower cost compare with those do not. Sometimes such changes can be high level due to the economic changes. However, these cannot be reflected in the model.

Secondly, the model gives the result to realize revenue maximization within the alliance at both individual level and alliance level. However, there are other factors that do not taken into consideration. Liner-shipping companies involve in alliances to share risk, get into new market and lower down capital investment etc. These factors cannot be reflected in the model. In addition, the model just search the revenue maximization in one unit period. While there are certain profits require long time to be realized and the profit can changing due to the more efficiency operation and the new technology occur in the alliance etc.

Thirdly, due to the limitation of the complexity of the model, only outbound trips are being considered while the inbound trips are ignored. While in practice, the relationship between Asia and Europe is not a supply-demand relationship. There is also un-neglectable transportation demand from Europe to Asia, which can make a difference to the optimal solution.

Chapter 4 Data input

4.1 Ports visited

By checking the current shipping networks of the two alliances. The network of the 2M alliance builds six routes that visits 17 ports in Asia and 15 ports in Europe (including Morocco). The detail of each route together with the time required to transport between two ports are shown in the appendix. The shipping network of the CKYHE alliance builds six routes that visits 17 ports in Asia and 11 ports in Europe (including Egypt and Israel). The detail information of the routes including the port visited are shown in the tables in the appendix.

In the model, it is impossible to take all the ports into consideration separately because in that way the data input and output is complicated. In this case, the ports needs to be selected and grouped following certain steps. Firstly, in the two alliances, there are ports that do not belong to either Asia or Europe while the scope of this thesis is the liner shipping network between the two regions. Under such situation, the ports, which are Tangier port in Morocco in the 2M alliance, and Port Said and Alexandra port in Egypt, and Ashdod Port in Israel in the CKYHE alliance, are not taken into consideration into the model.

Secondly, the Asian ports are grouped into 9 groups while the European ports are grouped into 7 groups. The reasons behind the grouping including the size of the ports ports and the physical locations of the ports. Each group contains 1 to 3 ports. The ports grouped and numbered for the 2M alliance can be shown in the following table:

Table 5 The grouped ports for 2M

1	Kobe, Japan	10	Algeciras, Spain
	Nagoya, Japan		Barcelona, Spain
	Yokohama, Japan		Sines, Portugal
2	Busan, South Korea	11	La Havre, France
	Kwangyang, South Korea		Southampton, UK
3	Dalian, China	12	Felixstowe, UK
	Xingang,China	13	Antwerp, Belgium
	Qingdao, China		Rotterdam, Netherlands
4	Shanghai, China	14	Wilhelmshaven, Germany
	Ningbo, China		Bremerhaven, Germany
5	Xiamen, China		Hamburg, Germany
6	Chiwan, China	15	Gothenburg, Sweden
	Yantian, China		Aarhus, Denmark
	Nansha New Port, China	16	Gdansk, Poland
7	Hong Kong		
8	Tanjung Pelepas, Malaysia		
9	Colombo, Sri Lanka		

The ports grouped and numbered for the CKYHE alliance can be shown in the following table:

Table 6 The grouped ports for CKYHE

1	Busan, South Korea	10	Piraeus, Greece
	Kwangyang, South Korea	11	Algeciras, Spain
2	Dalian, China	12	La Havre, France
	Xingang, China	13	Felixstowe, UK
	Qingdao, China	14	Antwerp, Belgium
3	Shanghai, China	15	Rotterdam, Netherlands
	Ningbo, China	16	Hamburg, Germany
4	Xiamen, China		
5	Taipei, Taiwan		
	Kaohsiung, Taiwan		
6	Yantian, China		
	Shekou, China		
	Nansha, China		
7	Hong Kong, China		
8	Singarpore		
	Tanjung Pelepas, Malaysia		
9	Colombo, Sri Lanka		

4.2 Number of ships and shipping capacity

Since in the model, it is assumed that the ships are homogeneous, while in practice, this is not usually the case. Therefore, an average ship capacity and number of ships allocated to each route shall be derived.

In the 2M alliance, detailed ship situation allocated in the shipping network between Asia and Europe cannot be found. However, there are totally 193 ships allocated in 22 routes with the total capacity of 2.4m TEU. (Lloyd's List) The number of routes between Asia and Europe is six. It is assumed that the number of ships are allocated proportionally according to the number of routes, the number of ships allocated for the 6 routes between Asia and Europe is about 53 (6*193/22). The average capacity of the ship is about 12000 TEU (2.4m/193). The number of ships allocated to each of the 6 routes is 9 (53/6), with the capacity of 108,000TEU (9*12000). The total capacity of the ships that provides the service between Asia and Europe is 636,000 TEU (53*12000). The table below shows the situation of the ship allocation and capacity. The AE1 route shown in the appendix spends the longest time travel from the origin to the destination, which is 45 days. Assume that all the ships spends about 90 days to perform a round trip in their correspondence routes, the number of round trips that one ship can perform is 4 (365/90). Therefore, the total transportation service the 2M alliance can provide is 2,544,000 TEU. Under the assumption that the partner companies in the alliance contribute the same capacity to the shipping network, the shipping capacity contributed by each partner in this case is 1,272,000 TEU (2544000/2). The data is shown in the table below:

Table 7 Shipping details of 2M alliance

Number of route	6	
Number of ships	53	
Capacity per ship	12,000	TEU
Capacity per route	108,000	TEU
Total transportation service per route	432,000	TEU
Capacity contributed per partner company	1,272,000	TEU
Total capacity	636,000	TEU
Total transportation service	2,544,000	TEU

In the CKYHE alliance, the number of ships attribute to each route together with the ship capacity are provided and the details are shown in the appendix of this thesis. Therefore, the average capacity per ship can be calculated as 13,000 TEU by divide the total capacity by the number of ships, which is 62. The number of ships allocated to each route is about 10 (62/6). The total capacity of all the ships involved in the alliance is 791,000 TEU. The number of trips that a ship can perform is assumed the same as in the 2M alliance since the distance and the ship size tend to be the same in the two alliances. The shipping details can be shown in the table below:

Table 8 Shipping details for CKYHE alliance

Number of route	6	
Number of ships	62	
Capacity per ship	13,000	TEU
Capacity per route	130,000	TEU
Total transportation service per route	520,000	TEU
Capacity contributed per partner company	632,800	TEU
Total capacity	791,000	TEU
Total transportation service	3,164,000	TEU

4.3 Revenue

To get the revenue between two group of ports, the world freight calculator is used to generate a reasonable freight rate. The size of the container is assumed to be 40 feet , which is 2 TEU per container, since container of this size is most commonly used in practice. (Council, 2015). The type of cargos put in the freight calculator is "automobile and motorcycles". This is because "Asia Pacific has a strong manufacturing market due to the availability of cheap labor. This translates into manufacturing huge amounts of textiles, electronics, automotive products, heavy equipment, consumer durable goods, and more. China, Japan and South Korea are major exporters of automobiles, industrial equipment and heavy machinery. Singapore, China, Japan, South Korea, Taiwan, and Malaysia are major exporters of semiconductors and electronic products." (Watch, 2010) The freight rate between grouped port 1 to grouped port 10 is calculated as the average freight rate between the member ports. For instance, in the 2M alliance, the freight from group 1 to group 10 is calculated as the average freight rate of: freight rate from Kobe to Algeciras, from Kobe to Barcelona, from Kobe to Sines, from Nagoya to Algeciras, from Nagoya to Barcelona, from Nagoya to Sines, from Yokohama to Algeciras, from Yokohama to Barcelona and from Yokohama to Sines.

The following table shows the average freight rates between each of the two grouped ports. *(Source of the table: http://worldfreightrates.com/en/freight World Freight Rate calculator)* The original unit revenue is dollars/2 TEU. Since in the calculation, the measurement of cargos transportation is TEU, the original revenue shall be divided by 2 to generate revenue per TEU. The outcome is shown in the table below.

