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Container seaport selection criteria for shipping lines in a global supply chain perspective: implications for regional port competition.

By

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Acknowledgements

After my graduate program, I came to Erasmus University Rotterdam to study Maritime Economics and Logistics (MEL). MEL gives me a very excellent and professional environment to learn, to discuss and to think of problems not only within maritime field but also in social and economic area.

As the words suggests, no pains, no gains. Four months' dedicated efforts on my thesis made me achieve a lot of professional knowledge as well as communication skills and writing skills. I really enjoy the 120 days' research time together with a combination of happiness, frustration and most importantly, the sense of accomplishment.

At this moment when I finish my thesis, I would like to give my great gratitude to those nice persons who helped me during my thesis writing time. I would like to thank Dr. van Asperen, my tutor, for his professional and kind instructions. I would like to thank Mr. Nieuwenhuizen and professor Gujar for their sincere suggestions on my questionnaire design and distribution. I also would like to thank staffs and professionals from Maersk Line, CMA CGM, and other distinguished shipping companies for the responses of my questionnaires. Finally, I would like to thank my family and friends for their supports on me. Without them, I could never be able to focus on my research.

Abstract

Shipping lines are heading for a more value-added business recent years – integration into global or regional supply chains. Most of liner shipping companies are observed involvements in this trend more or less nowadays. Under this circumstance, shipping lines' port selection criteria in the Northwest Europe – Asian route may differ from previous criteria. This thesis uses Analytic Hierarchy Process (AHP) to examine relative weight of eight selective port selection criteria (port location, water draft, size of hinterland, feeder services & intermodal connections, cargo volume, port charges, port efficiency and IT ability) among port of Hamburg, Rotterdam, Antwerp and Le Havre. Raw data is collected via distribution of questionnaires to various shipping lines operating in Northwest Europe – Asian route. The modal results show that port location, feeder services & intermodal connections, size of hinterland and port efficiency are the four most important port selection criteria. Port competition and development is also needed to re-think since the change in port selection criteria. Several competition suggestions are raised in favor of port's integration towards an element in supply chains.

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List of Abbreviations

AHP	Analytic Hierarchy Process
GDP	Gross Domestic Product
OECD	Organization for Economic Cooperation and Development
SCM	Supply Chain Management
TEU	Twenty foot Equivalent Unit
UNCTAD	United Nations Conference on Trade and Development

Chapter 1. Introduction

Recent years, a lot of trends are happening in maritime and shipping industry. The public wants this industry to be greener with lower green house gas emissions and high energy efficiency; global logistics integration forces freight forwarders, carriers and ports and other relevant parties to act more coordinately. In this respect, ports and shipping lines' relationship need to be strongly tied down.

1.1 Research Background

Maritime transport is the world's most important means of transport for cargo as well as people, which accounts for around 90% of cargo transportation in terms of volume in the globe. Nowadays, shipping routes can be found almost everywhere in every sea area. With the help of modern high technology, one can understand global shipping routes' prosperity both breadth and depth. Figure 1-1 provides the view of world shipping routes and number scales of their yearly journeys. The brighter the routes are, the more number of yearly journeys the routes exercise.

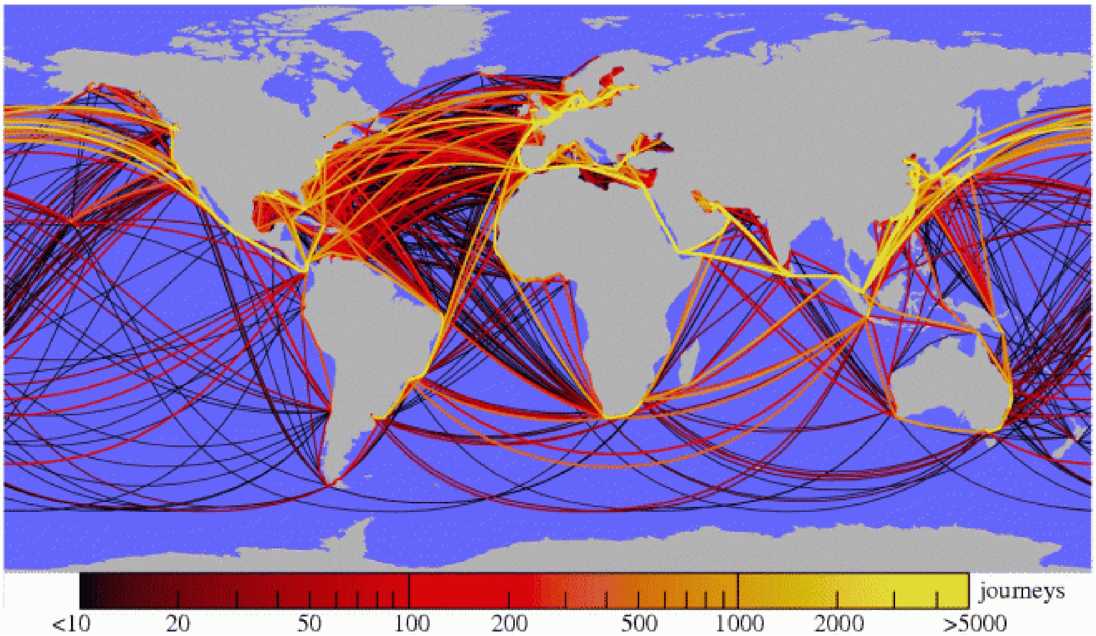

Figure 1-1 Global Shipping Routes
Source: *http://www.wired.com/wiredscience/2010/01/global-shipping-map/*

According to United Nations Conference on Trade and Development, in the year of 2009, there are approximately 7,843 millions of tons cargo is transported by sea (UNCTAD 2010). After transported on the sea along the shipping routes mentioned above, these huge volumes of cargo are loaded and unloaded in ports. As connections of both route-to-route and route-to-land, traditional ports provide cargo loading and unloading as their basic functions. Today's port functions are far more than cargo handling. As an interface between maritime and land, modern ports provides both basic and value-added services like cargo storage, transshipment, customs procedures, financial services, industry processing, intermodal transport and logistics area. For example, container transshipment accounts for most of its container throughput in port of Singapore since the location of the port in Southeast Asia is a major hub in the Asia-Europe route. Another example would be port of Rotterdam, where crude oil storage and refinery facilitates are established to speed up and facilitate oil industry procedures.

However, the emerge of container transport has accelerated cargo handling efficiency and shortened turnaround time of cargo in port ever since container was invented in 1950s. Container has many advantages; it provides a safe pattern of cargo transport since the boxes are locked and sealed; it's construction standards make it easy to build and easy to handle through highly standard equipments like straddle carrier and pallets. As a result of these advantages, container transportation becomes one of the most efficient and promising means of transport for high-value end industry products like electric products, toys, etc. Shipping lines are committed to deliver containers to destination ports initially, but since industries tend to build their global supply chains in order minimize total logistics costs, shipping lines are more and more integrated into supply chains. If shipping lines keep a blind eye on this particular trend, they will lose competitive position and customers. Today's shipping lines try hard to extend their business through both vertical integration (e.g. merger and acquisition of airlines and road transport) and horizontal integration (e.g. slot exchange with alliances).

The changes in supply chains and shipping lines will of course have influences on how shipping lines select proper port of call as well as ports themselves. Ports cannot survive without adapting to the new trends and developments under this situation. But how could ports react to shipping lines' change and how ports could develop to be more competitive under new situation remains a confusing problem to the world. none of the studies has examined port choice in a situation where a port is considered as an element of a supply chain (Magala, 2004) Since shipping lines need to select ports of call to deliver & transship containers and extend their logistics services, changes in port selection criteria will be indicators for this kind of change. By researching on port selection criteria, ports could identify key factors for competition and development, and then ports could be able to keep pace with logistics development and remain competitiveness. This paper has the ambition to explore in this point.

1.2 Problem Definition

Port selection criteria are a series of standards referred by shipping companies when they are choosing port of call on the shipping routes. Previous research and empirical findings show that port charges, port handling efficiency and port draft, etc. are important factors to be considered when selecting a port. But in global logistics era, those criteria may change to some extent when more and more liner shipping companies are involved into global supply chain. For example, shipping lines now consider how to minimize total cost through whole transport chain rather than simply selecting a port with minimum dues; therefore, a port with relatively higher charges but better connections to hinterland multimodal transportation may be a better choice than the port with lowest charges.

Indeed, port selection criteria do change under global logistics time. Yet lot of research has done on port selection issue but few of them focus on this new situation. The author has the ambition to explore further on port selection criteria from shipping line's perspective, taking global logistics influence into consideration and try hard to figure out this new situation's implications for regional port competition.

1.3 Objective of the Study

The author focus on exploring port selection criteria in a global supply chain perspective, those criteria may include local cargo volume, terminal handling charge, berth availability, port locations, feeder network and hinterland, etc. By redefine these selection criteria from shipping lines perspective, the author aims to find whether there is any change in port selection criteria when container shipping lines are increasingly involved into global logistics and what are implications from this change for regional port competition.

1.4 Research Questions

The research question for this thesis is port selection criteria for container shipping lines in a global supply chain perspective and their implications for port competition. In order to research deeply on this question, the following sub-questions are defined to be figured out.

a) Does container liner shipping market change to some extent due to its increasingly deep involvement into global supply chain?

b) If so, how does container liner shipping change and how do shipping lines react against this new challenge?

c) Do those changes above mentioned pose influences to port selection criteria from container shipping lines perspective?

d) If so, what are the changes and what are the most important port selection factors under the new situation?

e) What are the implications for port competition if taking those new port selection factors into consideration?

1.5 Research Methodology

Research methods employed by the author in this thesis include review of literature, which is used to find and conclude previous research outcomes, and empirical analysis of some ports, which is aimed to provide general empirical findings of the targeted ports in AHP model and support the research model and outcomes.

The author also proposes to use questionnaires distributed to target people to acquire original data which will be used in AHP (Analytic Hierarchy Process) model. The application of AHP is the major method used in this thesis. The results from AHP model will be analyzed through a few basic statistical techniques (average, quartile, etc). Besides, empirical findings will also be on the agenda of this thesis.

Finally, some analyses based on AHP outcomes will be employed to provided implications, suggestion as well as innovative thoughts for change of selection criteria and port competition.

1.6 Structure of the Study

This thesis has been structured into five chapters; the content of each chapter is described as follows.

In Chapter 1, a general introduction is given on the background information of this study. The problem and research questions and objective are explained. A few main research questions are listed in order to help the author better complete this study.

In Chapter 2, relevant literature is reviewed. Relevant research literatures are grouped into several categories, i.e. liner shipping market, global logistics chain, port competition and port selection criteria. In each category, the author not only lists research findings of literature, but also tries to summarize and classified as well.

In Chapter 3, research design and methodology, mainly the Analytic Hierarchy Process (AHP) is described. A detailed analysis of all the port selection factors is illustrated in this chapter. This chapter also includes a questionnaire design.

In Chapter 4, empirical findings in terms of Northwest European seaports (mainly within Hamburg - Le Havre range), liner shipping market and companies will be discussed from various sources. The author aims to provide empirical findings and conclusions on this topic as a supplement of AHP model.

In Chapter 5, data collection result and test of the questionnaire is presented. After that, the AHP model is conducted and results of this model is indicated, interpretation of the result is described as well.

In Chapter 6, the author will refine his findings from port development and competition's viewpoint. Some existing problems are to be re-thought while some new concepts will be come up with. Implications and recommendations for port development and competition will be given in this chapter in detail.

In Chapter 7, conclusions from the model result are drawn, recommendations and implications are given. Limitations of this thesis and several suggestions for further research are also made.

Chapter 2. Literature Review

2.1 Introduction

In this chapter, the author reviews literature in related academic fields. The author aims to accomplish a valuable and creative thesis both theoretically and methodologically through understanding, concluding and arguing against previous literature's pros and cons.

Figure 2-1 below shows inherent relationships and logic of elements to be discussed in this paper. As shipping lines involve further in global logistics services, their business is more than container transport from port to port. These changes to be discussed will influence shipping lines decision on port choice, which will finally result in changes in port selection criteria. By finding their selection criteria, this paper could provides information and implications for port development. Good and proper port development strategy will help port win the competition game eventually.

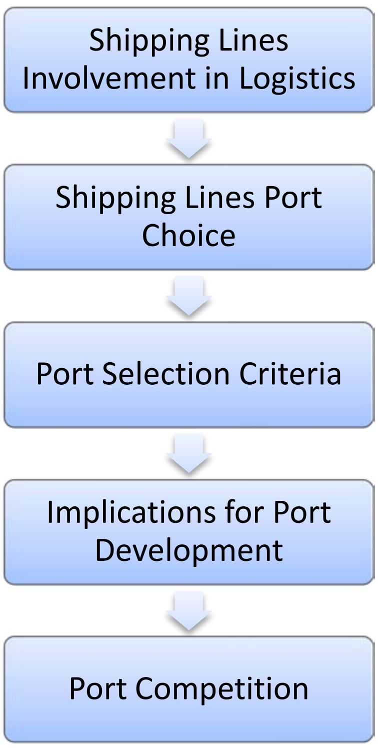

Figure 2-1 Inherent relationships and logic
Source: compiled by the author.

Based on this logic, section 2.1 reviews literature about shipping lines and their involvements in global logistics and section 2.2 is about shipping lines port choice decision making. Section 2.3 deals with literature in terms of port selection criteria and port development and competition are discussed in section 2.4. In each section, only literature related to this paper's topic is discussed in order to avoid verbosity.

2.2 Shipping Lines and Global Logistics

2.2.1 Definitions

Fayle (2006) defined liner service in his book *A Short History of the World's Shipping Industry:*

"*a fleet of ships, under common ownership or management, which provides a fixed service, at regular intervals, between named ports, and offer themselves as common carriers of any goods or passengers requiring shipment between those ports and ready for transit by their sailing dates*" (Fayle, 2006).

Shipping lines are companies providing liner services. For shipping lines, a fixed itinerary is very important, which means no matter the ship is filled or not, the company is obliged to accept cargo from all comers and to sail on the date fixed by a published schedule (Fayle, 2006).

According to Council of Supply Chain Management Professionals, supply chain is *"1) starting with unprocessed raw materials and ending with the final customer using the finished goods, the supply chain links many companies together. 2) The material and informational interchanges in the logistical process stretching from acquisition of raw materials to delivery of finished products to the end user. All vendors, service providers and customers are links in the supply chain."*

It is difficult to distinguish between logistics and supply chain management. However, the Council of Supply Chain Management Professionals defines logistics: *"The process of planning, implementing, and controlling procedures for the efficient and effective transportation and storage of goods including services, and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements. This definition includes inbound, outbound, internal, and external movements."*

It is obvious that the scope of logistics is smaller than the scope of supply chain. Supply chain emphasizes on exchanges and interest parties in the whole process from origin supplier (unprocessed raw material) to the final customer. Logistics emphasizes more on transportation and storage in separate or whole stages of a supply chain.

2.2.2 Involvement in global logistics

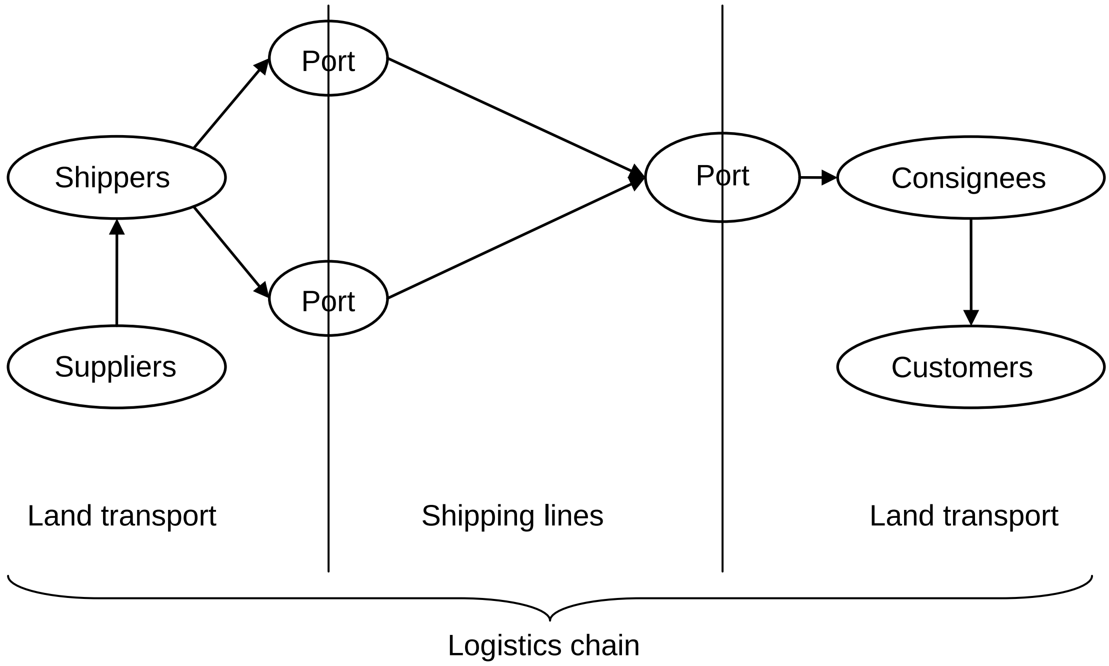

Figure 2-2 Global Logistics Chain
Source: Modified by author based on Magala & Sammons (2008).

Figure 2-2 shows a typical pattern of global logistics chains. Traditional shipping lines provide cargo transportation from port to port, while modern shipping lines tend to provide a package of logistics services. A package that releases suppliers and customers from need to care for transport details in between. Thus shipping lines need to extend their antennas from sea side to land side. In this process, some changes in the role of port have happened. Port now is more like an important element in logistics chain rather than just a pinpoint or a hub connecting sea and land.

It is obvious that shipping lines are integrating themselves into global supply chain management process. But the question is how to trigger the integration and control it. Heaver (2002) concluded that typically three ways towards integration: first, to increase liner shipping companies' geographical span of their services; second, to expand the range of their services in order to meet chippers' increasing logistics needs; third, to find new ways towards operation in order to achieve economies of scale. However, the expansion of network can be expensive and opportunity cost can be high, so that liner shipping companies usually choose to achieve their goal step by step rather than settle a matter on one go. Liner shipping companies choose to expand networks through slot charter agreement first, after cargo flow is cultivated and economies of scale is achieved, the companies will then take further steps in favor of the expansion (Heaver, 2002).

After American President Line (APL) first introduced its logistics network services in 1995, Maersk, MOL, CMA CGM and other shipping lines started to provide their own logistics services. Heaver (2002) analyzed pros and cons of vertical integration for shipping lines. He argued that vertical integration would bring advantages such as demand complementarities, opportunities for cost reduction, increasing visibility and market power.

2.3 Port Choice

2.3.1 Parties Involved in Port Choice

Ding, (2007) concluded the major stakeholders involved in port choice process along a logistics chain are 1) shippers, 2) consignees, 3) shipping lines, 4) port authorities 5) logistics service providers and 6) freight forwarders.

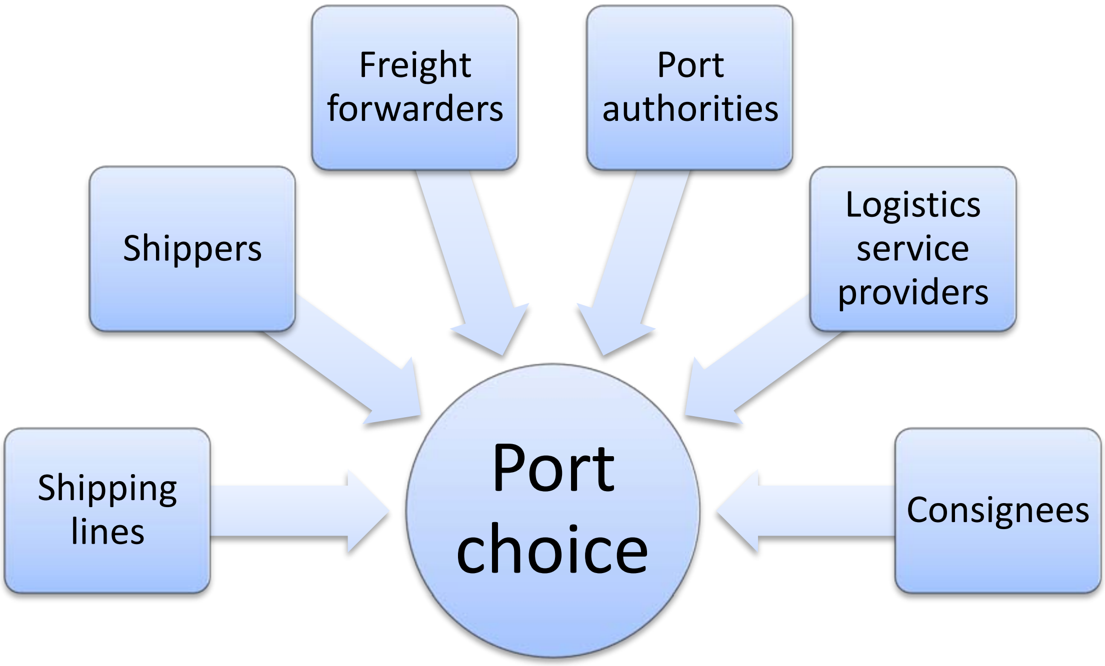

Figure 2-3 Parties involved in port choice
Source: (Ding, 2007).