Table 9 Revenue between ports in 2M alliance per TEU

Revenue							
	Ports Europe						
Ports Asia	10	11	12	13	14	15	16
1	1321.50	1551.89	1543.71	1537.87	1617.93	1726.58	1618.79
2	1214.43	1434.10	1425.92	1420.08	1500.14	1608.79	1501.00
3	1227.38	1447.06	1438.88	1438.88	1513.10	1621.75	1604.66
4	1239.16	1458.84	1450.66	1450.66	1524.88	1633.50	1525.74
5	1167.40	1397.72	1389.54	1377.85	1456.65	1569.64	1468.96
6	1151.05	1381.36	1373.18	1361.49	1440.29	1553.28	1452.60
7	1072.36	1292.00	1283.86	1272.18	1350.98	1459.63	1358.93
8	917.29	1134.86	1126.68	1115.00	1180.74	1288.69	1201.33
9	1427.26	1680.18	1672.00	1660.32	1734.48	1865.28	1768.38

Table 10 Revenue between ports in CKYHE alliance per TEU

Revenue							
	Ports Europe						
Ports Asia	10	11	12	13	14	15	16
1	1109.5	1230.78	1427.09	1425.92	1414.24	1425.92	1430.6
2	1122.46	1243.74	1440.05	1438.88	1427.19	1438.88	1443.56
3	1134.24	1255.52	1451.83	1455.16	1438.97	1450.66	1457.58
4	1048.21	1183.77	1390.7	1389.54	1377.85	1389.53	1394.21
5	1058.73	1194.28	1401.22	1400.06	1388.37	1400.41	1404.73
6	1031.85	1167.4	1374.35	1373.18	1361.49	1376.5	1377.85
7	960.78	1088.72	1285.03	1283.86	1272.18	1294.56	1288.54
8	762.34	891.72	1073.96	1072.79	1061.11	1083.22	1077.47
9	1324.73	1443.61	1673.17	1672	1660.32	1671.32	1676.68

4.4 Demand between two grouped ports

The demand of transportation between one grouped port in Asia and another grouped port in Europe can be treated as the amount of container export from the grouped Asian ports to the grouped European ports. However, there is no detailed data regarding this situation. Therefore, estimations are made based on available information. Firstly, It is assumed that the demand of transportation occurs evenly through the year. And then, the detailed throughput of the Asia ports can be achieved. Some of the ports' throughput is detailed from the year 2011 to 2014 while others only have the throughput data for certain years. The detailed throughput of each Asian port is put in the appendix of the thesis. An average amount of throughput from 2011 to 2014 of each port is applied in the calculation. It is further assumed that half of the throughput of each container is the amount of export container.

Secondly, it is assumed that 37% of the total container export from Asia ports are transported to Europe. This assumption is based on the export value separation shown in the figure 3 in this thesis. This percentage is calculated by using the formula: $\frac{\text{Amount of export to from Asia to Europe}}{\text{Total export from Asia}}$.

Thirdly, the allocation of the demand for each port in Europe is following a pro-rated basis according to the throughput of the Europe ports. In this situation, it is assumed that there is a positive linear relationship between the volume of container an European port imported and its throughput. The throughput of European ports that the two alliances visited together with other European ports whose throughput is in the top 100 ports of the world are the basement of allocating the demand. The other ports including Valencia port in Spain, Gioia Tauro port in Italy, Zeebrugge port in Belgium, Dublin port in Ireland, Las Palmas port in Spain and Marseilles port in France. The detailed throughput data collected and percentage are shown in the appendix. The percentage of the European port A is derived by using the formula: $\frac{\text{The throughput of port A}}{\text{Total European ports throughput}}$

Fourthly, the supply from each Asia port to each European port can thus derived. The aggregated demand are calculated for each port group. The results are shown in the table below:

Table 11 Demand for the 2M alliance

Demand								
		Ports Europe						
Ports Asia		10	11	12	13	14	15	16
	1	146,444	79,206	77,037	424,924	331,635	44,021	24,719
	2	341,306	184,599	179,544	990,341	772,918	102,597	57,612
	3	631,499	341,553	332,201	1,832,372	1,430,088	189,829	106,596
	4	884,154	478,204	465,110	2,565,480	2,002,247	265,777	149,243
	5	129,013	69,778	67,868	374,348	292,163	38,782	21,777
	6	292,672	158,295	153,961	849,225	662,783	87,978	49,402
	7	411,154	222,377	216,288	1,193,015	931,097	123,593	69,402
	8	135,857	73,480	71,468	394,205	307,660	40,839	22,932
	9	78,837	42,640	41,472	228,754	178,533	23,698	13,307

Table 12 Demand for CKYHE alliance

Demand							
	Ports Europe						
Ports Asia	10	11	12	13	14	15	16
1	171,875	199,369	112,107	179,544	418,287	572,053	442,114
2	318,010	368,881	207,426	332,201	773,934	1,058,438	818,020
3	445,242	516,465	290,414	465,110	1,083,575	1,481,905	1,145,299
4	64,969	75,361	42,376	67,868	158,112	216,236	167,119
5	210,425	244,086	137,252	219,815	512,107	700,362	541,278
6	149,769	173,727	97,689	156,452	364,490	498,479	385,252
7	207,049	240,170	135,050	216,288	503,890	689,124	532,594
8	356,176	413,152	232,320	372,070	866,818	1,185,467	916,195
9	39,701	46,051	25,895	41,472	96,618	132,136	102,122

Chapter 5 Results and analysis

5.1 Results for the 2M alliance

After putting the data including the demand and revenue between two ports stated above in the model, the optimized revenue in this case is $3.847 billion, the average revenue of transporting one container is $1512, and the situation of transportation and the amount of demand unsatisfied can be shown in the table below as a whole for the alliance:

Table 13 The transportation situation for 2M alliance as a whole

Number of container transported								
	Ports Europe							
Ports Asia	10	11	12	13	14	15	16	Total
1	0	79,206	77,035	424,922	127,886	44,021	24,719	777,789
2	14,600	37,410	36,560	35,954	44,267	55,549	44,356	268,695
3	15,945	38,755	37,906	37,906	45,613	56,894	55,120	288,138
4	17,168	39,978	39,129	39,129	46,836	58,114	46,925	287,280
5	9,717	33,632	32,783	31,569	39,751	38,782	17,101	203,334
6	8,019	31,933	31,084	29,870	38,052	49,785	39,331	228,074
7	0	22,655	21,809	20,597	28,779	40,060	29,604	163,504
8	0	969	5,489	0	11,102	22,311	0	39,870
9	36,699	42,640	41,472	60,899	68,600	23,698	13,307	287,316
Total	102,148	327,177	323,267	680,845	450,885	389,214	270,464	2,544,000

Table 14 Demand unsatisfied for 2M alliance

Unsatisfied Demand							
	Ports Europe						
Ports Asia	10	11	12	13	14	15	16
1	146,444	0	0	0	204,508	0	0
2	326,712	147,295	143,086	954,486	728,787	47,233	13,392
3	615,567	302,910	294,403	1,794,575	1,384,617	133,126	51,659
4	867,004	438,343	426,095	2,526,465	1,955,558	207,859	102,466
5	119,282	36,236	35,171	342,860	252,528	163	4,798
6	284,631	126,444	122,955	819,428	624,840	38,353	10,186
7	411,154	199,764	194,517	1,172,451	902,386	83,650	39,870
8	135,857	67,112	65,946	394,205	296,550	18,568	22,932
9	42,240	0	0	168,063	110,175	0	0

There are some aspects that can be observed from the above results.

Firstly, the theoretical results suggest that the transportation from the three ports in Japan, which is group 1, to European ports, are of high volume and demand of the European ports from the group 1 ports is highly satisfied. The total volume transported from group 1 ports is 777,034 TEU, while the capacity of one route in the alliance is 432,000 TEU. This means more than one route shall visited the group 1 ports. However, the actual situation suggests that only the route AE 1 in the alliance visited the group 1 ports together with other six Asia ports. This means there is high level of difference between the containers transported from the three Japanese ports to ports in Europe in theoretical situation and actual situation.

Secondly, all of the six routes of the 2M alliance visited the Shanghai port and Ningbo port, which suggests that the container flow from the two ports to the European ports are of high volume. In the model, the two ports are grouped together as group 4. The results suggest that the total container volume transported from the two ports is 286,426 TEU. Compare with other ports in Asia, this is not a high volume.

Thirdly, in the 2M alliance, of all the European ports, the Bremerhaven port in Germany is visited by 5 of all the 6 routes, which is the most commonly visited port in Europe. While in the result of the model, the container volume transported to Germany port is 449,174 TEU, which is just less than Antwerp port and Rotterdam port group. The Japanese ports in the model transport the highest volume of containers to the Germany ports. The routes regarding the Germany ports is thus shows certain level of consistency between theoretical result and actual situation.

Fourthly, all the routes in the 2M alliance visited the Tanjung Pelepas port in Malaysia. This suggest that the port has high level of cargo flow to Europe. While the results of the model shows that there is no trade flow from Tanjung Pelepas port to the ports group 10, 13 and 16 if the alliance wants to realize revenue maximization, and the total cargo flow from the port to Europe is the least of all the Asia ports.

The whole transportation amount are be separated into six shipping routes as stated in Chapter 4 and each route has a capacity of 432,000 TEU per year. There is various possibilities that can divide the six routes based on the result, one of the separation situation can be shown in the table below:

Table 15 Feasible routes for 2M alliance

	Ports Visited									
Route 1	1	2	3	4	5	10	11	12		
Route 2	1	3	12	13						
Route 3	2	3	4	5	12	13	14	15		
Route 4	1	2	3	4	14	15	16			
Route 5	3	4	5	6	7	9	14	15	16	
Route 6	6	7	8	9	10	11	12	13	14	15

By comparing the situation stated above with the actual routes, it can be concluded that there is certain level of difference between the theoretical results and actual situation. This proves that there is inefficiency exist in the alliance in the alliance perspective tested by the model. The detail comparisons between the actual situation and theoretical result can be shown in the table below.

Table 16 Comparison for 2M alliance as a whole

Port Number	Theoretical visited routes	Actual visited routes	Theoretical connected ports	Actual connected ports
1	3 routes	1 Route	10—16	12—15
2	3 routes	2 Routes	10—16	12—16
3	5 Routes	2 Routes	10—16	10,13,14
4	4 Routes	6 Routes	10—16	10—16
5	3 Routes	2 Routes	10—16	10,11,13,14
6	2 Routes	6 Routes	10—16	10—16
7	2 Routes	2 Routes	10—16	12—15
8	1 Route	6 Routes	10—15	10—16
9	2 Routes	1 Route	10—16	12—15
10	2 Routes	2 Routes	1—9	2—8
11	2 Routes	2 Routes	1—9	2—6，8
12	4 Routes	4 Routes	1—9	1—2，4—9
13	3 Routes	5 Routes	2—9	1—9
14	4 Routes	5 Routes	1—9	1—9
15	4 Routes	2 Routes	1—9	1—2,4,6—8
16	2 Routes	1 Route	1—7, 9	2,4,6,8

It can be observed from the table above that the theoretical results have a more connectively shipping network for all the ports involved in the alliance have connection with each other. In addition, the total number of routes visited of the theoretical results is 46 while in actual situation, the number is 49. This suggests that there is less duplication in the theoretical results compare with the actual situation. The biggest difference is regarding the Tanjung Pelepas port in Malaysia. Theoretically, it is not an profitable option to visit this port while in actual alliance situation, the 2M alliance treat Tanjung Pelepas port as an important port in the shipping network.

In addition, there is high level of difference between the theoretical results and the actual situation regarding the Asian port. While for the European port, the level of difference is low. This suggests that the shipping network efficiency require to be improved in the Asia area.

There are two companies involved in the 2M alliance, Maersk Line and Mediterranean Shipping Co. It is assumed in Chapter 4 that the two companies contribute even capacity to the alliance. Therefore, the capacity for the individual company is 1,272,000 TEU per year and the number of route is 3, which is half of the number of the total routes of the alliance. Put the capacity in the model and the results shows that the total revenue is $2.109 billion and the transportation details can be shown in the table below:

Table 17 Transportation situation for individual company in 2M alliance

Number of container transported							
	Ports Europe						
Ports Asia	10	11	12	13	14	15	16
1	0	0	0	0	207,249	44,021	24,719
2	0	0	0	0	0	2,000	0
3	0	0	0	0	0	189,829	0
4	0	0	0	0	0	265,777	0
5	0	0	0	0	0	2,000	0
6	0	0	0	0	0	2,000	0
7	0	0	0	0	0	2,000	0
8	0	0	0	0	0	2,000	0
9	2,000	42,640	41,472	228,754	178,533	23,698	13,307

Table 18 Unsatisfied demand for individual company in 2M alliance

Unsatisfied Demand							
	Ports Europe						
Ports Asia	10	11	12	13	14	15	16
1	146,444	79,206	77,037	424,924	124,386	0	0
2	341,306	184,599	179,544	990,341	772,918	100,597	57,612
3	631,499	341,553	332,201	1,832,372	1,430,088	0	106,596
4	884,154	478,204	465,110	2,565,480	2,002,247	0	149,243
5	129,013	69,778	67,868	374,348	292,163	36,782	21,777
6	292,672	158,295	153,961	849,225	662,783	85,978	49,402
7	411,154	222,377	216,288	1,193,015	931,097	121,593	69,402
8	135,857	73,480	71,468	394,205	307,660	38,839	22,932
9	76,837	0	0	0	0	0	0

From the result above, it can be observed that majority of the cargo flow is centralized in Colombo port in Sri Lanka, Gothenburg port in Sweden and Aarhus port in Denmark. This is because the freight rates from Colombo and to Gothenburg and Aarhus are high. However, of all the actual routes, only three routes visit the three ports separately. This suggests that in actual situation, the container flow regarding these three ports are low.

In addition, there is conflict situation between the theoretical results in the alliance level and in the individual level. For individual company to realize profit maximization, the Gothenburg port and Aarhus port shall bears the highest level of container flow and are the most important ports in the shipping route while in the alliance level, the container flow regarding these two ports is in the third place. There are various possibilities to separate three routes stated previously, one of the possibilities is shown in the table below:

Table 19 Feasible Routes for individual company in the 2M alliance

	Ports visited									
Route 1	1	2	14	15	16					
Route 2	3	4	5	6	7	8	9	14	15	16
Route 3	9	10	11	12	13	14				

From the table above, it is suggested that there are similarities exist between the theoretical results and the actually situation regarding ports connection. In actual situation, the routes in which Gothenburg port and Aarhus port are visited also visit all the Asian ports. In addition, the Japanese ports and South Korean ports are connected with the ports grouped as 14, 15 and 16. This suggests that the shipping network exists currently is reasonable for individual companies in the alliance.