2.3.2 Major Decision Makers

- Freight forwarders

A freight forwarder organizes shipment and cargo transportation by sea for individuals or companies. A freight forwarder can be an individual or a company, acts as a media between cargo owners and carriers or a carrier itself.

Port choice is important for shippers, shipping lines and even for ports. It is a complex process and highly depends on decision makers' personal preference. But the general procedure for port selection mechanism can still be concluded. Tongzon (2009) mentioned a general port selection process for freight forwarders. The match of demand and port services characters is the main content for the first stage of port choice and the second stage for port selection is to filter potential ports by several selection criteria.

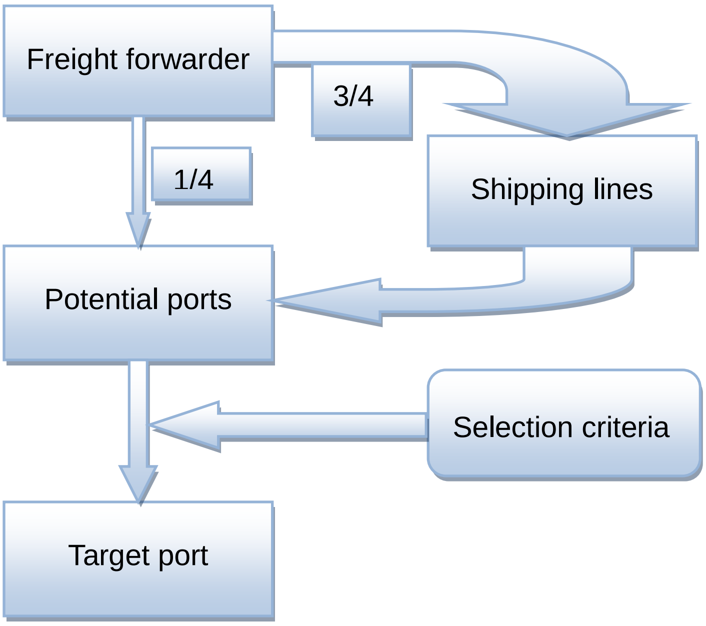

Figure 2-4 Port Choice Process for Freight Forwarders
Source: Compiled by author based on (Tongzon, 2009)

As Tongzon (2009) mentioned, port charges and locations became more important than what D'Este and Meyrick (1992) stated with port efficiency is still the most important factor. He also explained that the lower value-added goods and higher inland transport, the more sensitive to port charges for freight forwarders because of port charges' rising proportion in total costs.

- Shippers

The shippers are "*Individuals or businesses who tender goods or cargo for transportation - usually the cargo owners or their representatives and not to be confused with the party issuing the bills of lading or the ship's operator who is the carrier Shippers and freight forwarders*" (Glossary of Maritime Terms, 2011).

According to the definition, a freight forwarder can act as the representative of a shipper to arrange cargo transport for the shipper. In this way, port choice process for a shipper may be similar with a freight forwarder. Indeed, Langen (2007) mentioned that shippers' port choice is almost the same to freight forwarders with the only difference that shippers are less price-elastic, which means shippers are less sensitive to price changes.

- Consignees

A consignee is the receiver of cargo, usually is the importer of cargo. A consignee can decide the port of call by contract with carriers or shippers.

- Shipping lines

Tongzon (2009) also found that around 3 out of 4 freight forwarders choose to select a shipping line first and then choose ports among which served by the shipping line (as Figure 2-4 shows). This means that the shipping lines' role in port choice becomes more important than before. Lirn et al. (2010), Tongzon and Sawant (2007) and Chang *et al.* (2008) researched on shipping lines' port choice. They argued that as shipping lines evolve their roles in logistics, they are no longer only the media between shippers/freight forwarders and ports in terms of port choice, but a media between suppliers and final customers. Shipping lines today rely more on the wide range of port services as they extend their business into logistics (Tongzon and Sawant 2007). This conclusion is also of great importance for port competition.

2.4 Port Selection Criteria

2.4.1 Research methodology

Many research methods can be applied in this field.

- Questionnaires and interviews

Previous literature shows that the most used method is questionnaires and interviews. Chang and Tongzon (2008), Ha (2003) and Ding (2007) used this method to research. The pros of this method include that it is quick and easy to identify the relatively more important port selection criteria. But its drawbacks are obvious; the result of questionnaires and interviews highly depend on the candidates' personal point of view. Selection of target candidates and interviewees should be careful. Also, distribution of questionnaires may be time-consuming and responsive rate may be low. However, a validity and reliability test is needed if necessary.

- Discrete choice model

Based on the paradigm of ports as elements of value-driven chain system proposed by Robinson (2002), Magala &Sammons (2008) provided a new analytic framework for port choice, which uses discrete choice model. Garcia-Alonso & Sanchez-Soriano (2009) also used this method to test port selection from hinterland perspective. The discrete choice, involving a set of statistics procedures, is what decision makers choose from a group of alternatives, in which the choice result is discrete. It can be used to analyze the chosen quality of port selection.

- Analytic hierarchy process (AHP)

Analytic hierarchy process (AHP) is a structured analytic process for decision making. A typical analytic hierarchy includes three layers, which are goal layer, criteria layer and decision alternatives layer. It can present a clear relative importance of all criteria and relative importance of alternatives under each criterion through questionnaires for target group. Ugboma *et al.* (2006) used this method to explore port selection criteria among Nigerian ports. Lirn *et al.* (2010) also applied AHP to Taiwan ports. However, the risks for using this method are candidates' different levels of quality, lower response rate and inconsistency. Schoner and Wedley (1989) pointed that when alternative ports are added or deleted, weights on various factors need to be regenerated.

- Multicriteria analysis

Multicriteria analysis is a decision making tool for complex decision problems. Different from single criterion analysis, Multicriteria analysis is able to deal with complicated situations where more than one criterion exists and even their relative importance is not constant. Guy and Urli (2006) used this method in a case study for port of Montreal and New York. One point of their paper is when making decision, they not only considered to call at either port of Montreal or port of New York, but also considered to call at both ports with separate loops. This indicates that when researching on port selection problem, researcher should realize that port selection decision is not always fixed in a single service loop.

- Mixed integer programming

Mixed integer programming could be the most complex method with numerous variables and constraints. A perfect integer programming is expected to cover all possible variables and constraints. But in reality this could be a nightmare to solve. An alternative to the "perfect" programming is to reduce less important variables and constraints, which need to be done carefully and with professional experience. Another alternative to it is the so called heuristic method. Heuristic method is not designed to find the best answer but a good enough answer. When the problem is very complex and there is no need for an accurate answer, heuristic method can be applied. However, Aversa et al. (2005) used a mixed integer programming with 3,883 variables and 4,225 constraints for selection of a hub port in the East Coast of South America.

- Multinomial Logit model

Tiwari et al. (2003), Nir et al. (2003) and Malchow and Kanafani (2004) have employed the Multinomial Logit model to estimate the effect of important factors on port choice. The strengths of Multinomial Logit model are that the results of model can be more than two discrete outcomes, depending on a set of independent variables.

- Network-based Integrated Choice Evaluation model

Tang and Low (2011) raised a new method called Network-based Integrated Choice Evaluation (NICE) model, which requires port connectivity index derived from shipping lines' published schedules to establish service network of ports. They pointed that the most appealing feature of the model is its network perspective and nature. It allows "an explicit consideration of inter-port relationship". The research showed that when considering Asian ports, port efficiency and scale economies are the most important factors for liner shipping companies.

2.4.2 Research perspectives

It is very crucial that researcher need to identify from which perspective his/her studies start, since even for one fixed question, different parties will give different answers. Typically there are three parties involved in port selection procedure.

- Shippers

A shipper is an individual or a company who sends goods to destinations by ship. Shippers' requirements and destinations may pose an impact on both port selection and shipping line selection. But due to shipping lines or other logistics service providers' business extension, less and less shippers need to make decisions on port choice. Magala and Sammons (2008) made remarkable comment on this:

"Clearly, shipper's influence on port choice decisions is diminishing, particularly now that a single shipping line, a third-party service provider or a supply chain integrator may control the freight from the origin to the final destination using various transport arrangements and multiple alternative pathways designed to minimize the total logistics cost and maximize value for both the customer and the supplier." (Magala and Sammons, 2008)

- Shipping lines including main trunk and feeder service

Shipping lines are now the main actors in port selections. Wiegmans *et al.* (2008) and Guy and Urli (2006) explored selection criteria from shipping lines perspective. However, as Chang *et al.* (2008) mentioned, shipping lines for main trunks and feeder services may differ in terms of port selection criteria.

- Hinterland

As hinterland connection is an important selection criterion, Garcia-Alonso and Sanchez-Soriano (2009) researched on this topic from a hinterland perspective.

Their results presented that there did exist differences between hinterlands and shipping lines when it comes to selection.

2.4.3 Selection criteria from literature

Previous research identified more 20 criteria for port selection. Table 2-1 depicts the most considered port selection criteria by all parties. Table 2-2 shows the criteria's discussed frequency by various literatures.

Table 2-1 Major Port Selection Criteria

Port selection criteria	Which party emphasize
Geographical location	1. Hinterland
	2. Main trunk & feeders
Water draft	Main trunk
Feeder connection	Main trunk
Inland intermodal/hinterland connection	1. Main trunk & feeders
	2. Deep-sea carrier
	3. Also for terminal selection
Scope of hinterland(large/small)	Deep-sea carrier
Port reputation	
Port dues	Deep-sea carrier/main trunk
Terminal handling charge (THC)	1. Main trunk & feeders
	2. Also for terminal selection
Handling speed/efficiency	Also for terminal selection
Service reliability	1. Main trunk
	2. Also for terminal selection
Cargo volume	Main trunk & feeders
Transshipment cargo volume	Main trunk & feeders
Import and export cargo balance	
Cargo profitability	Main trunk
Berth availability	Feeder services
Information technology ability	Main trunk
Convenience of customs process	
Relationship between management and workers	Main trunk
Acceptance of special requirements	
Easiness of communication with staff	
Calling of competitors	
Slot exchange with cooperating lines	

Source: Compiled by author from various literature

Table 2-2 Discuss Frequency for Criteria

Criteria	Frequency	Criteria	Frequency
Geographical advantage	7	Transportation and port-user cost	2
Infrastructure	6	Time on the route	2
Low cost	6	Available number of berths	1
Intermodal link/network	6	Back-up space on terminal	1
Port operation/working hours	4	Congestion	1
Port equipment	4	Other modes Competitiveness	1
Port productivity	4	Containerized cargo proportion	1
Superstructure	4	Depth of the port	1
Cargo volume	3	Flexible operation process	1
Handling efficiency	3	Free time	1
Frequency of feeder service	3	Labor problems	1
Frequent port of call	3	Major container centre	1
Inland freight rates	3	Operation	1
Loading/discharging rate	3	Port service coverage	1
Numbers of sailing	3	Port tradition and organization	1
Related business operation	3	Privilege contract to carrier	1
Port charges Price conditions	3	Proximity to alternative loading centre	1
Size of hinterland	3	Quality of customs handling	1
Transit time	3	Regulations	1
Cargo-generating effect	2	Service considerations	1
Degree of integration (EDI)	2	Size of port/terminal	1
Port accessibility	2	State aides and influence on cost	1
Port berthing time length	2	Trade inertia	1
Port security	2		

Source: compiled by author based on Lirn *et al.* (2010)

The most discussed criteria are geographical location, port infrastructure (handling equipment), port cost (low cost, terminal handling charges), port intermodal connections/hinterland connections and port productivity (handling efficiency). The author will discuss and provide detail information for these criteria.

- Geographical location

When considering a port's physical conditions, geographical location is always the first factor that comes into one's mind. Garcia-Alonso & Sanchez-Soriano (2009) mentioned that Sargent (1938) proposed that cargo tends to seek the shortest route to access the sea. A port's location often plays an irreplaceable role in sea transportation.

- Water draft

-

As containerships tend to be larger and larger because of economies of scale, today's largest containership could have a draft of 16 meters. A port with insufficient draft may become a feeder port in a hub-spoke system.

- Feeder and Inland intermodal

Ports not only compete for cargo but also compete for hinterland. A good connection to hinterland through multimodal transportation means both quicker access to customers in hinterlands and larger hinterland than competitors. Furthermore, high qualified inland intermodal infrastructure and efficient connection to hinterland strengthens a port's role as a logistics hub in supply chain.

- Hinterland

Larger hinterland usually brings more customers and business for ports. In reality, hinterlands for different ports may overlap to some extent, for example, port of Rotterdam shares part of its hinterland with port of Amsterdam and port of Antwerp. The economic and political condition of hinterland also affects port choice. Hinterlands with high economic performance usually have more logistics needs and thus the port will benefit more from it.

- Port reputation

Port reputation is a port's overall quality or character as seen or judged by its stakeholders in general. It is hard to quantify and it may be not the same in different stakeholders. For instance, a port with high reputation in shipping lines' eye may hurt its local communities because of environmental pollution. In this paper, port reputation is mainly about major players in global logistics chain, i.e. shipping lines, customers, etc.

- Port dues

Branch (1998) mentioned that port dues only account for approximately 4 percent, which is a very small part, of total costs for containership operation.

- Terminal handling charge (THC)

Terminal handling charges (THC) are essentially charges collected by shipping lines to recover from the shippers the cost of paying the container terminals or mid stream operators for the loading or unloading of the containers, and other related costs borne by the shipping lines at the port of shipment or destination.

- Handling speed/efficiency

Handling speed/efficiency can be defined as the total number of container moves of gantry cranes in a container terminal within a single unit time.

- Service reliability

Port service reliability contains at least three key elements, accessibility, continuity and performance. Accessibility means that port services are available when shipping lines need them; continuity means shipping lines have uninterrupted service over desired duration and performance means that shipping lines' expectations can be met.

- Cargo volume

Cargo volume is call size or loading and unloading cargo for shipping lines in a particular port of call. Main trunk and feeder service providers differ in terms of cargo volume.

- Transshipment cargo volume

Transshipment cargo is cargo unloaded from a ship and then loaded to another ship heading for another port. Transshipment cargo volume is the number (TEU or box) of this kind of cargo.

- Import and export cargo balance

Cargo imbalance occurs because of trade imbalance. For shipping lines, cargo imbalance can be identified through the number of empty containers in the two sides of a loop service. For example, in the Asia – Pacific shipping routes, number of empty containers from China to USA is less than that from USA to China recent years.

- Berth availability

Berth availability is a state that when vessel needs to be operated at berth, the berth is available for the vessel to do that. The time window of a berth represents the berth availability period. Shipping lines tend to be in favor of high berth availability while ports tend to be in favor of low berth availability. Because high berth availability ensures service quality and availability whenever shipping lines come to the port and low berth availability means that the utilization of port infrastructure is high and thus ports could earn more from it (Saanen, 2011).

- Information technology ability

Previous studies show that the proliferation of Information technology in ports can lead companies to establish new and additional business relationships (Clemons and Row, 1993; Bowersox and Daugherty, 1995). Good IT system condition in both port and shipping line can promote coordination between shipping lines and port and even other logistics parties.

- Convenience of customs process

“*Ports are also expected to respond quickly to port users' needs.9 This means that ports would have to constantly monitor and understand the needs of port users in order to devise the quickest way to respond to them. Regular dialogues and social interactions between the port's public relations staff and the port users are quite useful in this regard.*” (Tongzon, 2002)

- Relationship between management and workers

Relationship between management and workers reflex the level of a port's management and organization. Mennis et al. (*2008*) remarked that the strikes are one the main reasons for delay in terminals. Shipping lines of course prefer ports with good relationship between their management and workers in order to make operations smoothly.

- Slot exchange with cooperating lines

Slot exchange is a result of strategic alliances recent years. “In an effort to increase market coverage, decrease overheads, share the cost of capital equipment and improve market control (Ryoo and Thanopoulou, 1999).” Shipping lines use slot exchange as a means of getting operational capacity (Feng and Haezendonck, 2008). Slot exchange can also help shipping lines use slot resources more effectively and efficiently.

2.5 Conclusion

In this chapter, literatures of port choice and port selection criteria are mainly discussed. The categories of port selection criteria have already been well summarized by previous researchers, and have been discussed from all related parties' perspectives. But as for shipping lines' integration in supply chains, no research has been done in this area in terms of port selection criteria. The author will dedicate himself to this topic trying to find the answer.

Chapter 3. Research Design and Methodology

3.1 Introduction

The purposes of designing a research are to help the researcher better understand the research, to get a clear view on how the research is going to be conducted, and to give directions and reflections of the research. During the design, the determination of choosing certain methodologies enables the researcher to obtain the relevant knowledge and to collect the correct and suitable data.

3.2 Research Design

This study is mainly to elaborate the key decision factors for port selection from liners companies who are involved into logistics services in the China-North West Europe trade routes. Through research process, the author tries to answer the research question and sub-questions above mentioned in Chapter 1. The research is organized in the following steps.

a) Step 1: literature reading and summary. In this step, the author read relevant literature for recent years as much as possible. Literature includes books, journal articles, conference theses and papers.

b) Step 2: based on the findings from Step 1, the author propose to refine key port selection criteria with consideration of shipping lines' integration into logistics chain and design a questionnaire to ask target group a set of questions on port selection criteria.

c) Step 3: the author will distribute the questionnaires to target group. After receiving enough responses during waiting period, the author will study the results of questionnaires, extract and conclude useful information based on Analytic Hierarch Process (AHP) theory.

d) Step 4: In the meantime, the author will also research on empirical evidences of decision alternatives to test criteria from the other side.

e) Step 5: at this stage the author proposes to conduct AHP and get the result for this topic, i.e. build the hierarchy and calculate relative importance of criteria.

f) Step 6: analysis of results from questionnaire and AHP will be the main topic at this stage. The author will try to interpret the model results, find the answers to the research questions of this paper.

g) Step 7: conclusions from research will be drawn, potential drawbacks of this paper will be addressed and further research recommendations will be given.

3.3 Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is developed by Thomas L. Saaty, which is designed to solve complex multicriteria decision problems combining quantitative with qualitative method together.

3.3.1 Introduction

The Analytic Hierarchy Process (AHP) is first developed by Thomas L. Saaty in the year of 1980 in his famous book *The Analytic Hierarchy Process: planning, priority setting, resource allocation*. Disappointed by other inaccurate models due to omission of key factors and simplifying assumptions, the author intended to establish a theory and method which could avoid these drawbacks and could be used for structured problems. As the author said in the book:

"…*We must stop making simplifying assumptions to suit our quantitative models and deal with complex situations as they are. To be realistic, our models must include and measure all important tangible and intangible, quantitatively measurable and qualitative factors….* " (Saaty, 1980)

An analytic hierarchy process is typically a set of hierarchies constructed and abstracted from the structures of a system, measured by pairwise comparisons to study the system's functions and components' impacts to system. The sections below will provide detail description of the AHP theory and its methodology.

In general, when human beings tend to make decisions, a series of factors will be considered. Figure 1-1 depicts how people make decisions typically. First a goal should be set up for decision making; then several alternatives are identified for selection. After that, criteria or priorities are addressed according to the goal, followed by resource allocation. Through these processes, one can build a system for decision making. Furthermore, performance of system should be measured in proper way, stability of the system should be guaranteed. One can also optimize the system and resolve conflicts arising from the system.