5.2 Results for the CKYHE alliance

After putting the data input including the demand and freight rate between each pair of ports stated in Chapter 4 into the model for the CKYHE alliance, the optimal revenue derived from the model is $4.59 billion and the average revenue for each container transported is $1451. Compare with the 2M alliance, the revenue per container is lower. This suggests that the 2M alliance has a more efficiency shipping network compare with the CKYHE alliance because factors put in the model such as freight rate and demand are derived from same method. The result can be shown in the table below:

Table 20 Transportation situation for CKYHE alliance as a whole

Number of container transported								
	Ports Europe							
Ports Asia	10	11	12	13	14	15	16	Total
1	0	0	112,107	179,544	418,287	568,054	88,219	1,366,212
2	0	0	67,750	67,237	62,110	67,237	69,289	333,623
3	0	0	72,916	74,376	67,276	72,403	75,438	362,409
4	0	0	30,541	45,599	40,473	45,595	47,647	209,855
5	0	0	50,721	50,213	45,086	50,366	52,261	248,647
6	0	0	38,938	38,425	33,298	39,881	40,473	191,013
7	0	0	0	0	0	3,946	0	3,946
8	0	0	0	0	0	2,000	0	2,000
9	2,000	46,051	25,895	41,472	96,618	132,136	102,122	446,295
Total	2,000	46,051	398,869	496,866	763,149	981,617	475,448	3,164,000

Table 21 Demand unsatisfied for CKYHE alliance

Number of container transported							
	Ports Europe						
Ports Asia	10	11	12	13	14	15	16
1	171,875	199,369	0	0	0	3,999	353,896
2	318,010	368,881	139,675	264,964	711,824	991,201	748,731
3	445,242	516,465	217,498	390,734	1,016,299	1,409,502	1,069,861
4	64,969	75,361	11,835	22,269	117,640	170,641	119,472
5	210,425	244,086	86,531	169,603	467,021	649,996	489,018
6	149,769	173,727	58,751	118,028	331,192	458,599	344,780
7	207,049	240,170	135,050	216,288	503,890	685,178	532,594
8	356,176	413,152	232,320	372,070	866,818	1,183,467	916,195
9	37,701	0	0	0	0	0	0

Some aspects can be observed from the results of the model shown above.

Firstly, four ports are barely visited in the result, including Singapore port, Tanjung Pelepas port in Malaysia, Piraeus port in Greece and Algeciras port in Spain. This is because the low freight rate among these port. While in the actual situation, Singapore port and Tanjung Pelepas port are two of the most commonly visited ports in the alliance.

Similar as in the 2M alliance situation, the Colombo port in Sri Lanka is visited most commonly, together with Hamburg port in Germany. In actual situation, the Colombo port is only visited in one route while the Hamburg port is visited by six routes of all the nine routes.

In actual routes of the CKYHE alliance, Shanghai port and Ningbo port are still the most important ports as well as in the situation of 2M alliance because the two ports are visited by most of the routes of the alliance. The result of the model in this case shows consistency that there is high level of container volume that is 362,409 TEU transported from Shanghai and Ningbo to European ports.

The results of the model show that the highest container volume outflow is from group 1 ports, which are Busan port and Kwangyang port in South Korea. The volume of container flow from these two ports which is 1,366,212 TEU, are three times higher than that from the Colombo port. The results suggest that all the container flow from the South Korean ports are to La Havre port in France, Felixstowe port in UK, Antwerp port in Belgium, Rotterdam port in the Netherlands and Hamburg port in Germany. While in actual situation, the NE6 route of the CKYHE alliance, which is the only route of the alliance that visited the two South Korean ports, visits Hamburg port, La Havre port and Rotterdam port.

Of all the ports in Europe, Rotterdam port in the Netherlands bears the highest volume of container inflow that is 981,617 TEU from all the Asian ports and most of the container inflow are from South Korean ports in the model. The actual situation shows consistency in this aspect given that Rotterdam port is visited by all the six routes in the alliance and thus can receive cargo from all the Asian ports. The European ports with the volume of container inflow in the second and third place are Antwerp port in Belgium and Felixstowe port in UK in the model. In actual situation, these two ports are also commonly visited by the routes, with Antwerp port is visited by two routes of the alliance and Felixstowe port is visited by four routes.

The whole transportation amount are be separated into six shipping routes and each route has a capacity of 520,000 TEU per year. There are various possibilities to separate the total transportation situation into six routes. One of the possibilities can be shown in the table below:

Table 22 Feasible routes for CKYHE as a whole

	Ports Visited							
Route 1	1	2	3	9	10	11	12	13
Route 2	2	3	4	5	6	12	13	14
Route 3	1	2	3	4	5	6	14	
Route 4	1	6	9	13	14	15		
Route 5	1	2	3	4	9	15		
Route 6	4	5	6	7	8	9	15	16

There are differences between the feasible routes and the actual routes, the detailed differences regarding to the number of routes visit each port and ports connective among each other are shown in the table below:

Table 23 Comparison for CKYHE alliance as a whole

Port Number	Theoretical visited routes	Actual visited routes	Theoretical connected ports	Actual connected ports
1	4 routes	1 Route	10—15	11, 12, 15, 16
2	4 routes	2 Routes	10—15	11, 12, 15, 16
3	4 Routes	5 Routes	10—15	10—16
4	3 Routes	1 Route	12—16	10, 13—16
5	3 Routes	3 Routes	12—16	12—16
6	4 Routes	4 Routes	12—16	10—16
7	1 Route	1 Route	15, 16	10, 13—16
8	1 Route	5 Routes	15, 16	10—16
9	4 Routes	1 Route	10—16	11, 13, 15, 16
10	1 Route	2 Routes	1—3, 9	3—8
11	1 Route	1 Route	1—3, 9	1—3, 6, 8
12	2 Routes	2 Routes	1—6, 9	1—3,5,6,8,9
13	3 Routes	4 Routes	1—6, 9	3—6,8,9
14	3 Routes	2 Routes	1—6, 9	3—6, 8
15	3 Routes	6 Routes	1—9	1—9
16	1 Route	6 Routes	4—9	1—9

From the table above, it is suggested that there are similarities between the theoretical results and the actual situation regarding to port 3, port 5, port 6, port 7 and port 15. However, there are high level of difference which suggest that the actual shipping network of the CKYHE alliance is not efficiency in the aspect of profit maximization. In addition, the 2M alliance shows the consistency between the actual situation and the theoretical result regarding the European ports, in which the two situations have similar number of visited routes and connected ports. While in the case of the CKYHE alliance, there shows no consistency either for Asian ports or European ports.

There are five companies involved in the CKYHE alliance, COSCO, K-line, Yang Ming Line, HANJIN and Evergreen. It is assumed in Chapter 4 that the five companies contribute even capacity to the alliance. Therefore, the capacity for the individual company is 632,800 TEU per year and the number of route is 1, which is about one fifth of number of routes in the alliance. Put the capacity in the model and the results shows that the total revenue is $1.005 billion and the transportation details can be shown in the tables below:

Table 24 Transportation situation for individual company in CKYHE alliance

Number of container transported							
	Ports Europe						
Ports Asia	10	11	12	13	14	15	16
1	0	0	0	0	0	0	2,000
2	0	0	0	0	0	0	2,000
3	0	0	0	0	0	0	216,557
4	0	0	0	0	0	0	2,000
5	0	0	0	0	0	0	2,000
6	0	0	0	0	0	0	2,000
7	0	0	0	0	0	2,000	0
8	0	0	0	0	0	2,000	0
9	2,000	2,000	25,895	41,472	96,618	132,136	102,122

Table 25 Unsatisfied demand for individual company in CKYHE alliance

Unsatisfied Demand							
	Ports Europe						
Ports Asia	10	11	12	13	14	15	16
1	171,875	199,369	112,107	179,544	418,287	572,053	440,114
2	318,010	368,881	207,426	332,201	773,934	1,058,438	816,020
3	445,242	516,465	290,414	465,110	1,083,575	1,481,905	928,742
4	64,969	75,361	42,376	67,868	158,112	216,236	165,119
5	210,425	244,086	137,252	219,815	512,107	700,362	539,278
6	149,769	173,727	97,689	156,452	364,490	498,479	383,252
7	207,049	240,170	135,050	216,288	503,890	687,124	532,594
8	356,176	413,152	232,320	372,070	866,818	1,183,467	916,195
9	37,701	44,051	0	0	0	0	0

From the results shown above, the Hamburg port in Germany and Colombo port in

Sri Lanka shall be most commonly visited port to realize profit maximization. The actual routes regarding the Hamburg port is consistent with that in the theoretical results while the Colombo port shall be the main port in the shipping network to realize profit maximization in individual company aspect. Similar with the situation of the 2M alliance, there is conflict of interest between the realization of revenue maximization in the alliance level and in the individual level. As the results shown of the individual company, most of the capacity is applied to provide the container transportation to the Hamburg port in Germany. While the results at the alliance level given that the container flow of the Hamburg port is in the fourth place and the container volume is about half the level of the Rotterdam port. The conflict of interests of the shipping network structure in the alliance level and in the individual company level explains the situation that in actual situation, the liner shipping alliance usually cannot last for a long time. This is because liner shipping companies apply shipping alliance as a way to get access to new market and avoid operational and capital risk. However, after they get familiar with the market and achieve insurance for the capital investment, they prefer to get rid of the alliance and take their own businesses.