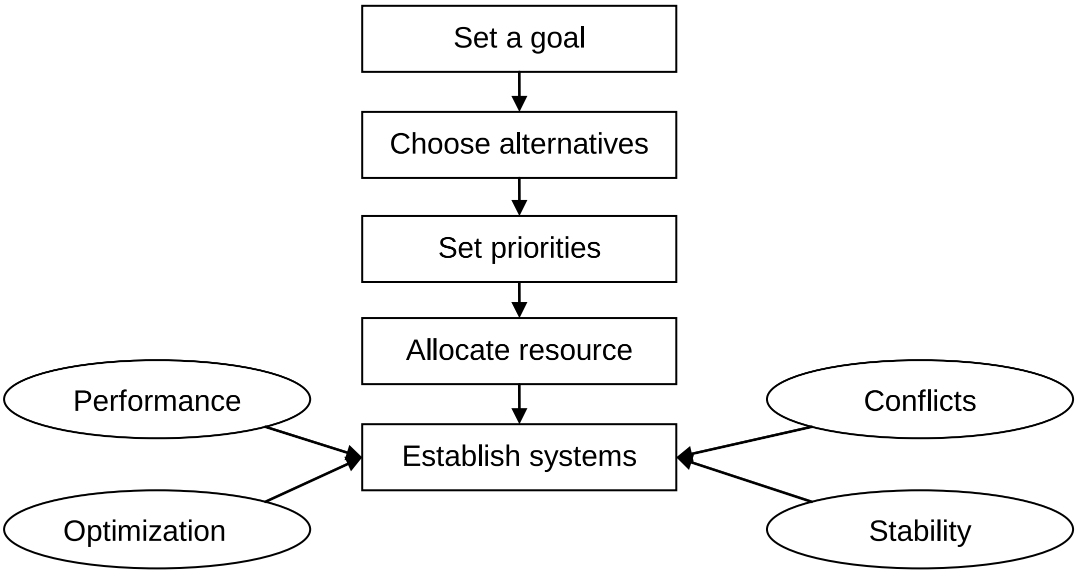

Figure 3-1 an illustration of how people make decisions
Source: compiled by author based on Saaty, (1980).

The establishment of an analytic hierarchy process is somewhat like the decision making process, which is proved to be very natural and is widely accepted by many people from various professional fields.

3.3.2 Hierarchies

As shows, a typical hierarchy structure has at least three layers. The first layer is the ultimate goal of a plan/problem needed to be solved, followed by sub objectives in the next layer. Constraints or criteria of the problem can be put in the next layer and the final layer is a series of decision alternatives or possible outcomes.

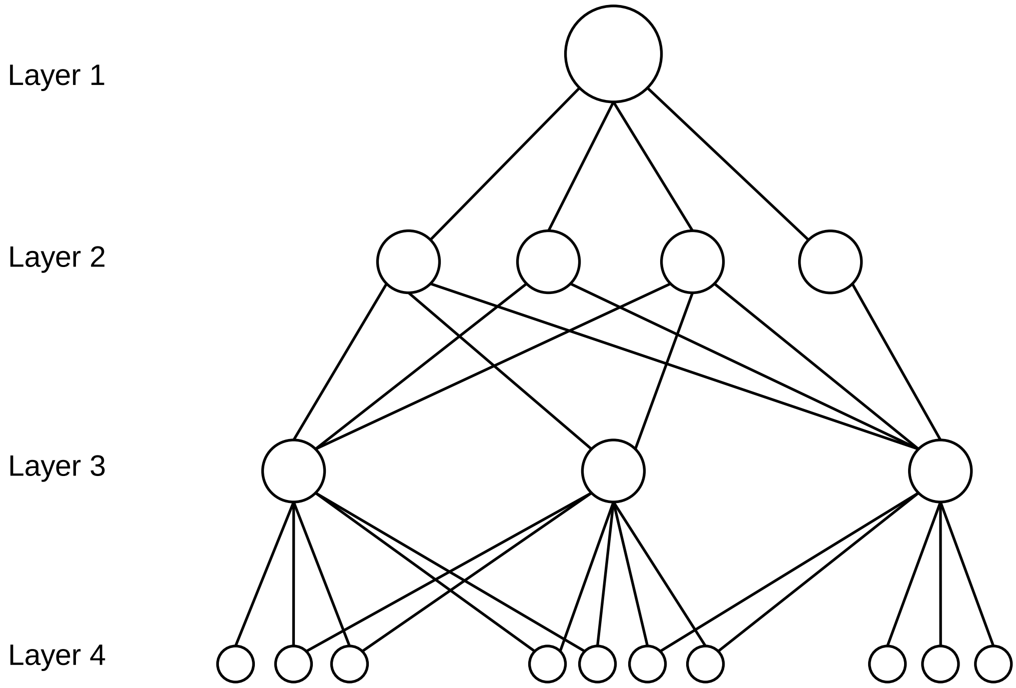

Figure 3-2 An example of hierarchies
Source: (Saaty, 1980).

In reality, the number of layers could be more than three and thus the hierarchical relations could be far more complex than the simple example. Each element in each layer is assumed to be independent. Through these layers, the process of decision making is broken into clusters and sub clusters just like what a human will do naturally (Saaty, 1980). In fact, the advantages of hierarchy are more than that. Through hierarchies, we can know it clearly how the changes in priorities in upper level affect priority changes in lower levels. Furthermore, detailed information could be provided in lower layers while overview of priorities could be given in higher layer by the model in terms of both structure and function. Last but not least, they are both stable and flexible. They are "*stable in that small changes have small effects and flexible in that additions to a well-structured hierarchy do not disrupt the performance*." (Satty, 1980)

3.3.3 Measurement

We cannot draw any conclusions on the hierarchies without any means of measurement. One suitable measurement for AHP is to compare each two elements in the same layer on their relative importance, which is the so called pairwise comparison. The problem after this is that how to measure the relative importance of each two elements. The answer to this question is to use scale comparisons.

Table 3-1 shows detail of scale comparisons. For example, when one considers that factor A is strongly important than factor B in a layer, he or she can remark 5 when comparing factor A to factor B. Or he/she may think that factor A is a bit more than strongly important than factor B but is also not very strongly important than factor B, then he/she can remark 6 for this comparison.

Table 3-1 Scale comparison

Intensity of importance	Definition
1	Equal importance
3	Weak importance
5	Essential or strong importance
7	Very strong or demonstrated importance
9	Absolute importance
2,4,6,8	Intermediate value between adjacent scale values

Source: (Saaty, 1980).

The scale comparison provides 9 degrees of comparison outcomes, which of course could be more specific and give more information to researchers. But it also could not be more than 9 degrees because of limits of cognitive capability of human beings which is beyond this paper's discussion.

3.3.4 Priorities

Priority or strength of each element in one hierarchy needs to be determined by pairwise comparisons and a series of calculation. This section deals with detailed method on priority calculation of each level.

Suppose that there are n elements in a specific level in AHP, which are element 1, 2,…,n, represented by $C_1, C_2, \cdots, C_n$. In order to determine priorities of elements in this layer, we need to compare all these n elements in pairs. To be more specific, first we use scale measurement to compare C_1 with $C_2, C_3, \cdots, C_n$, and then give a each comparison a scale number. If C_1 is less important than the compared element, i.e. C_3, then put reciprocal of outcome for comparison of C_3 with C_1. After all comparisons between C_1 and other elements are completed, then we compare C_2 with $C_3, C_4, \cdots, C_n$ and give importance degrees. In the end, we need to compare $n(n-1)$ times to finish all pairwise comparisons. Then we put outcomes into a square matrix.

Let a_{ij} be the comparison outcome of C_i comparing to C_j, then a comparison matrix can be drawn as follows. It is easy to recognize that $a_{ij} = 1/a_{ji}$ and $a_{ii} = 1$.

$$A = (a_{ij}), (i, j = 1,2, \cdots n)$$

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

Matrix A can also be expressed by using weight (absolute importance). Suppose w_i is the weight (absolute importance) of element C_i, then matrix A can also be expressed as follows, which is a square matrix, with its eigenvectors and corresponding eigenvalues. We need to find the eigenvector with the largest eigenvalue since this eigenvector is priority ordering of elements in the hierarchy.

$$A = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{bmatrix}$$

So,

$$w_i = \frac{w_i}{w_j} w_i = a_{ij} w_j, (i, j = 1,2, \cdots, n)$$

$$w_i = \frac{1}{n} \sum_{j=1}^{n} a_{ij} w_j \, , (i = 1,2, \cdots n)$$

Let λ_{max} be the largest eigenvalue of matrix A, then

$$w_i = \frac{1}{\lambda_{max}} \sum_{j=1}^{n} a_{ij} w_j \, , (i = 1,2, \cdots n)$$

3.3.5 Consistency

Consistency is a crucial problem for pairwise comparisons. When doing pairwise comparisons, if A is more important B, B is more importance than C, everyone knows that A is more important than C. In this situation there is no consistency problem. But if we consider another situation where a person gives 2 when A compares to B and 3 when B compares to C. Then we can deduce that when A is compared to C, the scale of importance should be 6 (2 times 3), but the person may give 5 or 7 when he simply only focus on comparison between A and C rather than precious comparison outcomes. Therefore, inconsistency occurs in this situation. Inconsistency is a violation of proportionality which may or may not entail violation of transitivity. (Saaty, 1980)

Saaty (1980) had an excellent remark on consistency problem. "*Our study consistency demonstrates that it is not whether we are inconsistent on particular comparisons that matters, but how strongly consistency is violated in the numerical sense for the overall problem under study*." (Saaty, 1980)

To measure consistency, we need to compare the largest eigenvalue λ_{max} to number of elements n. The closer λ_{max} is to n, the more consistent is the result (Saaty, 1980). A clearer indicator to consistency is the so called consistency index (C.I.) and consistency ratio (C.R.).

$$\mathrm{C.I.} = \frac{\lambda_{max} - n}{n - 1}$$

$$\mathrm{C.R.} = \frac{\mathrm{C.I.}}{\mathrm{R.I.}}$$

Where R.I. is random index, a modifier to C.I. to adjust the value of C.I. when n changes, R.I. changes accordingly.

Table 3-2 The value of R.I

n	3	4	5	6	7	8
R.I.	0.58	0.9	1.12	1.24	1.32	1.41
n	9	10	11	12	13	14
R.I.	1.45	1.49	1.51	1.48	1.56	1.57

Source: (Saaty, 1980).

If the value of C.R. is equal to or less than 0.10, then inconsistency could be deemed acceptable.

3.4 Apply AHP to Port Selection

3.4.1 Selection and Refinery of Criteria

According to the reviewed literature in Chapter 2, when choosing a port, these factors below are needed to be considered.

1. Geographical location
2. Water draft
3. Feeder connection
4. Inland intermodal/hinterland connection
5. Scope of hinterland

6. Port reputation
7. Port dues
8. Terminal handling charge (THC)
9. Handling speed/efficiency
10. Service reliability
11. Cargo volume
12. Transshipment cargo volume
13. Import and export cargo balance
14. Cargo profitability
15. Berth availability
16. IT ability
17. Convenience of customs process
18. Relationship between management and workers
19. Acceptance of special requirements
20. Easiness of communication with staff
21. Calling for competitors
22. Slot exchange with cooperation lines

These 22 factors almost cover all aspects of port selection problem; however, the author argues that these criteria are needed to be redefined to make it concise and efficient. The reasons for doing this are as follows. First, some factors are kind of overlapping more or less in terms of meaning and some factors are hard to measure and a bit ambiguous, i.e. cargo volume and transshipment cargo volume, relationship between management and workers. Second, considering responders' patience, it is not rational to leave too many factors in the questionnaire. Twenty two factors are more than enough that maybe bother responders and lead to absence of mind. Finally, the more factors are included in the questionnaire, the more pairwise comparisons need to be made. For instance, if the original number of factor is n, when one additional factor is included into the questionnaire, the additional number of pairwise comparison is $n\ (\frac{n(n+1)}{2} - \frac{n(n-1)}{2})$.

To make it concise, port dues and terminal handling charge can be seen as port cost, cargo volume and transshipment cargo volume can be deemed as cargo volume as a whole. Port reputation is hard to quantify and may be vague to responders according to preliminary interviews with professionals. Calling for competitors, import and export cargo balance and slot exchange are also ambiguous and not strongly relevant to this subject. Berth availability is part of port efficiency. As containerships become increasingly bigger, their draughts are increasing as well, the author also want to examine port water draft's influence on this issue, so water draft is also selected. After refinery, the author concluded eight criteria for port selection problem.

1. Geographical location

2. Water draft
3. Hinterland size
4. Feeder and intermodal connection
5. Cargo volumes
6. Port dues and terminal handling charges (THC)
7. Port efficiency and reliability
8. IT ability

3.4.2 Selection of decision alternatives

Figure 3-3 shows an overview of ports in the Hamburg – Le Havre range. There are more than 10 ports in this region. As we can see in Figure 3-3, port of Hamburg is located in the very north of HLH range, with port of Emden and Bremen located to the near south of it. Dutch ports and Belgium ports are located in the south and port of Le Havre is located in the very south of HLH range.

Figure 3-3 Ports in Hamburg - Le Havre range
Source: Compiled by author.

Table 3-3 illustrates top 6 container ports in HLH range in terms of container throughput measured in 1,000 TEU. Port of Rotterdam is the biggest port in HLH range with over 11 million TEU in the year of 2010, followed by port of Antwerp. Port of Hamburg and Bremenhaven, which are two Germany ports, ranked third and fourth. The last two ports are port of Zeebrugge and Le Havre.

Table 3-3 Top 6 container ports in Hamburg-Le Havre range (x 1,000 TEU)

	2008	2009	2010
Rotterdam	10,784	9,743	11,146
Antwerp	8,663	7,310	8,468
Hamburg	9,737	7,008	7,896
Bremen	5,529	4,565	4,888
Zeebrugge	2,210	2,328	2,500
La Havre	2,450	2,241	2,356

Source: Port Statistics, Port of Rotterdam 2010.

Since geographical location is a criterion of this research, ports in a relatively large geographical span is needed, otherwise if decision alternatives are too close, it may not make significant sense for decision makers when they are considering location differences, though it still needs research to confirm this. In order to test this opinion, the author first chooses the most southern and northern port in the HLH range, which are port of Le Havre and port Hamburg. To compare, the author also chooses port of Rotterdam and Antwerp since they are not far away to each other. The four ports come from four different places which covering all coastal countries in the HLH range. So at last there are four potential ports are chosen to be decision alternatives, which are port of Hamburg, Rotterdam, Antwerp and Le Havre.

3.4.3 Hierarchy Building

There are three hierarchies in this model, the first level is the goal, select a port. The second level is port selection criteria, and the lowest level is port selection alternatives, which are port of Rotterdam, Antwerp, Hamburg and Le Havre. Figure 3-4 is an illustration for the AHP model hierarchies for port selection criteria.

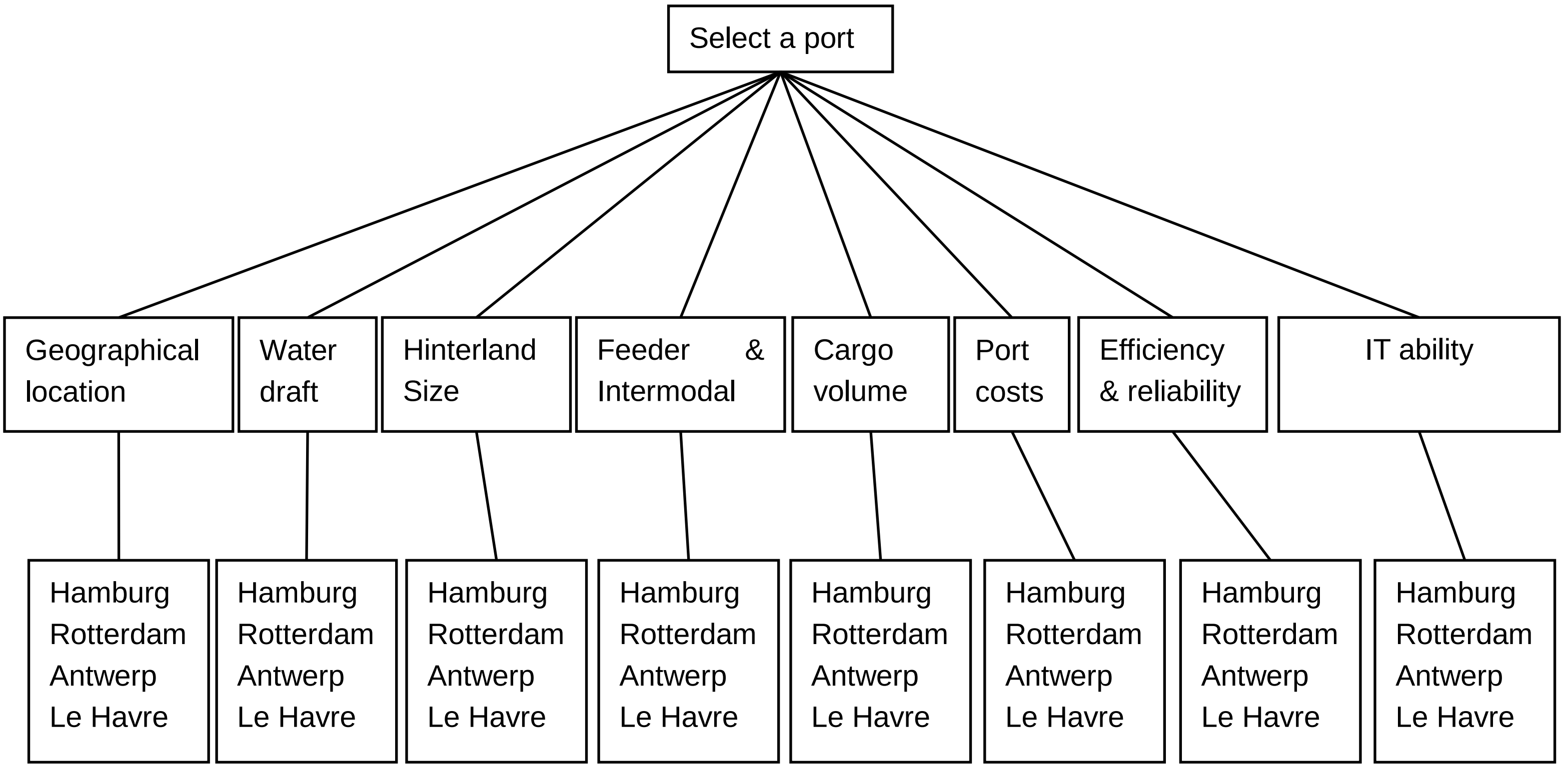

Figure 3-4 AHP for port selection
Source: Compiled by author

3.4.4 Questionnaire Design

In order to get priorities of every level, a questionnaire should be designed and distributed to target groups.

In the beginning of the questionnaire, a few preliminary questions and identifying questions will be asked. Since the target groups are mainly from liner shipping companies and port side, we are able to identify them with identifying questions. The questionnaires for the two groups will not be combined together and will be conducted AHP separately to see whether different point of view on port selection criteria exist or not.

After preliminary questions and identifying questions in the beginning of the questionnaire, the responders will be told the method of scale measurement and asked to make pairwise comparisons in a proper way to ensure that they are not easily become annoyed with too many comparisons. The sequence of these pairwise comparisons is as natural as what the hierarchies are, from higher level to lower level.

Our target responders are mainly from Maersk Line, CMG-CGM, Port of Rotterdam, Port of Amsterdam, and Port of Hamburg.

3.4.5 Model calculation

In the second level, the responders need to make 28 $(7 \times 8 \div 2 = 28)$ pairwise comparisons. The result is comparison matrix A.

$$A = \left(a_{ij}\right), (i, j = 1,2, \cdots ,8)$$

The author will use *Scilab*, a kind of scientific calculation software to calculate max eigenvalue, its eigenvector $W^1 = (W_1^1\ W_2^1\ \cdots\ W_8^1)^T$ and its C.R. value. W^1 is priority for criteria.

In the third level, responders are asked to make pairwise comparisons of four ports under each criterion. So the responders need to make 48 $(4 \times 3 \div 2 \times 8 = 48)$ pairwise comparisons totally in this layer. Similarly, the max eigenvalue and its eigenvector $W_n^2, (n = 1,2, \cdots ,8)$ are to be calculated, where W_n^2 is a column vector with four rows and one column. The C.R. values will also be checked in this layer for every criterion.

Then the matrix W^2 is defined as

$$W^2 = (W_1^2\ W_2^2\ \cdots W_8^2)$$

In which W^2 is a matrix with four rows and eight columns.

To get the overall priorities W,

$$W = W^2 \times W^1$$

In order to better interpret the priorities, each element in W will be normalized.

$$W'_i = \frac{W_i}{\sum W} \quad i = 1,2 \cdots n$$

3.5 Statistical Techniques to Analyze the Results

After drawing conclusions from each individual AHP processes, the author plan to put them together to apply statistical analysis on them. Statistical conclusions will be drawn from two or three basic statistical techniques such as mean, quartile, etc. Through this procedure, the author wants to find whether choice priorities are fully personal viewpoints or they can be shown some common trends.

3.6 Conclusion

This chapter focuses on research methodology design and modal application on port choice and selection criteria. The full range of research design has been shown with a series of analyzing techniques. Also, the author provides a deeper knowledge on the Analytic Hierarchy Process (AHP) method in terms of its history, theory and application.

Chapter 4. Empirical Findings

4.1 Introduction

It is also important to study empirical findings on this topic. In this chapter, empirical findings include data from company reports, database, other literature and other sources. The study will focus on two main parts, one is the ports located in the Asia-Europe route but mainly on the Europe side, the other one is shipping lines' efforts on integration into supply chain. Section 2 basically deals with empirical findings on the port side while section 3 focuses on shipping lines.