However, in this situation, there is only one route to visit all the ports. Even though there is assumption under the model that all the routes takes the same time to provide one trip, visit all the ports in one route makes the assumption unreasonable. If the individual company pursue the same service quality as in the alliance, more routes shall be built and thus it is difficult to determine whether the current shipping network is helpful for individual company of pursuing profit maximization.

Chapter 6 Further and Sensitivity Analysis

6.1 Further issues considered regarding the model

In this chapter, two issues that did not taken into consideration previously are going to be included in the model. One of the issues is the shipping network strategy which is not profit orientation. The other is the demand and market limitation.

The object of the model is to maximize revenue since it is assumed that the cost of operating the ship is constant. The determinants of the results are demand between each pair of ports and the freight rate. The model suggests that the shipping capacity shall be attributed to ports with high freight rate. Generally the freight rate mainly depends on the distance between the origin port and the destination port. Other factors including service, currency and cargo volume of the two ports. Since the ports grouped and numbered in Chapter 4 is according to the distance. Therefore, in the revenue matrix shown in Chapter 4.3, the freight rate shall increase from left to right, and from top to bottom.

By checking the freight rate matrix, it can be observed that even though the Colombo port in Sri Lanka bears the shortest distance to European ports compare with other Asian ports, the freight rate from this port to Europe is the highest among all the ports in Asia. That provides the reason that in the model, high level of capacity is attributed to satisfy the demand of this port. Compare with Shanghai port and Ningbo port, the freight rates from South Korean ports and North Chinese ports are lower. Other abnormal freight rates regarding the distance including the freight rate to La Havre port in France is too high while the freight rate to Gdansk port in Poland is too low.

There are possible three reasons that can explain the situation since there is lack of available information regarding the ports. The first reason of the high freight rate is because the cost of handling containers in the ports is high. The high cost may due to the inefficiency of the infrastructure of the ports, the high labour cost in certain regions, and the market situation of the region (for instance, the competition situation of the port in the region), etc. In practical situation, there is port charge discount regarding the volume of container handled through each port call. Therefore, increase the cargo flow of these port is profitable.

The second reason is that there is unbalanced import and export of the port which gives high volume of empty container transportation, and the cost of transporting such container requires non-add value cost which result in high transportation cost.

The third reason is due to the regulation of demand and supply. It is probable that the container flow of ports such as Shanghai port and Ningbo port is of high level, and the volume is also increasing. Even though currently there is abundant capacity of shipping transportation, it takes time to transfer the shipping capacity to such ports. In addition, the port itself may bear certain limitations that limits the container flow.

This result in the demand over supply, and thus the freight rate regarding the port is high.

Under the assumption that ship operating cost is identical, it is reasonable to attribute shipping capacity to ports with high freight rate. However, the current shipping networks of these two alliances show strategies that do not consistent with the objective of revenue maximization. There is two possible reasons behind this situation. The first reason is market occupation. Currently, the liner shipping market is a high competitive market. In such market, companies tend to be price taker, thus the market share is of paramount importance because this provides companies market power. Therefore, for instance, the 2M and CKYHE alliances choose Shanghai port and Ningbo port to be important ports in the shipping network may due to this reason. Because these two ports are two of the biggest ports in the world currently and have potential growing. The second possible reason is the cost of visit certain ports is low. In the model, it is assumed that the costs of each ship, whatever ports it visits, are the same. While in practice, this is not the case. The location of Tanjung Pelepas makes it easy to reach and stop on the routes from East Asia to Europe and the port charge and container handling cost of visiting this port is low.

Another issue of this model is the market situation. Because in the long run, the market structure can change and the alliances together with individual companies have the potential to occupy any percentage of the market share. Therefore, in the analysis shown in Chapter 4, the data of demand is applying the total demand of the market. While in the short run, the alliances and individual shipping companies are limited by their market occupation.

As previously mentioned in this thesis, there is abundant capacity exist in the shipping market, which makes the market of high level of competition. Therefore, the demand of each pair of ports needs to be shared among competitors in the market rather than chosen by individuals. The market situation shown in the Chapter 1 suggests that 2M alliance occupies 34% of the East Asia-Europe market while CKYHE occupies 23% of the market. The shipping networks of these two alliances show similarities. There is overlap of port visits, including Busan port and Kwangyang port in South Korea, Dalian port, Xingang port and Qingdao port in north-east China, Shanghai port and Ningbo port in middle-east China, Xiamen port, Yantian port and Nansha port in south-east China, Tanjung Pelepas port and Colombo port, etc. Therefore, it is not a free choice of port visits for individual shipping companies or alliances to choose. This means the demand data put in the model shall be limited.

For the 2M alliance, Tanjung Pelepas port in Malaysia is one of the most important ports given that all the six routes visit the port. Other ports including Shanghai port and Ningbo port are also visited by all the routes of the alliance. For CKYHE alliance, Shanghai port, Ningbo port, Rotterdam port and Hamburg port are important for the shipping network strategies since all the six routes of the alliance visit the ports mentioned above.

6.2 Sensitivity analysis for the 2M alliance

Now we take these shipping network strategies into consideration. Firstly, since Tanjung Pelepas port, Shanghai port and Ningbo port are visited by all the routes in the 2M alliance, we assume that at least 1/4 of the shipping capacity shall be attributed to these ports, which means that at least 1/12 of the shipping capacity is attributed to each of the port. Therefore, the volume of container outflow of these three ports shall be more than 212,000 TEU. The constrains add in the model is:

$$\sum_{j \in N_2} e_{ij} \geq 212{,}000$$

In addition, change the demand data put in the model as 34% of the original data, which is the market share of the alliance. The revised demand data is shown in the table below:

Table 26 Revised demand for sensitivity analysis (2M)

Demand								
		Ports Europe						
Ports								
Asia		10	11	12	13	14	15	16
	1	49,791	26,930	26,193	144,474	112,756	14,967	8,405
	2	116,044	62,764	61,045	336,716	262,792	34,883	19,588
	3	214,710	116,128	112,948	623,007	486,230	64,542	36,243
	4	300,612	162,589	158,137	872,263	680,764	90,364	50,743
	5	43,865	23,725	23,075	127,278	99,335	13,186	7,404
	6	99,509	53,820	52,347	288,736	225,346	29,912	16,797
	7	139,793	75,608	73,538	405,625	316,573	42,022	23,597
	8	46,191	24,983	24,299	134,030	104,604	13,885	7,797
	9	26,804	14,497	14,101	77,776	60,701	8,057	4,525

Maintain other constrains as the same as in the Chapter 5, the result for the 2M alliance can be shown in the tables below:

Table 27 Transportation situation for 2M alliance for sensitivity analysis

Number of container transported								
	Ports Europe							
Ports Asia	10	11	12	13	14	15	16	Total
1	20	26,930	26,193	144,474	112,756	14,967	8,405	333,744
2	0	62,764	61,045	84,048	53,867	34,883	19,588	316,194
3	12,505	45,818	44,578	44,578	55,832	64,542	36,243	304,095
4	80,807	114,119	112,879	112,879	124,134	90,364	50,743	685,925
5	0	19,465	18,009	35,323	47,272	13,186	7,404	140,659
6	0	35,855	34,615	32,842	44,791	29,912	16,797	194,812
7	0	22,304	21,070	19,299	31,248	42,022	15,513	151,457
8	0	18,794	18,113	71,721	81,690	13,885	7,797	212,000
9	25,456	14,497	14,101	77,776	60,701	8,057	4,525	205,114
Total	118,788	360,546	350,601	622,940	612,292	311,819	167,014	2,544,000

Table 28 Unsatisfied demand for 2M alliance for sensitivity analysis

Unsatisfied demand							
	Ports Europe						
Ports Asia	10	11	12	13	14	15	16
1	49,771	0	0	0	0	0	0
2	116,044	0	0	252,668	208,925	0	0
3	202,204	70,310	68,371	578,429	430,398	0	0
4	219,805	48,470	45,258	759,384	556,630	0	0
5	43,865	4,260	5,066	91,956	52,063	0	0
6	99,509	17,965	17,732	255,894	180,555	0	0
7	139,793	53,304	52,468	386,326	285,325	0	8,083
8	46,191	6,190	6,186	62,309	22,914	0	0
9	1,348	0	0	0	0	0	0

The demand fulfilment under this model is 31.84%. The grouped port 4, which includes Shanghai port and Ningbo port, shows its importance. The capacity limitation for each route is 432,000 TEU. One of the feasible routes regarding to the results above can be shown in the table below:

Table 29 Feasible routes for 2M alliance in sensitivity analysis

	Ports visited									
Route 1	1	2	3	4	10	11	15	16		
Route 2	1	2	3	4	11	12	13			
Route 3	1	2	3	13	14					
Route 4	4	5	6	7	8	9	10	11	12	13
Route 5	4	5	6	7	14	15	16			
Route 6	7	8	9	13	14	15	16			

The comparison between the result and the actual situation can be shown in the table below:

Table 30 Comparison for 2M alliance in sensitivity analysis

Port Number	Theoretical visited routes	Actual visited routes	Theoretical connected ports	Actual connected ports
1	3 routes	1 Route	10—16	12—15
2	3 routes	2 Routes	10—16	12—16
3	3 Routes	2 Routes	10—16	10,13,14
4	4 Routes	6 Routes	10—16	10—16
5	2 Routes	2 Routes	10—16	10,11,13,14
6	2 Routes	6 Routes	10—16	10—16
7	3 Routes	2 Routes	10—16	12—15
8	2 Routes	6 Routes	10—16	10—16
9	2 Routes	1 Route	10—16	12—15
10	2 Routes	2 Routes	1—9	2—8
11	3 Routes	2 Routes	1—9	2—6，8
12	2 Routes	4 Routes	1—9	1—2，4—9
13	4 Routes	5 Routes	1—9	1—9
14	3 Routes	5 Routes	1—9	1—9
15	3 Routes	2 Routes	1—9	1—2,4,6—8
16	3 Routes	1 Route	1—9	2,4,6,8

The above results still shows inconsistency with the actual situation. However, the results of the model shows fully connections among ports in Asia and Europe given that each of the Asian port is connected with all the European ports and vice versa. In addition, the number of total visited routes for the theoretical results is 44 while in actual situation, the number is 49. This means the duplication of the theoretical results is lower compare with that of the actual situation. Therefore, the actual shipping network of the 2M alliance still shows an inefficiency under the sensitivity analysis situation.

6.3 Sensitivity analysis for the CKYHE alliance

As stated previously, from the actual shipping network of the CKYHE alliance, it can be observed that Shanghai port, Ningbo port, Rotterdam port and Hamburg port are important because they are visited by all the six routes of the alliance. In this case, a constraint that at least 1/12 of the capacity, which is 263,667 TEU shall be attributed to each of the port mentioned above is included in the model. Therefore, the constraint put in the model shall be:

$$\sum_{j \in N_2} e_{ij} \geq 263{,}667$$

In addition, the demand data input of the model is changed as 23% of the original data. The revised demand data is shown in the table below:

Table 31 Revised demand for sensitivity analysis (CKYHE)

Demand							
	Ports Europe						
Ports Asia	10	11	12	13	14	15	16
1	39,531	45,855	25,785	41,295	96,206	131,572	101,686
2	73,142	84,843	47,708	76,406	178,005	243,441	188,145
3	102,406	118,787	66,795	106,975	249,222	340,838	263,419
4	14,943	17,333	9,747	15,610	36,366	49,734	38,437
5	48,398	56,140	31,568	50,557	117,785	161,083	124,494
6	34,447	39,957	22,468	35,984	83,833	114,650	88,608
7	47,621	55,239	31,061	49,746	115,895	158,499	122,497
8	81,921	95,025	53,434	85,576	199,368	272,657	210,725
9	9,131	10,592	5,956	9,539	22,222	30,391	23,488

The results are shown in the tables below:

Table 32 Transportation situation for CKYHE alliance for sensitivity analysis

Number of container transported								
	Ports Europe							
Ports Asia	10	11	12	13	14	15	16	Total
1	0	107	25,785	41,295	96,206	131,572	99,950	394,915
2	27,039	42,952	47,708	68,555	67,021	101,036	101,650	455,961
3	89,424	105,336	66,795	106,975	129,406	163,421	164,329	825,687
4	0	11,103	9,747	15,610	36,366	49,734	38,437	160,997
5	18,677	36,462	31,568	50,557	61,928	95,989	96,556	391,737
6	13,290	32,179	22,468	35,981	58,401	92,852	88,608	343,780
7	865	22,612	30,054	48,215	46,683	82,101	81,311	311,842
8	0	0	20,676	20,522	18,990	54,372	53,618	168,177
9	8,717	10,592	5,956	9,539	22,222	30,391	23,488	110,905
	158,013	261,344	260,756	397,250	537,222	801,469	747,947	3,164,000

Table 33 Unsatisfied demand for CKYHE alliance for sensitivity analysis

Unsatisfied Demand							
	Ports Europe						
Ports Asia	10	11	12	13	14	15	16
1	39,531	45,748	0	0	0	0	1,736
2	46,103	41,891	0	7,851	110,984	142,405	86,494
3	12,982	13,451	0	0	119,816	177,417	99,090
4	14,943	6,230	0	0	0	0	0
5	29,720	19,678	0	0	55,857	65,094	27,938
6	21,157	7,778	0	3	25,432	21,799	0
7	46,756	32,627	1,008	1,531	69,212	76,398	41,186
8	81,921	95,025	32,758	65,054	180,378	218,285	157,107
9	414	0	0	0	0	0	0

The demand fulfilment in this case is 57.48%, which is higher than that of 2M alliance. The highest level of container outflow is from Shanghai port and Ningbo port while the highest level of container inflow is to Rotterdam and Hamburg. This situation shows consistence with the actual shipping network of the CKYHE alliance. There are various possibilities of dividing the routes based on the transportation situation shown above. Each route with an equal transportation capacity of 520,000 TEU. One of the possibilities is shown in the table below:

Table 34 Feasible routes for CKYHE alliance in sensitivity analysis

	Ports Visited									
Route 1	1	2	3	10	11	12	13			
Route 2	1	2	3	11	14	15				
Route 3	1	2	3	14	15	16				
Route 4	4	5	6	7	8	9	10	11	12	13
Route 5	3	4	5	7	13	14	15	16		
Route 6	6	7	8	9	14	15	16			

The comparison between the shipping network shown above with the actual situation can be shown in the table below:

Table 35 Comparison for 2M alliance in sensitivity analysis

Port Number	Theoretical visited routes	Actual visited routes	Theoretical connected ports	Actual connected ports
1	3 routes	1 Route	10—16	11, 12, 15, 16
2	3 routes	2 Routes	10—16	11, 12, 15, 16
3	4 Routes	5 Routes	10—16	10—16
4	2 Routes	1 Route	10—16	10, 13—16
5	2 Routes	3 Routes	10—16	12—16
6	2 Routes	4 Routes	10—16	10—16
7	3 Routes	1 Route	10—16	10, 13—16
8	2 Route	5 Routes	10—16	10—16
9	2 Routes	1 Route	10—16	11, 13, 15, 16
10	2 Routes	2 Routes	1—9	3—8
11	3 Routes	1 Route	1—9	1—3, 6, 8
12	2 Routes	2 Routes	1—9	1—3,5,6,8,9
13	3 Routes	4 Routes	1—9	3—6,8,9
14	4 Routes	2 Routes	1—9	3—6, 8
15	4 Routes	6 Routes	1—9	1—9
16	3 Route	6 Routes	1—9	1—9

The above results of the CKYHE alliance shows the similar situation as of the 2M alliance. There is still certain level of difference between the theoretical shipping network and the actual network. The total number of the theoretical visited routes is 44 while the total number of the actual visited routes is 46. This shows lower level of port visit duplication in the theoretical situation. Similar as in the case of the 2M alliance, the theoretical results show that the port connection is intense. The results still show that the actual shipping network of CKYHE alliance is inefficiency.