4.2 Empirical Findings on Ports

4.2.1 Container Throughput

A port's container throughput is the number of TEU or container for all productive moves made by container handling equipments in a certain period of time. According to this definition, if 1 TEU is transshipped in a port, then its throughput is 2 TEU.

Port of Rotterdam is the largest container port in Europe with highest container throughput in the year of 2008, 2009 and 2010. Port of Antwerp and Hamburg is second and third largest container port respectively in terms of container throughput in Europe. Le Havre, located in the south of Hamburg-Le Havre range, is on the top 5 container ports in Europe. Table 4-1 gives detail data on container throughput of four ports in the past three years and their throughput ranking in European ports. Figure 4-1 depicts these data in a more friendly way. As far as we can see in Figure 4-1, all the four ports experienced a downturn in 2009 because of economic crisis. Container throughputs in port of Hamburg and Antwerp are similar, but they all never recovered to the level before the crisis (the year of 2008). The curve for port of Le Havre is almost flat, which means that container throughput is nearly unchanged in the past three years. Port of Rotterdam's situation is not the same from other three ports. After a downturn in 2009, container throughput in Rotterdam rebounded strongly to the highest level that it ever experienced, in the year of 2010, more than 11 million TEU container cargo is handled in port of Rotterdam.

Table 4-1 Container Throughput of Four Ports

	2008	**2009**	**2010**	**Rank in EU**
Hamburg	9,737	7,008	7,896	3
Rotterdam	10,784	9,743	11,146	1
Antwerp	8,663	7,310	8,468	2
La Havre	2,450	2,241	2,356	7

Source: Port Statistics, Port of Rotterdam, 2010

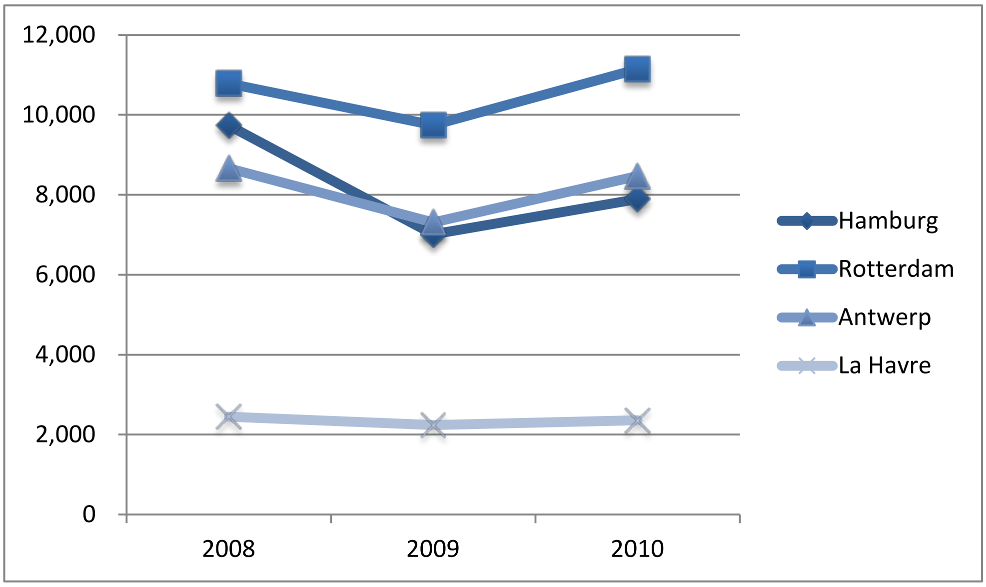

Figure 4-1 Container Throughput of Four Ports
Source: Port Statistics, Port of Rotterdam, 2010

4.2.2 Container Terminals and Port Infrastructure

Container terminal is a terminal where containerships call at port to handle containers. The conditions of container terminal strongly affect container handling speed. These conditions contain water draft, container handling equipments (RTG, RMG, trucks, etc.) container yard behind terminal and handling arrangement, etc. Figure 4-2 shows a typical container terminal system. The container terminal connects seaside and landside, export, import and transshipment containers are handled by cranes, trucks to their destinations. When a container terminal is involved into a supply chain, three typical kinds of logistics process may be realized.

- Import - containers are unloaded from ships and transported by rail, truck or barge to hinterland.
- Export – containers from hinterland transportation are loaded to containerships to next port.
- Transshipment – containers are unloaded and loaded to another ship to next seaport.

Container terminal as an important node in the supply chain within port area, its capacity and efficiency are key indicators to measure logistics efficiency. Terminal capacity is determined jointly by berth capacity, yard storage capacity, yard handling capacity and gate capacity (Saanen, 2011).

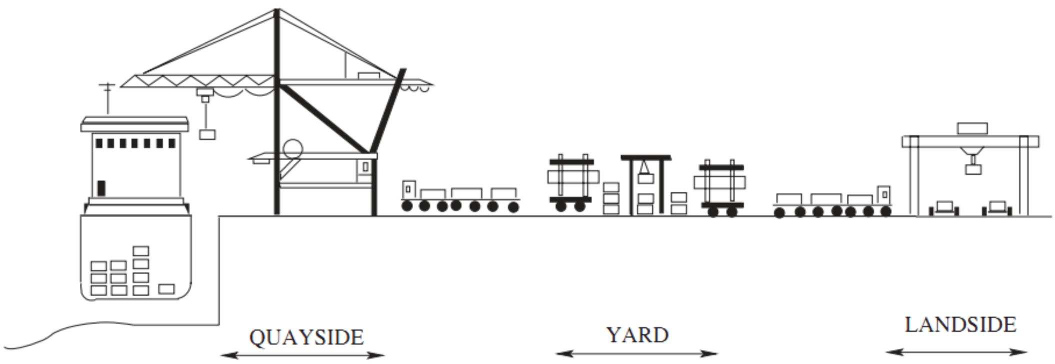

Figure 4-2 A Typical Container Terminal System
Source: (Monaco et al, 2009)

Table 4-2 Containers Terminals in thr Four Ports

Port	No. of container terminals	Total length (m)	Average length (m)	Max. draft (m)	Container throughput 2010 (x1000 TEU)
Hamburg	4	7,250	1,813	16.5	7,896
Rotterdam	3	11,650	3,883	21.6	11,146
Antwerp	16	18,345	1,147	18.1	8,468
Le Havre	23	6,921	301	15.2	2,356

Source: compiled by author based on portguide.com

Table 4-2 shows basic information of container terminals in the four ports. Port of Antwerp has the longest total berth length (18,345 m) but port of Rotterdam is the winner for average berth length (3,883 m) and maximum water draft (21.6 m). Port of Le Havre has shortest berth length, both in total and on average, and lowest water draft. It seems that there are some relationships between average berth lengths, max. water draft and yearly container throughput. Correlation study on these three items shows both strong positive correlations between average berth length and container throughput, max. water draft and container throughput as Table 4-3 shows below.

Table 4-3 Correlation Study

	Container throughput
Average length	0.867
Max. draft	0.882

Source: Compiled by author

4.2.3 Hinterland and intermodal connections

Most European ports struggle to become gateways to extensive inland networks (Notteboom, 2008). The Hamburg - Le Havre range is mainly between the

Rhine-Scheldt Delta and Helgoland Bay area. All the four ports (Hamburg, Rotterdam, Antwerp and Le Havre) have large scope of hinterland, which covers the whole Germany, Netherlands, Belgium, Southern Poland, Czech Republic, Hungary, Northern Italy, Southern France, part of United Kingdom and minor Madrid and its surroundings, etc. For instance, port of Rotterdam's hinterland covers a radius of 500 kilometers of Rotterdam. Container transport originated in port of Rotterdam could extend even to Greece. Port of Antwerp and Hamburg are the "must call" ports for many shipping lines (Notteboom, 2008).

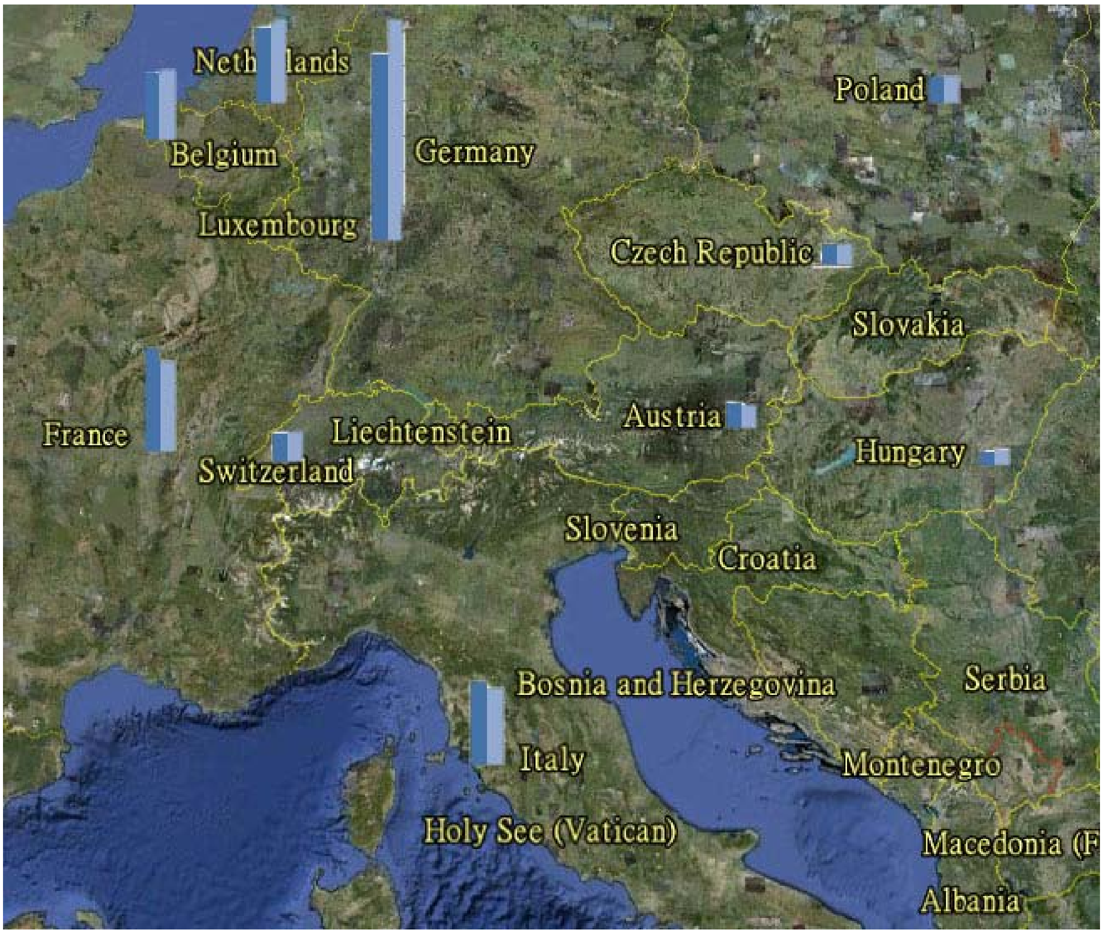

Figure 4-3 Major Hinterland for HLH Range and Total Trade (Import and Export) 2010
Source: compiled by author

The TEU trade in Hamburg – Le Havre range occupies over 40% of total EU27 TEU trade and still keeps increasing (Notteboom, 2008). Figure 4-3 shows the major hinterland of Hamburg – Le Havre range ports and scale of total import and export volume of hinterland countries. Trades in Northwest European countries are far more than those in other European regions compared to area of Hamburg – Le Havre range. This kind of cargo flow and trade imbalance happens because the dominant role of Hamburg – Le Havre range ports especially port of Hamburg, Rotterdam and

Antwerp.

The major means of intermodal transportation are rail, truck (road) and barge (inland waterways). As Table 4-4 and Figure 4-4 show, the major means of intermodal transport is road, especially in port of Le Havre, whose road transport dominates over eighty percent of total intermodal connections. Trucks are major tools for the door-to-door delivery and extension of logistics chain for short distance transportation.

Port of Rotterdam and Antwerp also strongly rely on barge transportation. As a cost-effective way of transport, waterways provide comparative advantages for ports. Port of Rotterdam is close to the “Great Rivers” Maas and Rhine, while port Antwerp is mainly close to the river of Scheldt.

Table 4-4 Port Modal Split 2010

	Hamburg	Rotterdam	Antwerp	Le Havre
Barge	2%	33.20%	33%	7.20%
Road	62%	55.90%	60%	86.80%
Rail	36%	10.90%	7%	6%

Source: Compiled by the author.

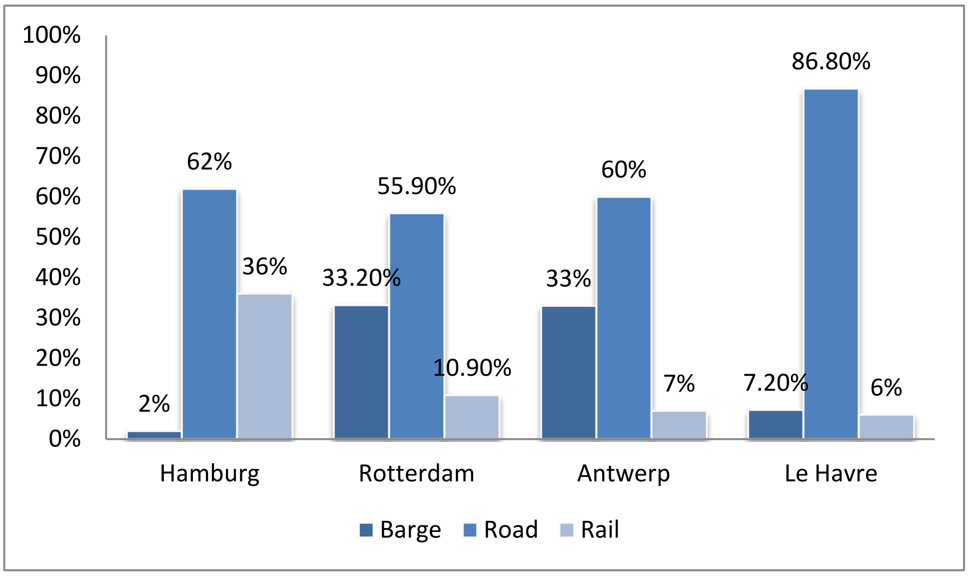

Figure 4-4 Port Modal Split 2010
Source: Compiled by the author.

Table 4-5 shows container transit time from four ports in Hamburg – Le Havre range, most of them could transport containers to area within 500 kilometers in less than 24 hours. This could be attributed to port’s intensive intermodal connection and infrastructure. Large hinterland, intensified intermodal connections and relatively short container transit time enable shipping lines to extend and optimize their logistics networks. Notteboom (2008) observed that even large flows of Italian cargo choose ports in Hamburg – Le Havre range rather than Italian ports. This means that cargo does not seek the shortest way to access to sea as Sargent concluded in 1938 (Garcia-Alonso & Sanchez-Soriano, 2009) but the logistics networks with lowest system costs.

Table 4-5 Container Transit Time from Ports

Port	Destination	Time (hrs)
Hamburg	Benelux, Germany	<12
	Other parts of Western Europe	<24
Rotterdam	Benelux, UK, Germany, France	<12
	Other parts of Western Europe	<24
Antwerp	Belgium	4-18
	Dutch	6-18
	Lower Rhine	18-24
	North of France	24-36
	Middle Rhine	22-24
	Upper Rhine	72
Le Havre	France, Belgium, UK	<12
	Other parts of Western Europe	<48

Source: Compiled by author.

4.3 Empirical findings about shipping lines

By August 2011, there are as many as 5,966 ships that provide liner services. Shippers are able to access 15,586,522 TEU through these ships. Among them, almost 97% of TEU capacity is operated by full cellular containerships (Alphaliner, 2011). Table 4-6 shows the top 30 world liner shipping companies in terms of TEU capacity (both existing and orderbook) and market share.

Table 4-6 Top 30 World Liner Shipping Companies

Rank	Operator	TEU	Share
1	APM-Maersk	2,426,188	15.60%
2	Mediterranean Shipping Co.	2,016,197	12.90%
3	CMA CGM Group	1,295,408	8.3%
4	COSCO Container L.	624,353	4.0%
5	Hapag-Lloyd	622,799	4.0%
6	Evergreen Line	614,115	3.9%
7	APL	580,658	3.7%
8	CSAV Group	525,483	3.4%
9	Hanjin Shipping	511,661	3.3%
10	CSCL	510,958	3.3%
11	MOL	420,821	2.7%
12	OOCL	415,638	2.7%
13	NYK Line	397,439	2.5%
14	Hamburg Süd Group	394,652	2.5%
15	K Line	342,763	2.2%
16	Yang Ming Marine Transport Corp.	336,328	2.2%
17	Zim	333,697	2.1%
18	Hyundai M.M.	316,108	2.0%
19	PIL (Pacific Int. Line)	265,919	1.7%
20	UASC	234,815	1.5%
21	Wan Hai Lines	171,423	1.1%
22	HDS Lines	88,744	0.6%
23	TS Lines	84,745	0.5%
24	X-Press Feeders Group	64,993	0.4%
25	MISC Berhad	63,709	0.4%
26	CCNI	60,957	0.4%
27	KMTC	52,271	0.3%
28	RCL (Regional Container L.)	50,447	0.3%
29	Matson	49,530	0.3%
30	Grand China Logistics	48,263	0.3%

Source: Alphaliner, 2011

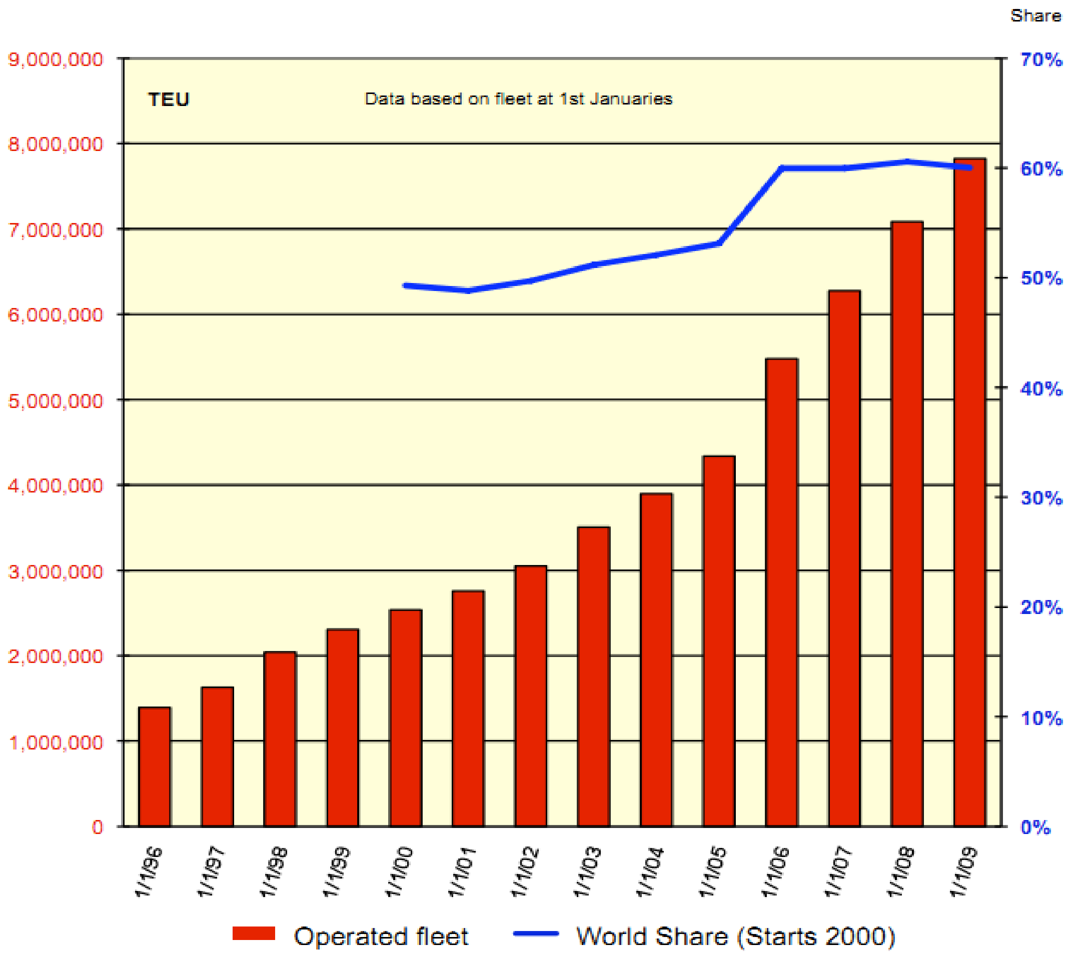

Figure 4-5 Top 10 Shipping Lines' TEU Capacity and Market Share
Source: Alphaliner, 2011

As Figure 4-5 depicts, the market share of top 10 liner shipping companies increased from 53% to nearly 60% between the year of 1996 to 2009. However, according to Table 4-6, the latest data shows that top 10 liner companies' market share is 62.4%, which demonstrates the trend that the liner market is increasingly concentrated in the last several years. In facts, by the year of 2011, the Concentration Ratio[1] for top 4 liner companies CR_4 is 40.8% and CR_{10} is 62.4%. This suggests that the liner shipping market is similar with a monopolistic competition market, and the concentration level is increasing slightly year by year. The scale of the biggest company, APM-Maersk, is over 50 times larger than the companies listed at the bottom of top 30 list.

[1] Concentration Ratio is a measurement of industry concentration level which is the sum of top n companies' market share. For example, CR_4 is total market share of top 4 companies in the industry.

4.4 Conclusion

This chapter is mainly about empirical findings about relevant parties in port selection process. From the port side, findings are mainly about port of Hamburg, Rotterdam, Antwerp and Le Havre. Container throughput, port infrastructure, hinterland economies and intermodal connections are discussed. As the shipping lines, empirical findings of liner market as well as liner shipping companies are discussed by the author from various sources.

Chapter 5. Research Results

5.1 Introduction

In this chapter, the author proposed to analyze the raw data obtained from questionnaires. By putting them into AHP model, three categories of results can be achieved. The first one is priorities of eight port selection criteria, which is drawn from the second hierarchy of the AHP model. The second group of results is priorities of the four ports (port of Hamburg, Rotterdam, Antwerp and Le Havre) under each of the eight criteria, which is the result of the third hierarchy. The last one is the overall priorities or the final result of port selection problem. This result is achieved jointly from the second and third hierarchies by using the method mentioned in chapter 3.

The data and model are first run in Scilab, which is a scientific calculating software and then run in GNU R, which is a statistical software for double check. The source code for one of the respondents will be provided in the appendices.

This chapter is organized in the following way. Section two presents and analyzes research results, and section three demonstrates implications drawn from section two for port competition practices and strategies.

5.2 Research Result Presentation and Interpretation

The author distributed the questionnaire shown in the appendix mainly to liner shipping companies like Maersk Line, CMA CGM, COSCO, China Shipping Inc. etc. All these companies own their business between Northwest Europe and Far East. It was frustrated that due to the summer vacations, the number of response are a bit less satisfactory than the author expected. But the respondents are located in a wide range of geographical area ranging from North Europe to Far East, from Rotterdam (Netherlands) to Ningbo (China). The author received 11 effective responses from those target companies eventually, and the response rate is 44%, which is not high but still feasible to continue this research. Yet for previous research using AHP as main methodology, the number of respondents could be as small as Yan Xiong (2007)'s, who received 5 results from respondents but still feasible; or as large as Ugboma et al (2006)'s, who received 190 returns. Eleven respondents are not a large number, but can be treated as available and significant enough for research.

5.2.1 Inconsistency Resolution

Before presenting the results, it is necessary to explain the high inconsistency appeared in few questionnaire respondents and how the author resolve this problem. For example, when making pairwise comparisons, few respondents acted like what

Table 5-1 shows. The question is that if port of Hamburg is 9 degree more important than port of Antwerp, then it is irrational that port of Antwerp is also 4 degree more important than port of Hamburg. This scenario brought so high inconsistency (the CR value was even higher than 0.5) to the AHP method that research could not continue with this kind of comparison results.

Table 5-1 An Example of High Inconsistency

	Hamburg	Rotterdam	Antwerp	Le Havre
Hamburg	1	3	9	7
Rotterdam	3	1	8	3
Antwerp	4	5	1	6
Le Havre	6	8	5	1

Source: Compiled by the author from questionnaire results.

In order to resolve this problem, the author returned to the original respondents to ask them,

1. First identify the least important criterion/port, then make numerical comparisons between other factors/ports and the least important criterion/port. The numerical rating standards are the same with the standards used in original pairwise comparisons. For example, as Table 5-2 shows, if one respondent considers that port of Hamburg ranks last among the four ports, he is expected to compare other ports to port of Hamburg, which means that the first column is needed to be filled in first.

Table 5-2 An Example of Inconsistency Resolution, Step 1

	Hamburg	Rotterdam	Antwerp	Le Havre
Hamburg	1			
Rotterdam	3	1		
Antwerp	5		1	
Le Havre	7			1

Source: Compiled by the author.

2. After the first set of comparisons is finished, the respondents are asked to identify the least important factor/port among the more important factors/ports in step 1. Then the numerical comparisons could be conducted in the same way. If there are n factors, the respondents need to do n-1 sets of comparisons to modify the high inconsistent matrix. Table 5-3 continues to show the example, if the respondent thinks port of Rotterdam is the second least important port, and then he needs to compare port of Antwerp and Le Havre to Rotterdam. There is also one point that the respondent need to pay attention to. According to the first column, port of Le Havre is more important than Antwerp, and then in the second column, the numerical rating of Le Havre also should be higher than Antwerp. All these keep inconsistency at a low level.

Table 5-3 An Example of Inconsistency Resolution, Step 2

	Hamburg	Rotterdam	Antwerp	Le Havre
Hamburg	1			
Rotterdam	3	1		
Antwerp	5	3	1	
Le Havre	7	5		1

Source: Compiled by the author.

3. After all the comparisons are done, it is the author's responsibility to fill the in blank cells with the inverse number of the inverse comparison. If Rotterdam-Hamburg is 3, then Hamburg-Rotterdam should be 1/3. Table 5-4 demonstrates the final pattern of modified comparisons. Consistency check shows its CR value is 0.07, which could be considered available for further research.

Table 5-4 An Example of Inconsistency Resolution, Step 3

	Hamburg	Rotterdam	Antwerp	Le Havre
Hamburg	1	1/3	1/5	1/7
Rotterdam	3	1	1/3	1/5
Antwerp	5	3	1	1/3

Le Havre	7	5	3	1

Source: Compiled by the author.

In this way, all the comparisons that were considered unfeasible are corrected then; consistency check confirmed that they are all available after the modifications.

5.2.2 AHP Results Presentation

Eigenvalue and eigenvectors are calculated for each comparison matrix. Eigenvector with the largest eigenvalue is chosen to be the factors priorities for its comparison result. These results are shown in the following Table 5-5 and Table 5-6.

As we can see it in Table 5-5, most Consistency Ratios (CR) of all comparison results from respondents are low (even less than 0.05) and only one group's consistency ratio is 0.1, which is large but still can be considered as effective answers. As for Consistency Ratio of selection alternatives shown in Table 5-6, there are 9 (highlighted) out of 88 groups that whose CR values are slightly higher than 0.1, the maximum available value of inconsistency.

Table 5-5 Priorities for Port Selection Criteria

Criteria	Res1	Res2	Res3	Res4	Res5	Res6	Res7	Res8	Res9	Res10	Res11
Location	0.4978	0.6262	0.3862	0.4792	1.0000	0.3452	0.3268	0.6280	-0.2381	-0.1949	-0.7505
Draft	0.2038	0.2938	0.1637	0.1897	0.3333	0.1413	0.1471	0.0664	-0.1607	-0.1278	-0.0781
Hinterland	0.4702	0.2938	0.1637	0.4792	0.3333	0.3452	0.6409	0.2975	-0.7158	-0.7168	-0.3408
Intermodal	0.4132	0.6262	0.1637	0.4792	0.3333	0.7682	0.6409	0.2975	-0.5050	-0.4824	-0.3890
Cargo volume	0.1151	0.1355	0.7832	0.0889	0.2000	0.0913	0.1471	0.1451	-0.0506	-0.3065	-0.0781
Port charges	0.0403	0.0409	0.0441	0.0394	0.1111	0.0636	0.0411	0.0664	-0.1188	-0.0861	-0.0447
Efficiency	0.4978	0.1355	0.3862	0.4792	1.0000	0.3452	0.1471	0.6280	-0.3491	-0.3065	-0.3604
IT	0.2369	0.0694	0.0771	0.1897	0.3333	0.1413	0.0708	0.0664	-0.1077	-0.0610	-0.1587
CR	0.03	0.03	0.03	0.02	0.02	0.02	0.03	0.02	0.10	0.02	0.04

Source: Compiled by the author

Table 5-6 Priorities for Alternatives and Final Results

	Ports	Res1	Res2	Res3	Res4	Res5	Res6	Res7	Res8	Res9	Res10	Res11
Location	Hamburg	0.2858	0.2630	0.8110	0.3605	0.6649	0.7766	0.2313	0.4034	0.3919	(0.1137)	0.1222
	Rotterdam	0.6762	0.9170	0.5124	0.6567	0.6922	0.2243	0.8955	0.8233	0.8773	(0.8830)	0.5364
	Antwerp	0.6762	0.1440	0.1479	0.6567	0.1102	0.4163	0.3754	0.3696	0.2323	(0.2875)	0.2606
	Le Havre	0.0618	0.2630	0.2404	0.0861	0.2581	0.4163	0.0607	0.1514	0.1510	(0.3531)	0.7934
	CR	0.05	0.20	0.04	0.01	0.02	0.01	0.09	0.04	0.05	0.13	0.06
Draft	Hamburg	0.1179	0.3038	0.2505	0.4163	0.3282	0.2243	0.5300	0.3337	0.2484	(0.3089)	(0.1302)
	Rotterdam	0.6768	0.8898	0.8099	0.7766	0.8658	0.4163	0.8244	0.2103	0.1620	(0.7823)	(0.8233)
	Antwerp	0.2645	0.3038	0.4674	0.4163	0.3579	0.7766	0.0858	0.9099	0.5287	(0.5211)	(0.5115)
	Le Havre	0.6768	0.1536	0.2505	0.2243	0.1210	0.4163	0.1790	0.1286	0.7953	(0.1448)	(0.2089)
	CR	0.02	0.14	0.01	0.01	0.04	0.01	0.06	0.06	0.05	0.03	0.03
Hinterland	Hamburg	0.2603	0.2219	0.8841	0.8366	0.9270	0.3487	0.4380	0.1836	0.5031	(0.5599)	(0.6958)
	Rotterdam	0.6811	0.8807	0.2406	0.4677	0.3285	0.2013	0.8673	0.3982	0.8200	(0.7585)	(0.6203)
	Antwerp	0.6811	0.2219	0.1350	0.2734	0.0779	0.6473	0.2282	0.1296	0.2230	(0.2886)	(0.1942)
	Le Havre	0.0671	0.3547	0.3771	0.0812	0.1632	0.6473	0.0615	0.8893	0.1571	(0.1670)	(0.3055)
	CR	0.02	0.07	0.08	0.06	0.14	0.01	0.12	0.06	0.05	0.07	0.03
Intermodal	Hamburg	0.5439	0.1859	0.8705	0.2875	0.4290	0.8126	(0.5090)	(0.8072)	(0.8763)	(0.4246)	0.8020
	Rotterdam	0.5898	0.8986	0.4193	0.8830	0.7788	0.4887	(0.8036)	(0.4785)	(0.4170)	(0.8556)	0.5098
	Antwerp	0.5898	0.2810	0.1221	0.3531	0.4290	0.2920	(0.2854)	(0.3110)	(0.1335)	(0.2852)	0.2714
	Le Havre	0.0920	0.2810	0.2269	0.1137	0.1591	0.1252	(0.1169)	(0.1506)	(0.2011)	(0.0796)	0.1522
	CR	0.01	0.07	0.11	0.13	0.01	0.03	0.03	0.05	0.06	0.08	0.03

Cargo volume	Hamburg	(0.5735)	0.1859	0.8720	0.7970	0.7953	0.2167	0.5411	(0.3017)	(0.4738)	0.3487	0.8066
	Rotterdam	(0.5735)	0.8986	0.3337	0.5409	0.5287	0.6879	0.8153	(0.5033)	(0.8418)	0.6473	0.5162
	Antwerp	(0.5735)	0.2810	0.1304	0.1051	0.1620	0.6879	0.1914	(0.7979)	(0.2245)	0.6473	0.2712
	Le Havre	(0.1147)	0.2810	0.3337	0.2472	0.2484	0.0812	0.0765	(0.1379)	(0.1287)	0.2013	0.0967
	CR	0	0.07	0.02	0.05	0.05	0.05	0.09	0.05	0.06	0.01	0.23
Port charges	Hamburg	0.5000	0.2440	0.6203	0.4887	0.5689	0.5000	0.5000	0.4082	0.5573	0.5000	0.6325
	Rotterdam	0.5000	0.8298	0.3055	0.5911	0.5689	0.5000	0.5000	0.5774	0.7701	0.5000	0.6325
	Antwerp	0.5000	0.3549	0.1942	0.4159	0.3441	0.5000	0.5000	0.4082	0.1693	0.5000	0.3162
	Le Havre	0.5000	0.3549	0.6958	0.4887	0.4841	0.5000	0.5000	0.5774	0.2601	0.5000	0.3162
	CR	0	0.09	0.03	0.03	0.03	0.00	0.04	0.07	0.00	0.04	0.00
Efficiency	Hamburg	0.4622	0.1859	0.4121	0.8934	0.8608	0.6508	(0.6328)	0.2973	0.8904	(0.3128)	(0.3453)
	Rotterdam	0.2413	0.8986	0.8880	0.3142	0.3540	0.6508	(0.7233)	0.5790	0.4133	(0.8984)	(0.8685)
	Antwerp	0.8508	0.2810	0.1847	0.2960	0.3540	0.3621	(0.2468)	0.7358	0.1650	(0.2944)	(0.3453)
	Le Havre	0.0657	0.2810	0.0869	0.1242	0.0918	0.1477	(0.1243)	0.1867	0.0953	(0.0913)	(0.0853)
	CR	0.13	0.07	0.07	0.04	0.06	0.01	0.06	0.08	0.04	0.04	0.04
IT	Hamburg	0.5000	0.5000	0.6325	0.5689	0.2774	0.5547	0.8581	0.5689	0.4135	(0.6473)	0.8099
	Rotterdam	0.5000	0.5000	0.6325	0.4841	0.5547	0.5547	0.4136	0.3441	0.8228	(0.6473)	0.4674
	Antwerp	0.5000	0.5000	0.3162	0.5689	0.5547	0.2774	0.2609	0.5689	0.3524	(0.3487)	0.2505
	Le Havre	0.5000	0.5000	0.3162	0.3441	0.5547	0.5547	0.1564	0.4841	0.1669	(0.2013)	0.2505
	CR	0	0.00	0.00	0.03	0.00	0.00	0.05	0.03	0.10	0.01	0.01
Final priorities	Hamburg	0.8161	0.5306	1.5597	1.5597	2.4018	1.3991	0.1760	0.2978	(0.4484)	0.6533	0.1144
	Rotterdam	1.2312	1.9692	1.1050	1.1050	2.0577	0.9788	0.5181	0.8589	(0.8930)	1.3020	0.0704
	Antwerp	1.4506	0.5459	0.3821	0.3821	1.0080	0.9600	0.1296	0.6498	(0.3368)	0.3372	0.0662
	Le Havre	0.3964	0.6154	0.5827	0.5827	0.7859	0.6907	0.0352	0.4912	(0.2503)	0.1810	0.2567

As far as we can see that some of the criteria or decision alternatives' priorities, in other words, their eigenvectors are negative and they are difficult to interpret although all the final priorities are positive numbers. In order to tackle this problem, the author proposes to normalize all the priorities. After normalizations, the values of priorities are resized into numbers between 0 and 1. This process makes it easier and much more straightforward to interpret and compare results both from vertical and horizontal perspectives.

$$W'_i = \frac{W_i}{\sum W} \quad i = 1,2 \cdots n$$

The normalization results are demonstrated in the following Table 5-7 and Table 5-8. In order to better depict the normalization results, the author uses box plots shown in from Figure 5-1 till Figure 5-10 to make the results more straightforward. These box plots present 0, 25%, 75% and 100% quartile of normalization results respectively without excluding the outliers. The reason for not excluding the outliers is that the questionnaires and pairwise comparisons are reflections of particular liner shipping companies' own point of view and tastes; different companies may have different view on the same problem due to their own business backgrounds and experiences, etc.

It is interesting but not surprising that all the respondents agree with the argument that we are living in an era that logistics, especially global logistics plays a more important role in cargo transportation, industry processes and even our daily lives. Furthermore, they all agree that when it comes to liner shipping who involves in logistics chains, port selection criteria will certainly change to some extent when liner companies adjust their strategies and roles towards increasingly intensified logistics integration processes. In the next a few paragraphs, the author will dedicate his efforts in explaining what the changes on earth are.

Table 5-7 Normalized Priorities for Port Selection Criteria

Criteria	Res1	Res2	Res3	Res4	Res5	Res6	Res7	Res8	Res9	Res10	Res11	Mean
Location	0.2011	0.2819	0.1781	0.1976	0.2744	0.1540	0.1512	0.2860	0.1060	0.0854	0.3411	0.2052
Intermodal	0.1669	0.2819	0.0755	0.1976	0.0915	0.3427	0.2965	0.1355	0.2249	0.2114	0.1768	0.2001
Hinterland	0.1900	0.1323	0.0755	0.1976	0.0915	0.1540	0.2965	0.1355	0.3187	0.3141	0.1549	0.1873
Efficiency	0.2011	0.0610	0.1781	0.1976	0.2744	0.1540	0.0681	0.2860	0.1554	0.1343	0.1638	0.1704
Cargo volume	0.0465	0.0610	0.3613	0.0367	0.0549	0.0408	0.0681	0.0661	0.0225	0.1343	0.0355	0.0843
Draft	0.0823	0.1323	0.0755	0.0782	0.0915	0.0630	0.0681	0.0303	0.0716	0.0560	0.0355	0.0713
IT	0.0957	0.0312	0.0356	0.0782	0.0915	0.0630	0.0328	0.0303	0.0479	0.0267	0.0721	0.0550
Port charges	0.0163	0.0184	0.0203	0.0163	0.0305	0.0284	0.0190	0.0303	0.0529	0.0377	0.0203	0.0264

Source: Compiled by author.