Chapter 7 Conclusion and future research

7.1 Conclusion

The aim of this thesis is to evaluate the efficiency of the two alliance, 2M and CKYHE, regarding their shipping network built between the regions of Asia and Europe. The thesis defines the efficiency as profit maximization in alliance level and individual level.

A supply-demand model is built to analyze the optimal situation. In the model, the Asian ports are treated as supplier while the European ports are treated as customer. Under the assumptions that the ships involved in the two alliances are homogeneous, there are same number of ships attributed to each route, and the cost of each ship of performing one round trip are the same, the object of the model is to maximize revenue. The data input of the model including the demand between each two pair of ports, the freight rate of transporting one 40-feet container from each of the Asian ports to each of the European ports, and the capacity, the number of ships, the number of routes of each of the alliance. After getting an overall transportation situation, six routes, which is the actual number of routes in both of the alliance, are separated based on the situation. And then the derived shipping network is compared with the actual shipping network in two aspects, the number of routes visited by certain port and port connection. An assumption made for efficiency evaluation in the individual level is that all the partners in the alliance contributed equal capacity. The optimal solution and shipping network for individual company is derived to compare with that of the alliance.

The results show that there is high level of difference between the theoretical results and the actual shipping network in both of the alliance. This suggests that the current shipping networks are not efficient and there is high potential of improving the network. In the alliance level, the 2M alliance shows a more efficiency shipping network compare with the CKYHE alliance. In addition, there is conflict between the optimal solution in the alliance perspective and the individual company level. This explains the situation that there is the trust issue among partners of alliance because liner shipping companies treat alliance as a way to get access to new market and after they familiar with the market, they prefer to get rid of the alliance and take out separate business. The 2M alliance shows a reasonable shipping network for the objective of revenue maximization in the individual company level, while the result of the CKYHE alliance does not show the same situation.

However, there is some aspects that are not taken into consideration in the model. Therefore, in the sensitivity analysis, two factors, which are the limitation of demand and the shipping network strategy made by each of the two alliances, are taken in the model. Even though in the long run, the alliances together with the individual companies can freely change their market share in the market by taking promotion and competition strategies, in the short run, they are limited by the current market share also because the current liner shipping market is of high competition and the players in the market do not have the market power to determine the situation.

The results of the new model after put sensitivity factors into consideration still show high level of difference compare with the actual situation. From the aspects of either duplication or port connection, the theoretical results are better compare with the actual situation.

The final conclusion is that there is high potential for both the 2M alliance and the CKYHE alliance to improve their shipping network efficiency. The suggestions of achieving that derived from the model include that the two alliances shall attribute more capacity to the Colombo port in Sri Lanka because the high freight rate regarding this port. For the 2M alliance, more shipping capacity shall be attributed to the Japanese ports and the Gdansk port in Poland. For the CKYHE alliance, more shipping capacity shall be attributed to the South Korean ports, the Hong Kong port in China, the Algeciras port in Spain, and the Antwerp port in Belgium.

7.2 Recommendation for future research

There are some deficiencies exist in this thesis that can be improved in the future research. Firstly, the mathematical model built in this thesis is under high level of assumptions. The biggest assumption is that the supply-demand model treats the Asian ports as supplier and the European ports as customer. Other assumptions including the ships involved in the alliance are homogeneous and same shipping capacity is attributed to each of the shipping route. A more complicated model in the future research involves programming shall be built to avoid such assumptions and reflect the actual situation more appropriately.

Secondly, the data input in the model, especially the demand data between each pair of ports involves high level of estimation. More appropriate data shall be put in the model in the future research to achieve a more reliable result.

Thirdly, to evaluate the efficiency of the alliance does not just include the object of profit maximization. Other factors including the access of market and sharing risk are more important for liner shipping companies. In addition, the liner shipping market is changing. Therefore, when making strategies of shipping network, the long term development in the changing environment shall be the most important element of consideration. In the future research of evaluating the shipping network of alliances, such situations shall be taken into consideration.

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Appendix

A. The shipping network of the 2M alliance

The 2M alliance builds its shipping network that contains six shipping routes published in the following tables.(Maersk, 2015)

AE1						
	Colombo	Felixstowe	Rotterdam	Bremerhaven	Gothenburg	Wilhelmshaven
From	Sri Lanka	UK	Netherlands	Germany	Sweden	Germany
Kobe, Japan	19	34	36	38	39	45
Nagoya, Japan	17	33	35	36	38	44
Yokohama, Japan	16	31	33	35	36	42
Ningbo, China	13	28	30	32	33	39
Shanghai, China	11	26	28	30	32	38
Hong Kong	9	24	26	28	29	35
Yantian, China	8	23	25	27	29	34
Tanjung Pelepas, Malaysia	3	18	20	22	24	30
Colombo, Sri Lanka	n\a	14	16	18	19	25

AE2			
	Antwerp	Hamburg	Bremerhaven
From	Belgium	Germany	Germany
Busan, South Korea	35	38	40
Xingang, China	31	35	37
Qingdao, China	29	33	35
Shanghai, China	28	31	33
Ningbo, China	26	30	32
Hong Kong	24	27	29
Yantian, China	23	27	29
Tanjung Pelepas, Malaysia	18	22	23

AE5				
	Algeciras	Rotterdam	Bremerhaven	Wilhelmshaven
From	Spain	Netherlands	Germany	Germany
Dalian, China	32	36	38	40
Busan, South Korea	30	34	36	38
Qingdao, China	27	31	34	35
Ningbo, China	26	30	32	34
Shanghai, China	24	28	31	32
Xiamen, China	22	26	29	30
Yantian, China	21	25	27	29
Tanjung Pelepas, Malaysia	16	20	22	24

AE6							
	Sines	La Havre	Bremerhaven	Hamburg	Rotterdam	Antwerp	Felixstowe
From	Portugal	France	Germany	Germany	Netherlands	Belgium	UK
Ningbo, China	27	31	33	35	37	38	40
Shanghai, China	26	29	32	33	35	37	38
Xiamen, China	24	27	30	31	33	35	36
Chiwan, China	22	26	28	30	32	33	35
Nansha New Port, China	21	25	27	29	31	32	34
Yantian, China	20	24	26	28	30	31	33
Tanjung Pelepas, Malaysia	15	19	21	23	25	26	28

AE9						
	Barcelona	Port Tangier	Southampton	Le Havre	Antwerp	Felixstowe
From	Spain	Morocco	UK	France	Belgium	UK
Ningbo, China	24	26	30	32	34	35
Shanghai, China	23	25	29	30	32	34
Yantian, China	20	22	26	28	30	31
Chiwan, China	19	21	25	27	29	30
Tanjung Pelepas, Malaysia	15	17	21	22	24	26

AE10				
	Felixstowe	Bremerhaven	Gdansk	Aarhus
From	UK	Germany	Poland	Denmark
Busan, South Korea	30	33	36	42
Kwangyang, South Korea	28	31	34	40
Shanghai, China	26	29	32	38
Ningbo, China	25	27	31	36
Yantian, China	22	25	28	34
Tanjung Pelepas, Malaysia	18	20	23	29