Table 5-8 Normalized Priorities for Alternatives and Final Results

	Ports	Res1	Res2	Res3	Res4	Res5	Res6	Res7	Res8	Res9	Res10	Res11
Location	Hamburg	0.1681	0.1657	0.4738	0.2048	0.3854	0.4236	0.1480	0.2308	0.2372	0.0695	0.0713
	Rotterdam	0.3977	0.5778	0.2994	0.3731	0.4012	0.1223	0.5730	0.4711	0.5309	0.5393	0.3132
	Antwerp	0.3977	0.0907	0.0864	0.3731	0.0639	0.2270	0.2402	0.2115	0.1406	0.1756	0.1522
	Le Havre	0.0364	0.1657	0.1405	0.0489	0.1496	0.2270	0.0388	0.0866	0.0914	0.2156	0.4633
Draft	Hamburg	0.0679	0.1840	0.1409	0.2270	0.1962	0.1223	0.3273	0.2109	0.2407	0.1758	0.0778
	Rotterdam	0.3899	0.5389	0.4554	0.4236	0.5176	0.2270	0.5092	0.1329	0.1517	0.4452	0.4918
	Antwerp	0.1524	0.1840	0.2628	0.2270	0.2139	0.4236	0.0530	0.5750	0.6563	0.2966	0.3056
	Le Havre	0.3899	0.0930	0.1409	0.1223	0.0723	0.2270	0.1105	0.0813	0.0927	0.0824	0.1248
Hinterland	Hamburg	0.1541	0.1321	0.5402	0.5043	0.6194	0.1891	0.2746	0.1147	0.2954	0.3156	0.3832
	Rotterdam	0.4031	0.5245	0.1470	0.2819	0.2195	0.1091	0.5438	0.2488	0.4814	0.4276	0.3416
	Antwerp	0.4031	0.1321	0.0825	0.1648	0.0521	0.3509	0.1431	0.0810	0.1309	0.1627	0.1069
	Le Havre	0.0397	0.2112	0.2304	0.0490	0.1090	0.3509	0.0385	0.5556	0.0923	0.0941	0.1682
Intermodal	Hamburg	0.2996	0.1129	0.5312	0.1756	0.2389	0.4729	0.2968	0.4620	0.5383	0.2581	0.4621
	Rotterdam	0.3249	0.5457	0.2559	0.5393	0.4337	0.2844	0.4686	0.2739	0.2562	0.5201	0.2938
	Antwerp	0.3249	0.1707	0.0745	0.2156	0.2389	0.1699	0.1664	0.1780	0.0820	0.1734	0.1564
	Le Havre	0.0507	0.1707	0.1385	0.0695	0.0886	0.0729	0.0682	0.0862	0.1236	0.0484	0.0877

Cargo volumes	Hamburg	0.3125	0.1129	0.5222	0.4715	0.4586	0.1295	0.3331	0.1733	0.2839	0.1891	0.4771
	Rotterdam	0.3125	0.5457	0.1998	0.3200	0.3048	0.4110	0.5019	0.2891	0.5044	0.3509	0.3053
	Antwerp	0.3125	0.1707	0.0781	0.0622	0.0934	0.4110	0.1178	0.4583	0.1345	0.3509	0.1604
	Le Havre	0.0625	0.1707	0.1998	0.1463	0.1432	0.0485	0.0471	0.0792	0.0771	0.1091	0.0572
Port charges	Hamburg	0.2500	0.1368	0.3416	0.2463	0.2894	0.2500	0.2500	0.2071	0.3172	0.2500	0.3333
	Rotterdam	0.2500	0.4652	0.1682	0.2979	0.2894	0.2500	0.2500	0.2929	0.4383	0.2500	0.3333
	Antwerp	0.2500	0.1990	0.1069	0.2096	0.1750	0.2500	0.2500	0.2071	0.0964	0.2500	0.1667
	Le Havre	0.2500	0.1990	0.3832	0.2463	0.2463	0.2500	0.2500	0.2929	0.1481	0.2500	0.1667
Efficiency	Hamburg	0.2853	0.1129	0.2622	0.5488	0.5184	0.3593	0.3664	0.1653	0.5693	0.1959	0.2100
	Rotterdam	0.1490	0.5457	0.5650	0.1930	0.2132	0.3593	0.4188	0.3219	0.2643	0.5626	0.5281
	Antwerp	0.5252	0.1707	0.1175	0.1818	0.2132	0.1999	0.1429	0.4091	0.1055	0.1843	0.2100
	Le Havre	0.0406	0.1707	0.0553	0.0763	0.0553	0.0815	0.0720	0.1038	0.0609	0.0572	0.0519
IT	Hamburg	0.2500	0.2500	0.3333	0.2894	0.1429	0.2857	0.5080	0.2894	0.2355	0.3509	0.4554
	Rotterdam	0.2500	0.2500	0.3333	0.2463	0.2857	0.2857	0.2449	0.1750	0.4687	0.3509	0.2628
	Antwerp	0.2500	0.2500	0.1667	0.2894	0.2857	0.1429	0.1545	0.2894	0.2007	0.1891	0.1409
	Le Havre	0.2500	0.2500	0.1667	0.1750	0.2857	0.2857	0.0926	0.2463	0.0951	0.1091	0.1409
Final results	Hamburg	0.2096	0.1449	0.4297	0.3411	0.3841	0.3473	0.2049	0.1296	0.2325	0.2641	0.2253
	Rotterdam	0.3162	0.5379	0.3044	0.3427	0.3291	0.2430	0.6033	0.3738	0.4631	0.5264	0.1387
	Antwerp	0.3725	0.1491	0.1053	0.2335	0.1612	0.2383	0.1508	0.2828	0.1746	0.1363	0.1304
	Le Havre	0.1018	0.1681	0.1605	0.0827	0.1257	0.1715	0.0410	0.2138	0.1298	0.0732	0.5057

Source: Compiled by author

5.2.3 Interpretation of Priorities for Port Selection Criteria

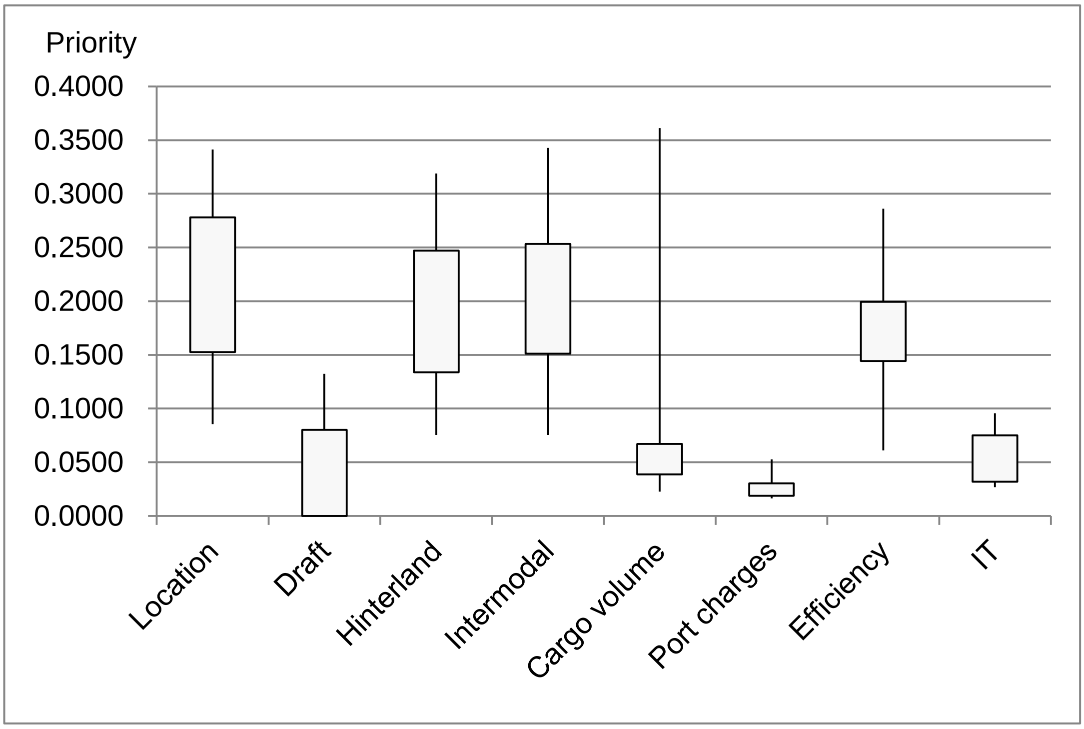

Figure 5-1 Box Plot for Criteria Priorities
Source: compiled by author.

Figure 5-1 shows the box plot of normalized priorities of port selection criteria. The result shows that port location ranks the highest (average 0.2052) priority among those criteria, closely followed by feeder and intermodal connections, with a normalized mean priority of 0.2001. Port's hinterland is the last one of the top three most important selection criteria with an average score of 0.1873. Cargo handling efficiency is slightly lower than hinterland, whose mean priority is 0.1704. Cargo volume ranks fifth among these criteria with an average priority of 0.0843. Box plot shows that though cargo volume is less important than the four factors above mentioned, but it is much more dynamic to influence shipping companies' port choice. The three least important criteria are port/terminal draft, IT ability and port charges. They are all considered of priorities around 0.05. Among the three, port draft is the most dynamic one while port charge (port dues and terminal handling charges, THC) is the least dynamic. The reason for that will be discussed in the following paragraphs.

The result shows that port location is the most important factor to consider when a company selects a port from a liner shipping company's perspective. Of course when shipping companies choose port of call, the location of port is one of the key decisive factors to think over. It could be ridiculous and uneconomic that a liner company unloads its cargo in port of Le Havre but the cargo is expected to arrive at Denmark eventually. The location of a port determines how far the cargo can find its way to access to sea from a logistics supplier or how far can the cargo to be delivered from seaside to its final destination. The meaning of port location to a liner shipping company is not just a geographical coordinate which helps the company find shortest or most economic way to the destination but could be deemed as a node of importance, often also of strategy, with better logistic convenience.

5.2.4 Interpretation of Priorities for Port Location

Figure 5-2 depicts normalized priorities for port location among port of Hamburg, Rotterdam, Antwerp and Le Havre. Port of Rotterdam ranks the mostly considered port in terms of location, half of its scores lie between 0.35 and 0.53. Hamburg is the second mostly considered port, with half of its scores are between 0.2 and 0.3. Antwerp and Le Havre is much similar compare to Rotterdam and Hamburg. The differences are that Antwerp is a litter more important than Le Havre overall, but scores for Le Havre (from less than 0.05 to more than 0.45) lie broader range than Antwerp does (from a bit more than 0.05 to less than 0.4). The broader range for Le Havre makes it clear that the location of this port is important for the company's business than any other alternatives. Despite this particular situation, Rotterdam and Hamburg are the two ports of geographical importance for liner companies in the Northwest Europe – Far East shipping route.

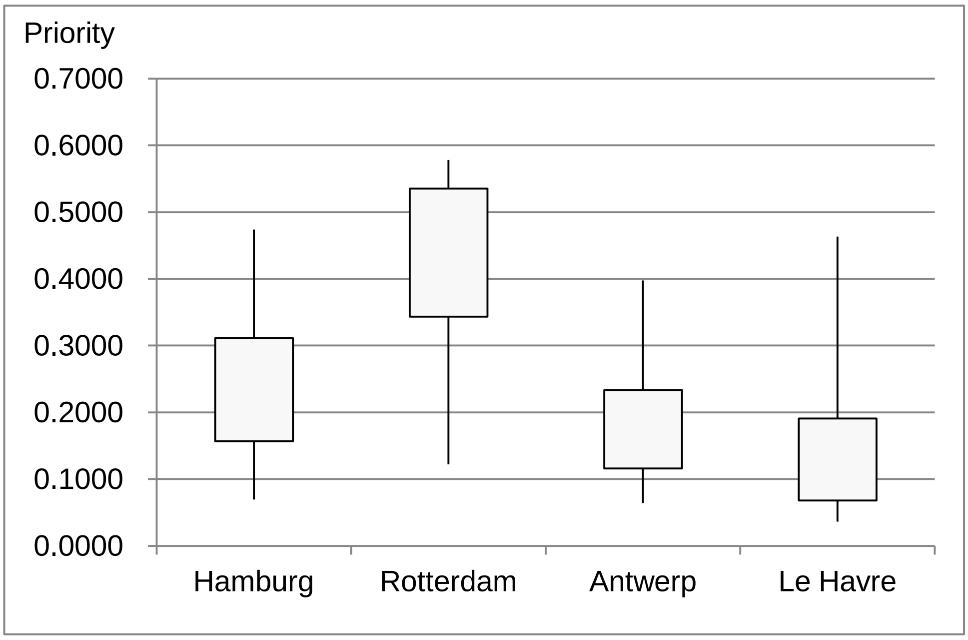

Figure 5-2 Box Plot for Port Priorities under Location
Source: compiled by author.

5.2.5 Interpretation of Priorities for Feeder Services and Intermodal Connections

As for the second important criterion, feeder and intermodal connections, liner shipping companies now consider it almost equally important compared to port location. This is obvious evidence that shipping lines concern logistics more than before. Figure 5-3 shows alternatives' priorities in terms of this criterion. Port Rotterdam and Hamburg are the top two ports to be considered as ports of call. Antwerp and Le Havre are the last two. This conclusion is also in favor of empirical findings that good feeder and intermodal network and fast transit time could attract more cargo and ships. One interesting point is that, in the Benelux region, port of Rotterdam and Antwerp are geographically close but the gap between their priorities seem to be bigger than their actual distance. Apart from port reputation, shipping lines tend to consider more on other criteria when the two ports are close. If the company takes feeder and intermodal connections into consideration, Rotterdam is a better choice than Antwerp. For instance, the construction of Maasvlakte 2 in the Mass River Delta intensifies feeder connections for Rotterdam and strengths its role as a major European logistics hub.

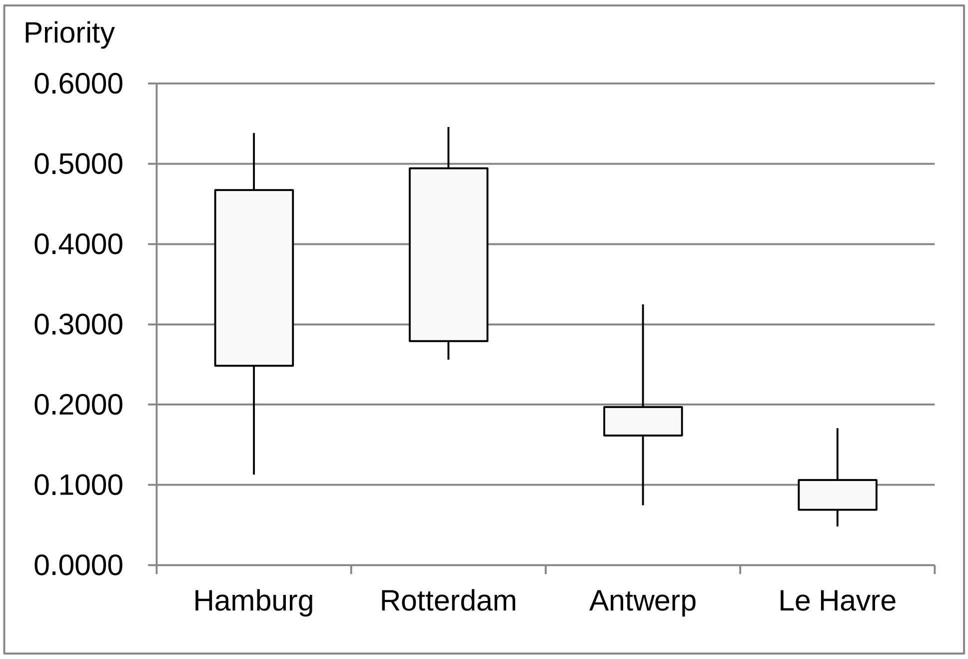

Figure 5-3 Box Plot for Port Priorities under Feeder and Intermodal Connections
Source: compiled by author.

5.2.6 Interpretation of Priorities for Hinterland Size

The third mostly considered factors for liner shipping is size of hinterland. Size of hinterland is a measurement of the degree of shipping lines' logistics chain extension towards a port's hinterland. Both Rotterdam and Hamburg's priorities are higher while Antwerp and Le Havre's are similar lower. As studied in Chapter 3, hinterland is strongly linked to its economy. The AHP result confirms that shipping lines prefer hinterland with higher economic development, which means more potential business after all. The existence of a logistics chain linking port of Rotterdam to Greece (hinterland) also shows a clue of hinterland extension.

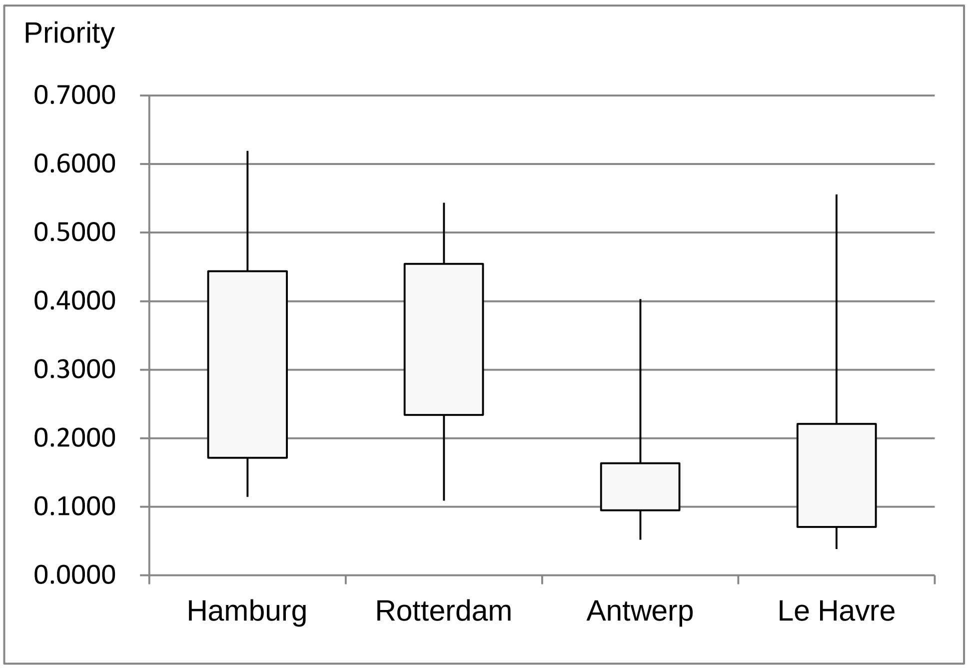

Figure 5-4 Box Plot for Port Priorities in terms of Hinterland Size

Source: compiled by author.

5.2.7 Interpretation of Priorities for Cargo Handling Efficiency

Cargo handling efficiency is the fourth important factor. If cargo handling efficiency is the only factor to consider in port selection, a shipping company will choose the port of call with highest cargo handling efficiency. The result showed in Table 5-8 below more or less reflexes four ports' cargo handling efficiency. Rotterdam has the highest efficiency, Hamburg is the second. Antwerp and Le Havre ranks third and fourth. As mentioned in Chapter 3, port of Rotterdam has long specialized container terminal and Hamburg also has four long container terminals. It is obvious that the many short, general terminals which can load and unload not only containers but also other cargo types makes container handling efficiency low in port of Le Havre. Besides, handling equipment is also a key element for raising handling efficiency. The average score of Antwerp is much lower than Rotterdam again in this item, but there are still companies that in favor of port of Antwerp. It seems that when shipping lines need to chose a port of call between port of Rotterdam and Antwerp, Rotterdam is always the first choice to many companies. This does not necessarily mean that the handling efficiency in Antwerp is really much lower than Rotterdam's. If it were true, then port of Antwerp should not be the second largest port in terms of TEU throughput.

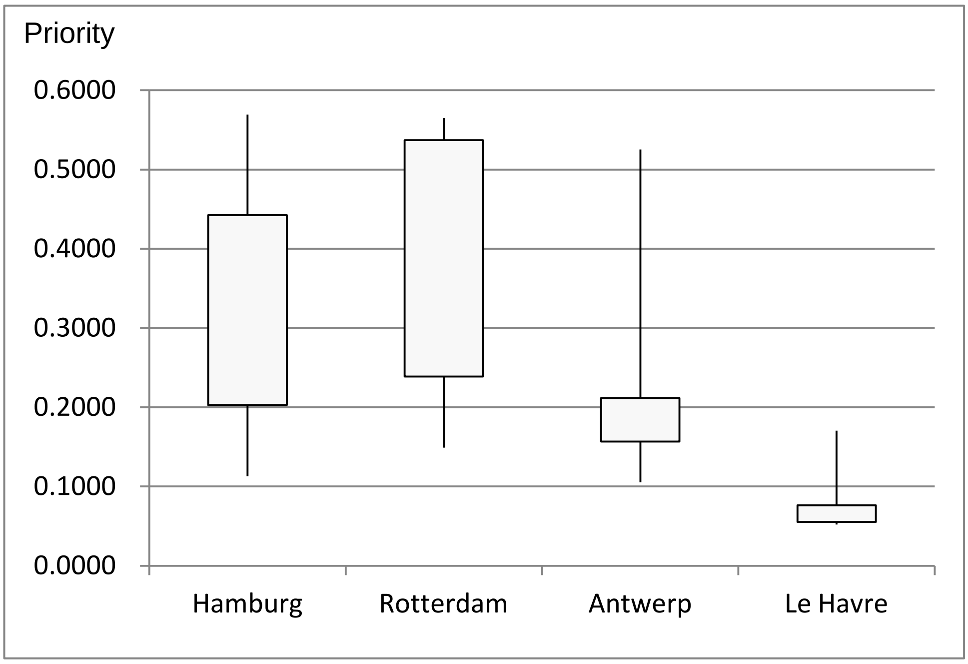

Figure 5-5 Box Plot for Port Priorities under Cargo Handling Efficiency
Source: compiled by author.

5.2.8 Interpretation of Priorities for Cargo Volume

The next factor to be considered is cargo volume. Though short sea shipping is very successful in Europe, when it comes to the Northwest Europe – Asian shipping line, hub-spoke is still a dominant pattern. Big ports with enough water draft and handling equipment are able to serve big container ships with large volume of cargo. The priorities in terms of cargo volume for shipping lines are showed in Figure 5-6 Box Plot for Port Priorities under Cargo Volume.

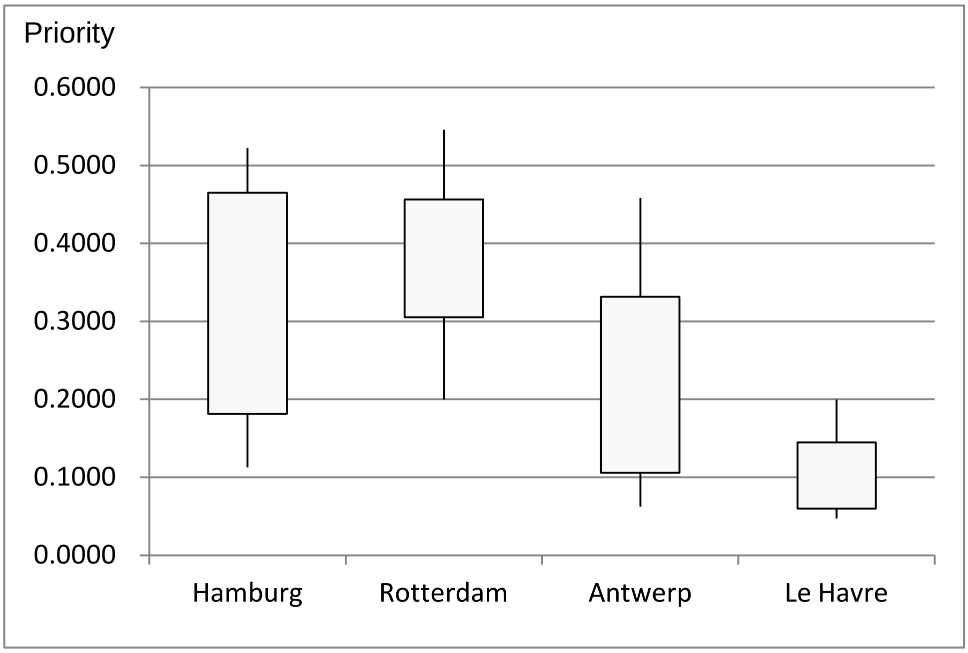

Figure 5-6 Box Plot for Port Priorities under Cargo Volume
Source: compiled by author.

5.2.9 Interpretation of Priorities for Port Draft

Port draft is the sixth criterion needed to think of. Shipping lines do not consider port draft as a very important determinant of port selection because most of the four ports are able to handle the most of containerships sailing in this route. Although the biggest containership in the world (Emma Maersk) will be frustrated in port of Hamburg and Le Havre, most containerships are still not that large in this route; besides, ships in feeder services are much smaller than that. But the results shows that water draft is not so important, shipping lines still have preferences for that. Port of Rotterdam, along with its deepest container terminals among the four ports, ranks first. Antwerp is the second with extremely dynamic priorities among all the respondents. In conclusion, shipping lines operating in main trunk with big vessels will emphasize more on water draft than those companies who only provide feeder services and water draft is not a problem for this kind of companies.

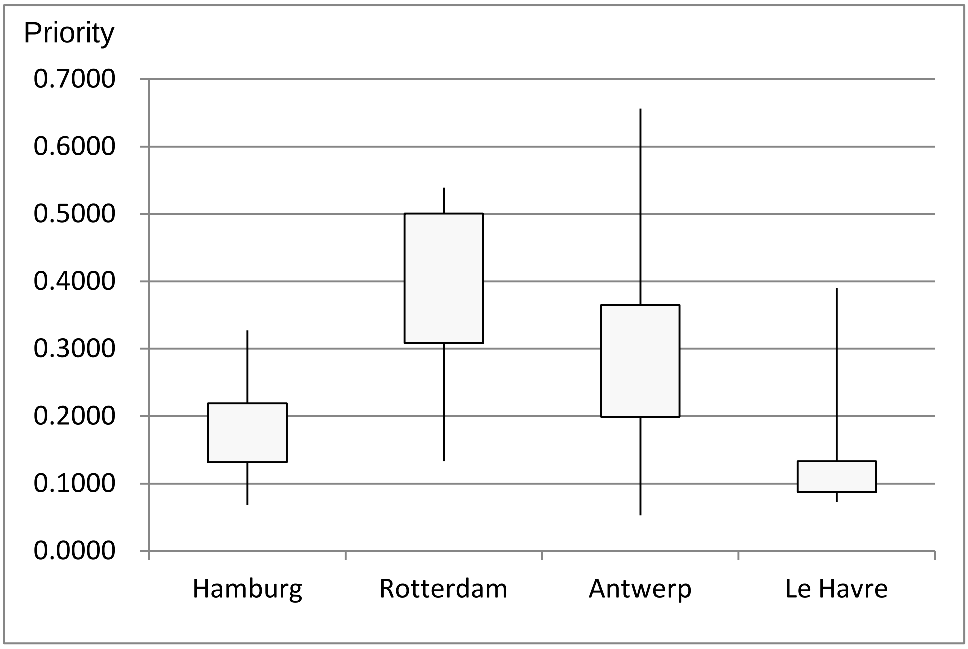

Figure 5-7 Box Plot for Port Priorities under Draft
Source: compiled by author.

5.2.10 Interpretation of Priorities for IT Ability

IT ability is the second least important criterion in port selection. There is no big difference between choice priorities for IT ability, but Rotterdam and Hamburg are slightly more advanced. In fact, 2 respondents thought that IT abilities are equally important in the four ports. IT ability in four ports is enough for some liner companies. Some shipping lines emphasize more on IT's function in logistics chains and hope IT can promote coordination and lower costs in their integration process. Though here IT ability is not a significant factor, it is well known that information flow, cash flow and cargo flow are three key elements in supply chain and IT ability enable large logistics operators to keep their management efficient (Notteboom and Rodrigue, 2005). Of course IT ability should be paid attention, if shipping lines want to have their business extended to logistics services. All the four alternative ports in this research are selected from developed countries, which means that their IT ability could satisfy customers' requirements. As a result, when a liner company selects a port of call from the four, IT ability here is not a very important factor to take consideration.

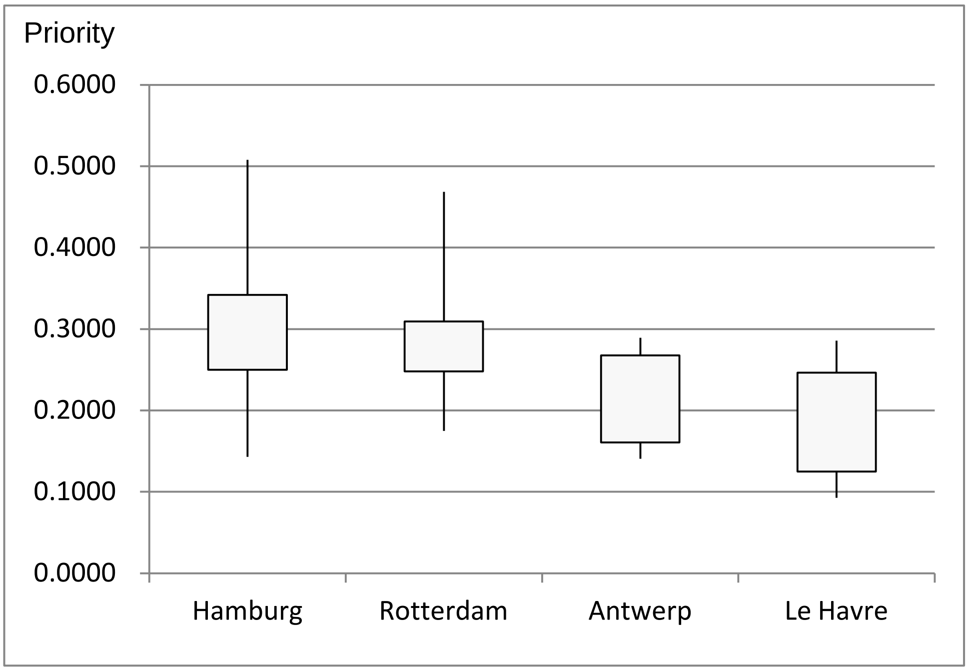

Figure 5-8 Box Plot for Port Priorities under IT Ability
Source: compiled by author.

5.2.11 Interpretation of Priorities for Port Charges

Port charges, including port dues and terminal handling charges (THC), is the least important criterion in port selection. This is not a surprising result as port dues and terminal handling charges only account for less 5% of total costs in a single deep sea voyage. When shipping lines are more involved in logistics chains, port charge is continuing to lose its position as a port selection criterion. As the port charges in the four ports (Figure 5-9), many respondents considered there's no difference between them (equally important). Shipping companies do not treat port dues and handling charges as an important factor any more but focus on cost minimization of the whole logistics chain. Some results also showed that port charges in Rotterdam and Hamburg tend to be more competitive. They argued that both Hamburg and Rotterdam could give some discount on port charges due to green shipping, and the competitive bunker price in Rotterdam was also highlighted by some companies. This made Rotterdam almost a “must” port of call for port choice.

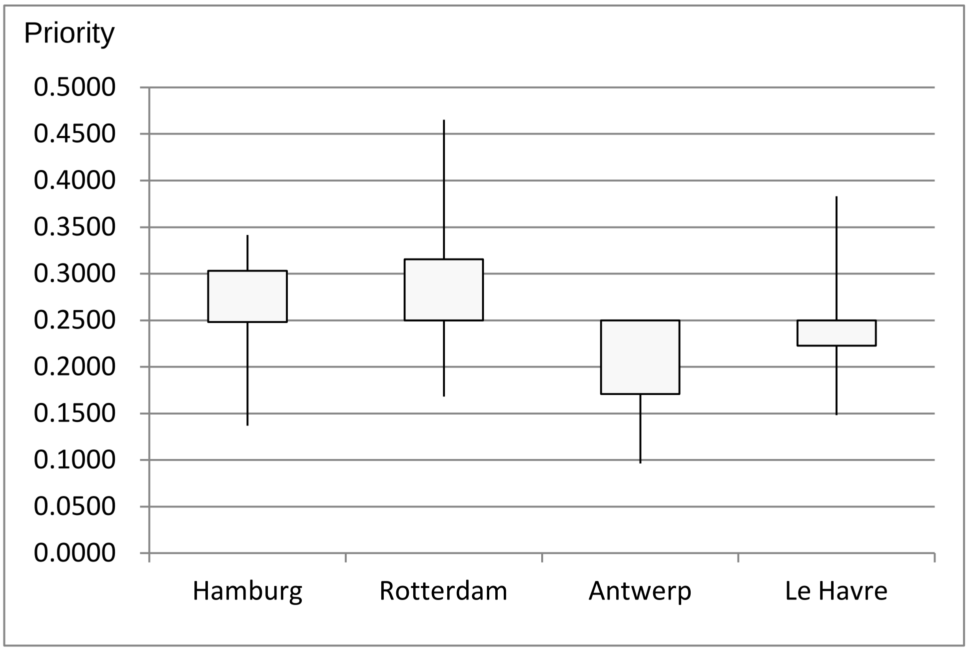

Figure 5-9 Box Plot for Port Priorities under Port Dues and Terminla Handling Charges
Source: compiled by author.

5.2.12 Interpretation of Priorities for Final Choice Result

Figure 5-10 shows the situation of final priorities of this research. Most respondents vote Rotterdam as the first priority for port selection in the so called HLH range. Hamburg is the second alternative; Antwerp and Le Havre are the third and fourth choice respectively. Priorities of Rotterdam and Le Havre are more dynamic than Hamburg's and Antwerp's, which means that shipping lines choice on these two ports are different more flexible. Taking port of Le Havre for example, though the majority of respondents thought it should not be the port of good choice, there does exist one or two companies that prefer Le Havre. This has something to do with companies' business pattern (main trunk or feeder services), location of main customers and degree logistics integrations, etc. Also for the similar reason, there is a respondent who showed his strong preference for port of Hamburg. Port of Rotterdam is seen as a main hub port that attracts a large number of liner shipping companies. On the other hands, Le Havre is expected to act as a transshipment port or a feeder port as a supplement of major hub ports. Antwerp shares a large part of its hinterland with Rotterdam but is thought to be less accessible than Rotterdam for main trunks. However, some shipping companies are fully in favor of Rotterdam while some of them consider Hamburg or Antwerp are at least equally important with Rotterdam.

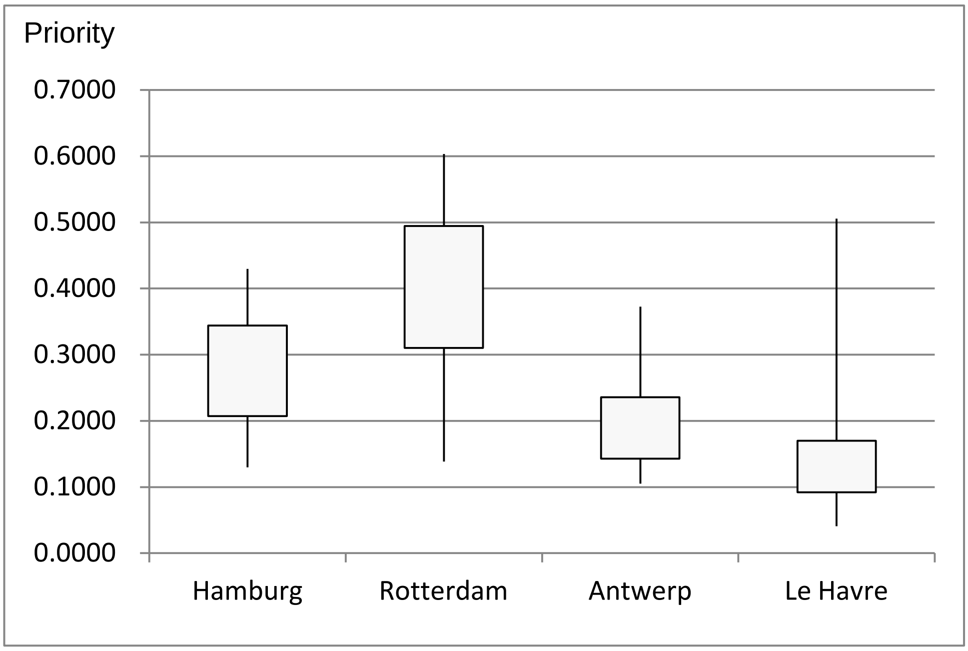

Figure 5-10 Box Plot for Overall Priorities
Source: compiled by author.

To compare the research results with previous literature, port location is the most important criterion whether logistics integration happens or not and this conclusion can be confirms by Chang and Tongzon (2008), Garcia-Alonson and Sanchez-Soriano (2009), Lirn et al (2010), Guy and Urli (2006) and Malchow and Kanafani (2004). Some of them still conclude that port location is more than important but could be the most crucial factor for port selection (Guy and Urli (2006) and Malchow and Kanafani (2004)). Feeder networks and intermodal connections are also highlighted by Chang and Tongzon (2008), Lirn et al (2010). Together with hinterland size, the third important criterion, feeder networks and intermodal connections form the foundation for liner shipping's way towards a logistics integrated package of services. The sum of weight of hinterland and feeder & intermodal connections is nearly 40% of total criteria. Port efficiency, a criterion that still shows its importance in this research, is also emphasized by Ugboma (2006), Tang and Low (2011). Many previous literature concluded port dues and terminal handling charges was an important criterion needed to concern about, these literature includes Chang and Tongzon (2008), Lirn et al (2010); while this paper finds that port charges is not a significant criterion in the new logistics situation that shipping lines are facing. However, Guy and Urli (2006) argued that port charges may not significant but the total transit cost, including port dues, terminal handling charges and other logistics costs, could account for 38% of total weight in port selection. This confirms that shipping lines tend to minimize total costs in their whole logistics services rather than the port part only.

Figure 5-11 shows a radar plot of the same results as Figure 5-1 Box Plot for Criteria Priorities. The pros of radar plot are obvious, it can demonstrate which results are most similar (i.e. the clusters in the plot) or are there any outliers in the results. It can also demonstrate which dimension shows higher or lower numeric results. The average normalized priorities are showed besides each selection criterion.

Malchow and Kanafani (2004) concluded that port choice behavior varies significantly across carriers and this argument is confirmed in this paper. And Figure 5-11 is just a perfect proof of this variation, similarities and differences co-exist in various shipping lines. Furthermore, this paper also finds that the variation of choice for candidate ports under each criterion is less than the variation of those criteria. In other words, shipping lines tend to be more certain about the candidate ports under each selection criterion rather than the criteria themselves.

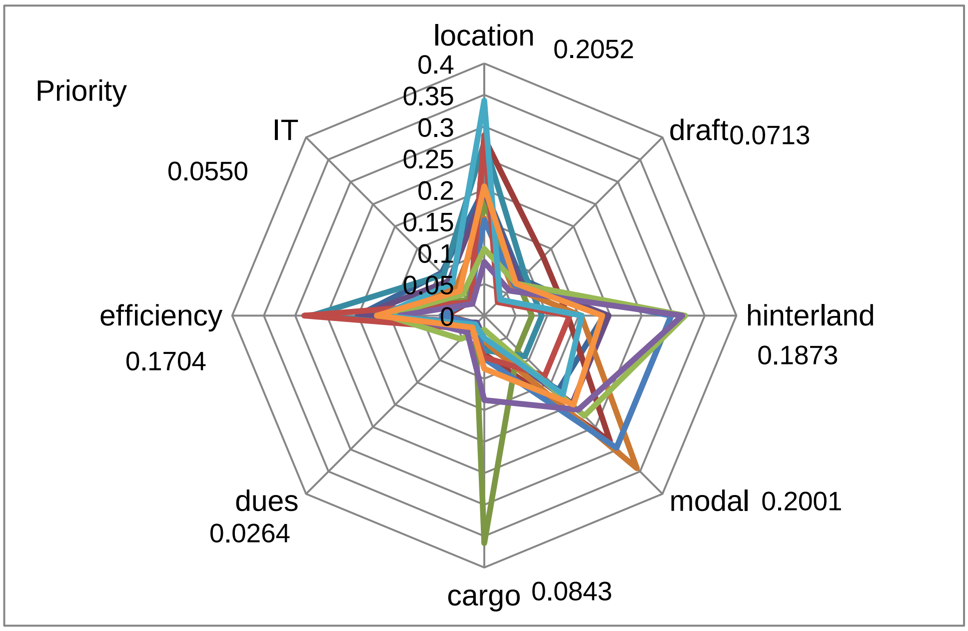

Figure 5-11 Rader Plot of Normalized Priorities of Criteria by repondents
Source: compiled by author

This is an interesting phenomenon that possible reasons may be:

1) Though maritime procedures for shipping lines are almost identical, business varies hugely in the logistics processes for shipping lines, which determines the very different point of views on port selection criteria;

2) Ports' conditions are hard to change in a certain period of time, to a given criterion, a candidate port's excellence level on it is not difficult to identify. For example, due to the restrictions of port infrastructure (handling equipment and container yard ability, etc) and superstructure (level of management and stevedores' productivity, etc), efficiency of a port can be seen as fixed and hardly to change in the short term. When comparing port efficiency with all decision

alternatives, it would be an easier task to find out which port is more efficient than others. This reduces variations of priorities in the third level of AHP in this paper.

5.3 Conclusion

To conclude, along with the processes of liner shipping companies' involvements in logistics services in Northwest Europe and Asian shipping route, size of hinterland, feeder network and intermodal connections become more important in port selection procedure than before. Though port location is still very crucial for port choice, port dues and terminal handling charges are less important due to the emphasis on total logistics costs minimization. Port efficiency remains to be an important factor, cargo volume and water draft are nearly equally important. This result answers the research questions raised in Chapter 1, and the answer is that shipping lines' integration in supply chain services forces port selection criteria to change.

Chapter 6. Implications: Re-think Port Competition and Port's Role

6.1 Introduction

In this chapter, based on AHP model results and interpretations of last chapter, the author will focus on the implications for port development and competition both regionally and internationally.

6.2 The Importance of Port Location and Hinterland

It will never be too late to emphasize the importance of port location even in this logistics era. A good location of a port must be able to provide easy access to hinterland for ships and cargo. Ports compete for hinterland, and a reasonable port location accelerates this access and helps port gain competence from the very beginning. For the four existing ports in this thesis, Hamburg, Rotterdam, Antwerp and Le Havre, geographical expansion will be the solution for the sake of better location. Port of Antwerp, Rotterdam and Le Havre are all river ports located in the delta area while Hamburg is a river port located off the sea. The recent development of Rotterdam, construction of Maasvlakte 2 which is closer to the sea,

6.3 Intermodal, Intermodal, Intermodal

The role of intermodal connections (barge, rail and truck) will never be overestimated for port's development and competition. Intermodal connections to a port are what arteries to a human. Giant carriers in liner market like Maersk Line need to partly depend on a port's intermodal connections before they are able to build their own logistics chains; small companies fully depend on intermodal connections to help them provide logistics services. A port's strengths on intermodal connections ensure its attractiveness on shipping lines and third party logistics service providers, not only that, efficient and continuous intermodal connections are able to extend a port's hinterland coverage. Figure 5-12 shows the relationship between hinterland's size and intensity and breadth of intermodal connections of a port. The thickness of arrows means intermodal intensity while the length of arrows stands for intermodal breadth. Size of hinterland could be expanded with intensified and broad intermodal connections, and this could promote port's integration in supply chains as goods must be transported via ports before they go to warehouses or distribution centers. Development of intermodal connections not only will facilitate shipping lines' logistics services but also accelerate ports' paces towards the fourth generation of port in which a wide range of logistics and value-added activities can be observed with in port area (Paixão and Marlow, 2003).

Intermodal connections can be developed horizontally and vertically. Horizontal development means new builds of intermodal transport while vertical development is to encourage efficiency and to promote logistics orientation functions of existing intermodal networks. For example, the new concept of AMSbarge in port of Amsterdam is a logistic concept for cargo transport in congested regions providing daily services between companies and the deepsea, shortsea and hinterland services in Amsterdam seaport and airport regions to reduce high congestion costs.