B. The shipping network of the CKYHE alliance

The CKYHE alliance builds its network that contains nine shipping routes published as follows:(DUPIN, 2015)

Route	**Vessel applied**	**NO. of vessels**							
NE2	14000TEU	10							
Ports visited									
Nansha	Kaohsiung	Yantian	Singarpore	Piraeus	Rotterdam	Felixstowe	Hamburg	Antwerp	Hong Kong
China	Taiwan	China	Singarpore	Greece	Netherlands	UK	Germany	Belgium	China

Route	**Vessel applied**	**NO. of vessels**					
NE3	13000TEU	11					
Ports visited							
Xingang	Dalian	Qingdao	Shanghai	Ningbo	Singapore	Rotterdam	Hamburg
China	China	China	China	China	Singapore	Netherlands	Germany

Route	Vessel applied	NO. of vessels					
NE5	14000TEU	10					
Ports visited							
Shanghai	Ningbo	Yantian	Tanjung Pelepas	Rotterdam	Felixstowe	Hamburg	Kaohsiung
China	China	China	Malaysia	Netherlands	UK	Germany	Taiwan

Route	Vessel applied	NO. of vessels							
NE6	13000TEU	11							
Ports visited									
Qingdao	Kwangyang	Busan	Shanghai	Yantian	Singapore	Algeciras	Hamburg	Rotterdam	La Havre
China	South Korea	South Korea	China	China	Singapore	Spain	Germany	Netherlands	France

Route	Vessel applied	NO. of vessels						
NE7	14000TEU	10						
Ports visited								
Ningbo	Shanghai	Xiamen	Singarpore	Piraeus	Hamburg	Rotterdam	Felixstowe	Antwerp
China	China	China	Singarpore	Greece	Germany	Netherlands	UK	Belgium

Route	Vessel applied	NO. of vessels						
NE8	8500TEU	10						
Ports visited								
Taipei	Ningbo	Shanghai	Shekou	Colombo	Felixstowe	Hamburg	Rotterdam	Le Havre
Taiwan	China	China	China	Sri Lanka	UK	Germany	Netherlands	France

C. The throughput of Asian ports (Council, TOP 50 WORLD CONTAINER PORTS, 2015)

	2011	2012	2013	2014	Export to Europe
	TEU	TEU	TEU	TEU	TEU
Kobe, Japan		2,563,619			474,270
Nagoya, Japan	2,710,000	2,660,000	2,620,000		492,717
Yokohama, Japan	3,083,432	3,052,775	2,888,000	2,880,029	550,571
Busan, South Korea	17,690,000	17,040,000	16,180,000		3,139,450
Kwangyang, South Korea		2,148,192			397,416
Dalian, China	10,860,000	8,920,000	6,400,000		1,614,433
Xingang,China	13,010,000	12,300,000	11,590,000		2,275,500
Qingdao, China	15,520,000	14,500,000	13,020,000		2,654,133
Shanghai, China	31,500,000	32,527,600	33,617,000	35,285,000	6,147,994
Ningbo, China	17,330,000	16,830,000	14,720,000		3,014,267
Xiamen, China	8,010,000	7,200,000	6,470,000		1,336,933
Yantian, China	10,264,000	10,667,000	10,796,000	11,673,000	2,007,250
Chiwan, China	724,000				133,940
Nansha New Port, China	4,820,000				891,700
Hong Kong	24,384,000	23,117,000	22,352,000	22,270,000	4,260,689
Tanjung Pelepas, Malaysia	7,630,000	7,700,000	7,500,000		1,407,850
Colombo, Sri Lanka	4,262,887	4,187,105	4,306,196	4,907,901	816,964
Taipei, Taiwan	13,420,000				2,482,700
Kaohsiung, Taiwan	9,636,288	9,781,221	9,937,718	10,590,000	1,847,467
Shekou, China	989,333				183,027
Singapore	29,937,700	31,649,000	32,578,700	33,869,300	5,921,605

D. The throughput of European ports (Council, TOP 50 WORLD CONTAINER PORTS, 2015)

	2011	2012	2013	2014	Average	Percentage
	TEU	TEU	TEU	TEU	TEU	
Algeciras, Spain	3,600,000	4,114,231	4,336,459	4,560,000	4,152,673	5.64%
Barcelona, Spain		1,756,429			1,756,429	2.38%
Sines, Portugal		1,200,000			1,200,000	1.63%
La Havre, France	2,215,262	2,303,750	2,486,264		2,335,092	3.17%
Southampton, UK	1,563,040	1,475,510	1,491,270		1,509,940	2.05%
Felixstowe, UK	3,519,000	3,700,000	3,740,000	4,000,000	3,739,750	5.08%
Antwerp, Belgium	8,664,243	8,629,992	8,578,269	8,977,738	8,712,561	11.83%
Rotterdam, Netherlands	11,876,921	11,865,916	11,621,046	12,297,570	11,915,363	16.17%
Wilhelmshaven, Germany		980,000			980,000	1.33%
Bremerhaven, Germany	5,915,487	6,115,211	5,830,711	5,780,000	5,910,352	8.02%
Hamburg, Germany	9,014,165	8,863,896	9,257,358	9,700,000	9,208,855	12.50%
Gothenburg, Sweden				837,000	837,000	1.14%
Aarhus, Denmark		1,300,000			1,300,000	1.76%
Gdansk, Poland			1,200,000		1,200,000	1.63%
Piraeus, Greece				3,580,000	3,580,000	4.86%
Genoa, Italy	1,847,102	2,064,806	1,988,013	2,172,944	2,018,216	2.74%
Valencia, Spain		4,469,754			4,469,754	6.07%
Gioia Tauro, Italy	3,090,000	2,720,000	2,300,000		2,703,333	3.67%
Zeebrugge, Belgium		1,953,170			1,953,170	2.65%
Dublin, Ireland		1,918,317			1,918,317	2.60%
Las Palmas, Spain		1,207,806			1,207,806	1.64%
Marseilles, France		1,061,193			1,061,193	1.44%
Total					73,669,804	1

E. The demand calculation between each pair of ports

	Algeciras, Spain	Barcelona, Spain	Las Palmas, Spain	Marseilles, France	Total
Kobe, Japan	26,734	11,307	7,776	6,832	474,270
Nagoya, Japan	27,774	11,747	8,078	7,097	492,717
Yokohama, Japan	31,035	13,127	9,027	7,931	550,571
Busan, South Korea	176,967	74,850	51,471	45,223	3,139,450
Kwangyang, South Korea	22,402	9,475	6,516	5,725	397,416
Dalian, China	91,004	38,491	26,468	23,255	1,614,433
Xingang,China	128,267	54,252	37,307	32,778	2,275,500
Qingdao, China	149,610	63,280	43,514	38,232	2,654,133
Shanghai, China	346,555	146,580	100,795	88,560	6,147,994
Ningbo, China	169,910	71,866	49,418	43,420	3,014,267
Xiamen, China	75,361	31,875	21,919	19,258	1,336,933
Yantian, China	113,146	47,857	32,909	28,914	2,007,250
Chiwan, China	7,550	3,193	2,196	1,929	133,940
Nansha New Port, China	50,264	21,260	14,619	12,845	891,700
Hong Kong	240,170	101,583	69,853	61,374	4,260,689
Tanjung Pelepas, Malaysia	79,359	33,566	23,082	20,280	1,407,850
Colombo, Sri Lanka	46,051	19,478	13,394	11,768	816,964
Taipei, Taiwan	139,947	59,192	40,704	35,763	2,482,700
Kaohsiung, Taiwan	104,139	44,047	30,289	26,612	1,847,467
Shekou, China	10,317	4,364	3,001	2,636	183,027
Singapore	333,793	141,182	97,084	85,299	5,921,605
	5.64%	2.38%	1.64%	1.44%	1