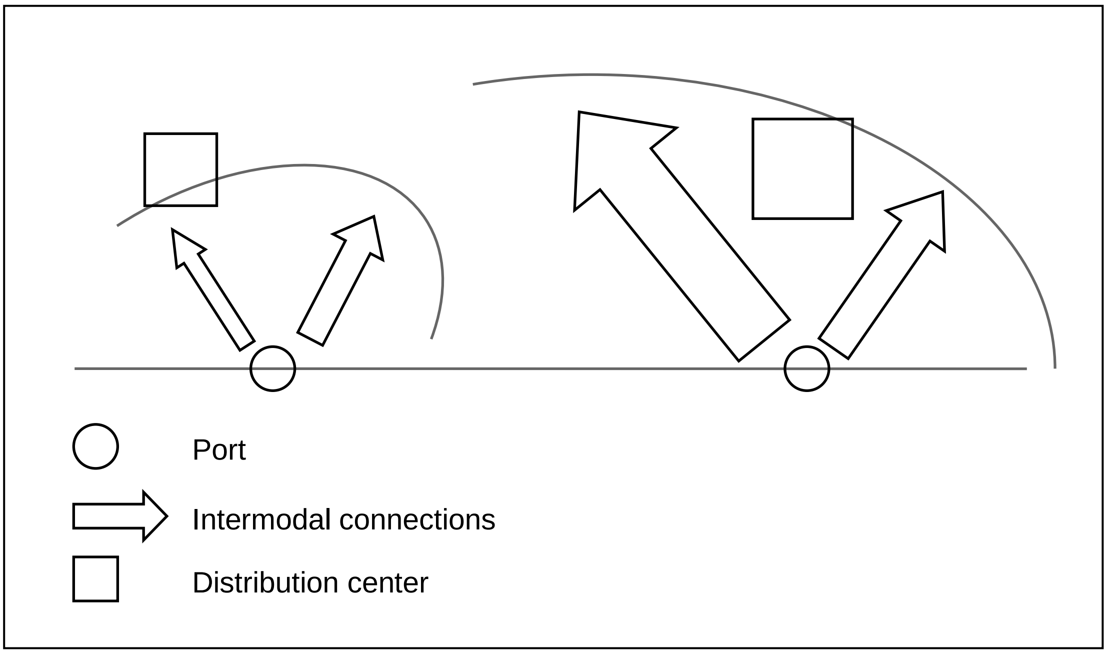

Figure 5-1 Intermodal Connections and Hinterland Expansion
Source: compiled by author

6.4 A New View of Port Efficiency

An old, out-of-date knowledge will never lead to new success. New development needs update-to-date knowledge and viewpoints. As the fourth most importance criteria for port selection, port efficiency is the factor needed to be re-considered for the sake of continuous development. Traditional opinion on port efficiency is the so-called cargo handling efficiency, the loading and unloading speed of containers. However, as port becomes an element of global or regional supply chains or even a distribution center of a region, port efficiency should be redefined as port logistics efficiency to fit the new trends in maritime industry. Figure 5-13 depicts the conceptual framework of port logistics efficiency, which is an organic combination of various efficiency indicators measuring supply chain performance. It should be noted that port logistics efficiency is not just a collection of various numbers but a systematic indicator which could reflex a port’s performance as an element of supply chains. Few researches have done on this new concept, but some research results could be used. Trujillo and Tovar (2007) analyzed European ports' economic efficiency, and they were the first one to research on technical efficiency of port authorities. They highlighted that European ports' efficiency is limited by limited access to the right level of information. In supply chain management, information flow and its efficiency is crucial for supply chain's whole efficiency. This also should be paid great attention to in port sectors. In this connection, port logistics efficiency should be able to measure each factor's efficiency in logistics chains within the port and hinterland area dynamically and help logistics stakeholders find potential solutions to increase whole supply chains efficiency.

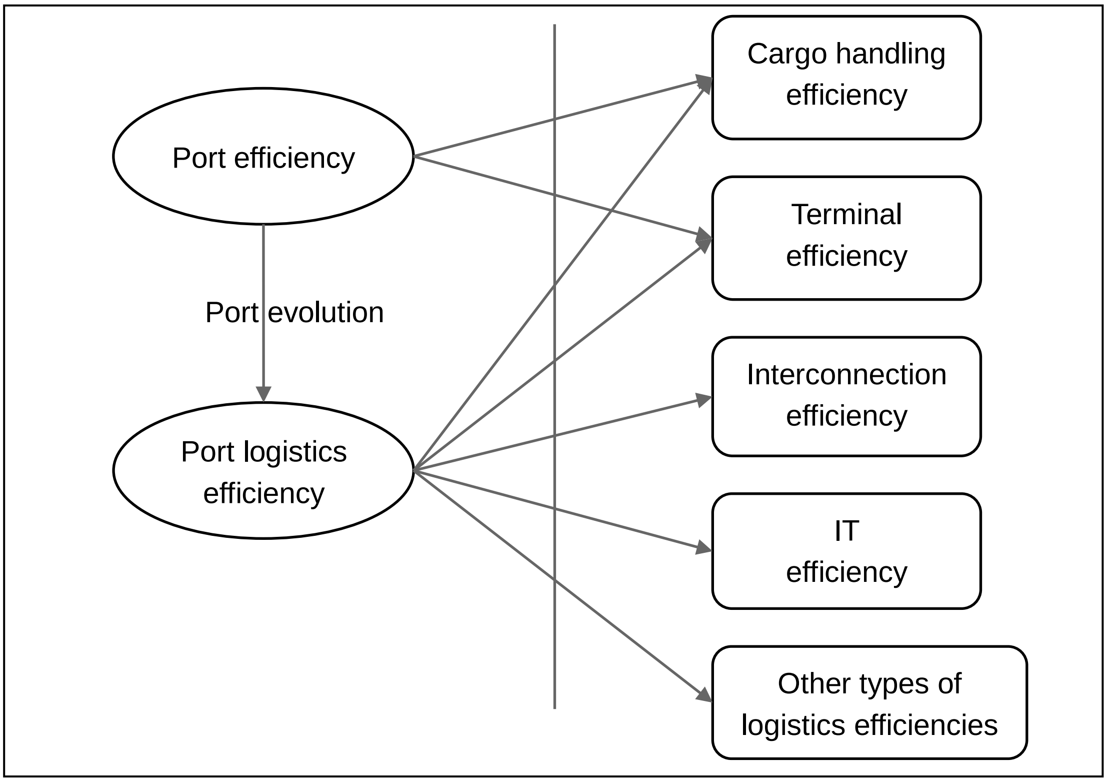

Figure 5-2 Concept of Port Logistics Efficiency
Source: compiled by author

6.5 Possible Ways, towards Port-centric Logistics and Port Regionalization

A lot of researches have been done recent years for sake of seeking solutions of port reform. As one group of main customers of ports, shipping lines are heading towards logistics integrations, the needs for ports to provide logistics services are rising. For a port, it is better to positively reform itself to offer value-added services and activities rather than negatively accept and is driven by shipping lines' logistics requirements.

Mangan et al (2008) came up with a concept called port-centric logistics, and defined it as:

“We define port-centric logistics as the provision of distribution and other value-adding logistics services at a port. Ports are increasingly recognizing that higher profit margins can be made on some non core port activities and this is driving them to engage in activities beyond simply providing berths for ships and other core port services.”

In port-centric logistics, port competition is towards the competition for supply chains rather simply competition for transshipment and hinterland. Driving by itself, port becomes an irreplaceable node of supply chains.

Notteboom and Rodrigue (2005) argued that existing port functions could not fit fully into logistics integration in value chains and freight distribution. They brought up “port regionalization” as a new phase of port development. Port regionalization is “a concept approach to port-hinterland relationships in a changing market environment” (Notteboom and Rodrigue, 2005). The authors introduced a phase of port development called “regionalization” indicating not only port and hinterland should be well connected but also port and port should be of high accessibility both spatially and functionally.

Since there is still significant room for inland logistics functions to reduce costs, one of the most urgent functions of port regionalization is to optimize inland freight distribution and reduce inland logistics costs through containerization, intermodality and ICT (information and communication technology) (Notteboom and Rodrigue, 2005).

6.6 Conclusion

In chapter, the author discussed implications for port competition and development based on the AHP results. The significance of port location is highlighted once again, intermodal connections and hinterland accessibility are put on to a never given important position. Port efficiency is re-considered into port logistics efficiency with several combined and joint indicators; finally, two new concepts from other literatures for port development, port-centric logistics and port regionalization, are introduced to management for extension of port functions and economic position.

Chapter 7. Conclusions and Recommendations

7.1 Introduction

In this chapter, conclusions of this research will be given. The author will also analyze drawbacks of this thesis and give recommendations for further research. The chapter is organized as follows, section 2 deals with conclusions and section 3 provides drawbacks and recommendations.

7.2 Conclusion

In this paper, the author researched on port selection criteria in the Hamburg – Le Havre range in Northwest Europe – Far East shipping route with the consideration of shipping lines' integration in global supply chains.

The most important finding is that when shipping lines are choosing ports of call in the Northwest Europe – Far East route, feeder services and intermodal connections are the second most significant selection criterion behind port location, the most significant selection factor. Hinterland size is the third factor to be considered. This finding generates valuable implications for port competition and development including the emphasis of intermodal connections and new concepts for port development such as port-centric logistics and port regionalization.

In the last chapter, the author thinks it is the right time and should be able to give the answers for the five sub questions come up with in the first chapter of this thesis after the whole research process. Those answers draw a more detailed conclusion of what the author did as well as what this thesis is about.

1. Does liner shipping market change to some extent due to its increasingly deep involvement into global supply chain? How does liner shipping change and how do shipping lines react against this new challenge? When shipping lines are driving themselves to fit into global supply chains and value chains to provide their customers logistics services (end to end, added value, etc), liner shipping market is also heading to this increasing trend. Shipping lines not only compete for traditional container services but also put their efforts in competition for supply chains and value added activities.

2. Do those changes above mentioned pose influences to port selection criteria from shipping lines perspective? What are the changes and what are the most important port selection factors under the new situation? Port selection criteria change with this trend. According to the research results, the four most important port selection criteria now are port location, hinterland size, feeder services & intermodal connections and port efficiency. Port dues and terminal handling

charges (THC) is not a significant criterion. Port's IT ability is attracting more attention on it.

3. What are the implications for port competition if taking those new port selection factors into consideration? Port location is still a very significant factor in port selection; and cargo distribution pattern is related to a location of a port. Strength and breadth of intermodal connections are important for all parities participating in supply chain activities. It is also wise that port reforms itself towards a more logistics integrated way rather than driven by shipping lines' logistics requirements. But current port development and competition ideas do not fully meet this strategic fit. New concept of port-centric logistics and port regionalization are possible solutions for port development and competition as port is a node of supply chains.

7.3 Further Research Recommendations

This paper confirms the argument that port selection criteria will change as shipping lines integrate themselves into global supply chains and gives a general idea of what are the changes exactly. However, there is no perfect thing in the world and this thesis is not an exception. The author thinks the major drawbacks of this thesis and recommendations from the author are,

1. The omission of some influential criteria. For example, after the results came out, the author found that the gap between priorities of Rotterdam and Antwerp seems bigger than what they actually were. The author considers part of reason is that Rotterdam's reputation is higher than Antwerp especially to Asian companies. If companies are not familiar with the ports, they probably will choose the port with higher reputation to reduce potential risks. Also, many "soft" criteria are omitted such as port management level, relationship between stevedores and management, and response to shipping lines' special demands, etc. The author suggests that all the influential criteria should be examined next time to get a better view of relative weights of port selection criteria.

2. Hierarchies are not fully optimized. In this research, the author used the most basic hierarchy structure (3 hierarchies) because of considerations of time limit, model complexity and respondents' judgment ability as well as patience. The author does suggest further researchers add a hierarchy before the criteria layer – the categories of port selection criteria, such as port infrastructure, marketability, operational ability of port and convenience of port, etc. by doing this, researchers should be able to identify each category's priority in port selection process. These findings can make the research more precise and are better for port competition.

3. More research needs to be conducted on port logistics efficiency. As mentioned

above, the author thought this concept will benefit all parties within port logistics activities and value-added processes.

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Appendices

I. Questionnaire

Appendix 1 Questionnaire

Dear Sir/Madam,

First I want to express my gratitude for your participation in this questionnaire. This questionnaire is part of my thesis research — container port selection criteria for northern European ports in the Asia-Europe shipping route in the global logistics era. Your response to this questionnaire is really important for my research and thesis. It will be very appreciated if you could answer these questions with patience. When you finish this questionnaire, please pass it to the person who gave it to you or send it to wlgyyk@gmail.com. Thank you.

Liguo Wang

Erasmus University Rotterdam

17-07-2011

Questionnaire

Name: ______________________________ Date: _________________________

Company: ____

Email: _____________________________

1. Which sector do you work in?

☐ Shipping line ☐ Port ☐ 3PL ☐ Other:________

2. Do you agree that we are now living in a global logistics era and this influences our lives in many aspects?

☐ Yes ☐ No

3. If so, do you think port selection criteria will change more or less compared to the criteria before the global logistics era?

☐ Yes ☐ No

4. Based on our research, we find that there are 8 basic criteria that have been proved to be very important when shipping lines are selecting container ports of call. Those factors are as follows:

   1. Geographical location
   2. Water draft
   3. Hinterland size
   4. Feeder and intermodal connection
   5. Cargo volumes

6. Port dues and terminal handling charges (THC)
7. Port efficiency and reliability
8. IT ability

Imagine that you need to choose a port of call between four ports in North Europe: Hamburg, Rotterdam, Antwerp and Le Havre, for the Europe – Asia shipping route; you are asked to make pair-wise comparisons between each selection criterion.

The table below contains the numerical rating for judging criteria. For example if draft is strongly more important when compared with location please write down “5” for draft. If draft is somewhere between strongly more important and very strongly more important please write down “6”.

Verbal judgment	Numerical rating
Extremely more important	9
	8
Very strongly more important	7
	6
Strongly more important	5
	4
Moderately more important	3
	2
Equally important	1

Original factor	Compared factors	Your Rating
Geographical location	Water draft	
	Hinterland size	
	Feeder and intermodal connection	
	Cargo volumes	
	Port dues and terminal handling charges	
	Port efficiency and reliability	
	IT ability	
Water draft	Hinterland size	
	Feeder and intermodal connection	
	Cargo volumes	
	Port dues and terminal handling charges	
	Port efficiency and reliability	
	IT ability	
Hinterland size	Feeder and intermodal connection	
	Cargo volumes	
	Port dues and terminal handling charges	
	Port efficiency and reliability	
	IT ability	
Feeder and intermodal	Cargo volumes	

connection	Port dues and terminal handling charges	
	Port efficiency and reliability	
	IT ability	
Cargo volumes	Port dues and terminal handling charges	
	Port efficiency and reliability	
	IT ability	
Port dues and terminal handling charges	Port efficiency and reliability	
	IT ability	
Port efficiency and reliability	IT ability	

9. You are also asked to make pair-wise comparisons between four ports; Hamburg, Rotterdam, Antwerp and Le Havre, under each selection criterion mentioned above. The verbal judgment is the same as the previous comparison. If one is less important than another, just leave it blank. For example, if port of Rotterdam's location is more important than the port of Antwerp's location, put "5" in the corresponding cell.

a) Geographical location

Compare / Original	Hamburg	Rotterdam	Antwerp	La Havre
Hamburg	1			
Rotterdam		1		
Antwerp			1	
La Havre				1

b) Water draft

Compare / Original	Hamburg	Rotterdam	Antwerp	La Havre
Hamburg	1			
Rotterdam		1		
Antwerp			1	
La Havre				1

c) Hinterland size

Compare / Original	Hamburg	Rotterdam	Antwerp	La Havre
Hamburg	1			
Rotterdam		1		
Antwerp			1	
La Havre				1

d) Feeder and intermodal connection

Compare / Original	Hamburg	Rotterdam	Antwerp	La Havre
Hamburg	1			
Rotterdam		1		
Antwerp			1	
La Havre				1

e) Cargo volume

Compare / Original	Hamburg	Rotterdam	Antwerp	La Havre
Hamburg	1			
Rotterdam		1		
Antwerp			1	
La Havre				1

f) Port dues and terminal handling charges (THC)

Compare / Original	Hamburg	Rotterdam	Antwerp	La Havre
Hamburg	1			
Rotterdam		1		
Antwerp			1	
La Havre				1

g) Port efficiency and reliability

Compare / Original	Hamburg	Rotterdam	Antwerp	La Havre
Hamburg	1			
Rotterdam		1		
Antwerp			1	
La Havre				1

h) IT ability

Compare / Original	Hamburg	Rotterdam	Antwerp	La Havre
Hamburg	1			
Rotterdam		1		
Antwerp			1	
La Havre				1

10. What criteria do you think are also important or need to be considered seriously given that shipping lines themselves are increasingly integrated into global logistics chain?

____

____

Thank you for your participation and feedback!

Appendix 2 Scilab Source Code for One Example

```
lel_a=[1 3 1 1 5 9 1 3;1/3 1 1/3 1/3 3 7 1/3 1;
1 3 1 1 3 9 1 3;1 3 1 1 3 9 1 1;
5 1/3 1/3 1/3 1 5 1/5 1/3;1/9 1/7 1/9 1/9 1/5 1 1/9 1/7;
1 3 1 1 5 9 1 3;1/3 1 1/3 1 3 7 1/3 1]
[vec_a,val_a]=spec(lel_a)
lel_b1=[1 1/3 1/3 7;3 1 1 9;3 1 1 9;1/7 1/9 1/9 1]
[vec_b1,val_b1]=spec(lel_b1)
lel_b2=[1 1/5 1/3 1/5;5 1 3 1;3 1/3 1 1/3;5 1 3 1]
[vec_b2,val_b2]=spec(lel_b2)
lel_b3=[1 1/3 1/3 5;3 1 1 9;3 1 1 9;1/5 1/9 1/9 1]
[vec_b3,val_b3]=spec(lel_b3)
lel_b4=[1 1 1 5;1 1 1 7;1 1 1 7;1/5 1/7 1/7 1]
[vec_b4,val_b4]=spec(lel_b4)
lel_b5=[1 1 1 5;1 1 1 5;1 1 1 5;1/5 1/5 1/5 1]
[vec_b5,val_b5]=spec(lel_b5)
lel_b6=[1 1 1 1;1 1 1 1;1 1 1 1;1 1 1 1]
[vec_b6,val_b6]=spec(lel_b6)
lel_b7=[1 1/5 1/3 5;5 1 3 9;3 1/3 1 7;1/5 1/7 1/9 1]
[vec_b7,val_b7]=spec(lel_b7)
lel_b8=[1 1 1 1;1 1 1 1;1 1 1 1;1 1 1 1]
[vec_b8,val_b8]=spec(lel_b8)
```

Appendix 3 R Source Code for One Example

```
lel_a <- matrx(c(1,3,1,1,5,9,1,3,1/3,1,1/3,1/3,3,7,1/3,1,

1,3,1,1,3,9,1,3,1,3,1,1,3,9,1,1,

5,1/3,1/3,1/3,1,5,1/5,1/3,1/9,1/7,1/9,1/9,1/5,1,1/9,1/7,

1,3,1,1,5,9,1,3,1/3,1,1/3,1,3,7,1/3,1),nrow=8,byrow=T)

eig_a <- eigen(lel_a)

lel_b1 <-
matrix(c(1,1/3,1/3,7,3,1,1,9,3,1,1,9,1/7,1/9,1/9,1),nrow=4,byrow=T)

eig_b1 <- eigen(lel_b1)

lel_b2 <-
matrix(c(1,1/5,1/3,1/5,5,1,3,1,3,1/3,1,1/3,5,1,3,1),nrow=4,byrow=T)

eig_b2 <- eigen(lel_b2)

lel_b3 <-
matrix(c(1,1/3,1/3,5,3,1,1,9,3,1,1,9,1/5,1/9,1/9,1),nrow=4,byrow=T)

eig_b3 <- eigen(lel_b3)

lel_b4 <-
matrix(c(1,1,1,5,1,1,1,7,1,1,1,7,1/5,1/7,1/7,1),nrow=4,byrow=T)

eig_b4 <- eigen(lel_b4)

lel_b5 <-
matrix(c(1,1,1,5,1,1,1,5,1,1,1,5,1/5,1/5,1/5,1),nrow=4,byrow=T)

eig_b5 <- eigen(lel_b5)

lel_b6 <- matrix(c(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1),nrow=4,byrow=T)

eig_b6] <- eigen(lel_b6)

lel_b7 <-
matrix(c(1,1/5,1/3,5,5,1,3,9,3,1/3,1,7,1/5,1/7,1/9,1),nrow=4,byrow=
T)

eig_b7 <- eigen(lel_b7)

lel_b8 <- matrix(c(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1),nrow=4,byrow=T)

eig_b8 <- eigen(lel_b8)
```