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Location decision of dry port in the Hinterland of Ningbo port : an AHP approach / by Yizhen Li.

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LOCATION DECISION OF DRY PORT IN THE HINTERLAND OF NINGBO PORT – AN AHP APPROACH

By

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

MASTER OF SCIENCE

(INTERNATIONAL TRANSPORT AND LOGISTICS)

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DECLARATION

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

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

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ABSTRACT

Title of Dissertation: **Location Decision of Dry Port in the Hinterland of Ningbo Port – An AHP Approach**

Degree: **Master of Science in International Transport and Logistics**

In order to enhance Ningbo port's capability of canvassing cargoes and its competitive advantage in the ever intensifying competition among major ports in the Yangtze River Delta (YRD), the strategy of establishing dry port network is a must. However, the appropriate approach and reliable models have not been found to fit into the scenario of Ningbo port. With a view to helping decision-makers of Ningbo Port Group Ltd. to make the right decision, this dissertation studies Ningbo port's scenario and advances AHP dry port location decision model of Ningbo port.

In the first place, basic definition, function and classification of dry port are examined by literature study, which is the foundation of the continued in-depth research. Next, the specific scenario of Ningbo port is investigated while the problems encountered in dry port location decision of Ningbo port are raised.

The main achievement of this dissertation is the establishment and application of the AHP dry port location decision model of Ningbo port. Dry port location factors, which are identified from relevant literature using Delphi technique, are structured into a hierarchy tree, with the main objective of selecting best dry port locations lying at the top level and the decision alternatives which are chosen out at the preliminary selection stage of dry port locations lying at the bottom level. The final result seems to be of great value to Ningbo Port Group Ltd., for it offers the investment priority order of establishing dry ports in the hinterland of Ningbo port.

KEYWORDS: Dry port, Common hinterland, Forrester Effect, Location decision, Analytic Hierarchy Process, Delphi technique

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CFS	Container Freight Station
CY	Container Yard
EC	Empty Container
ECT	European Container Terminals
EDI	Electronic Data Interchange
FC	Full Container
FCL	Full Container Load
FDI	Foreign Direct Investment
ICD	Inland Container Depot
LCL	Less than Container Load
POS	Point of Sale
RMG	Rail Mounted Gantry
RTG	Rubber Tired Gantry
TEU	Twenty-foot Equivalent Unit
YRD	Yangtze River Delta

1. Introduction

1.1 Background

Ningbo port, a bright pearl in the affluent Yangtze River Delta with naturally endowed deep water, has attracted more and more attention from both home and abroad, not only because of its escalating rank in the world's container ports, but also due to its strikingly rapid growth rate in terms of container traffic. According to statistics from Ningbo Port Group Ltd., the average growth rate of container traffic in the last five years is about 42%, which is deemed as the lightning speed in the port industry.

However, the major concern that will impair such brilliant growth rate comes down to the pressure from neighbouring container ports that are competing for more cargoes, especially in the common hinterland. Hence, it is of practical significance to enhance Ningbo port's capability of canvassing cargoes. In other words, there is real need to build certain scale of network for canvassing cargoes. Establishing dry ports, which is new to China but already has some developments abroad, might be the right solution.

It is informed that the top managers of Ningbo port Group Ltd. are very keen on the dry port strategy, but decision-makers are worried about its location choice in the hinterland of Ningbo port. One difficulty may lie in the lack of dry port application experience of Ningbo port. Moreover, the main headache is the determination of exact dry port locations for the reason that no appropriate location models to date fit into the picture of Ningbo port.

1.2 Dry Port Development

The emergence of dry ports is highly related with the trend of containerization and subsequently enormous growth of intermodal traffic. With the rise of container revolution and the development of ISO containers, container transport between different modes becomes possible. Since mid-1970s, intermodal container transport has extended inland, which is promoted by shipping lines competing for more cargoes. Not surprisingly, pioneers set inland branches where empty containers are allowed to be returned and container cargoes are received. Because shipping companies normally issue their own bills of lading assuming full responsibility for the container transport between inland branches and ports and provide door-to-door services, shippers and consignees fell satisfied and welcomed such practice. It is the customers' needs and favorable response that encourage the container operators to build high quality inland intermodal terminals that finally develop into sophisticated dry ports, the functions of which are similar to those of seaports, such as transshipment, storage, value-added services, customs clearance and so on.

American President Lines (APL) and Sea-Land Services might take the lead in the construction of dry port networks. Nowadays many benefits can be enjoyed from North American dry port networks that were initially established at the end of 1980s and the beginning of 1990s by these two large American flag container shipping lines at that time. Besides, dry ports have some level of development in Europe since early 1990s as rail network in Europe is rather well developed. Surely those actors who are interested in dry port implementation promote such growth by funding.

Similarly, dry port development projects are also gaining sweeping popularity in the emerging container markets. Indian has already built some state-owned dry ports depending on the railway organization called Concor. Those dry ports, habitually called ICDs by Indians, offer various services, such as transportation, container maintenance, storage of units, packing and unpacking, etc, but focus on customs activities. Another country that takes great initiative is China. In the early days, Chinese container carriers including COSCO, OOCL, and Evergreen have established similar dry port networks in North America as its foreign competitors to fight for the market share and enhance their competitive advantage. Along with the booming Chinese economy, trade globalization and the introduction of the advanced technology, Chinese container transport industry gradually enters into the era of intermodalism. COSCO, the biggest shipping lines in China with the advantage of its huge containership fleet, has established many inland branches dealing with sea-rail intermodal operations, which can be deemed as the simple dry ports at the early stage.

Since 2000, the fierce competition among Chinese container ports, the extent of which is still on the increase, has exerted intense pressure on the top managers of ports. There is broad consensus in the port industry that it is of utmost importance to construct dry port networks aiming at raising the capability of canvassing cargoes, hence ranking high in the tough competition. However, there is no fully operational dry port up till now. In a sense, dry port development that is still in its infancy has a long way to go.

1.3 Literature Review on Dry Port Location Problem

The research on dry port location problem seems to be extremely limited. The United Nations (1990, 1992a) acted as a pioneer in this area, proposing an economic model to evaluate the financial and economic consequences of a single dry port. However, such a model only stays at the single dry port level.

Fortunately, the article by Xu (1999) entitled *A Discrete Choice Based Facility Location Model for Inland Container Depots* bridged this gap. The dry port location problem at the network level was well formulated and solved, with discrete choice analysis being developed and applied in addressing both the endogenous demand and market competitiveness, both of which are critical characteristics of facility location problems for the private sector. Albeit many benefits can be enjoyed from this thesis, the model is based on several assumptions, which may not be practical in the real world. Furthermore, it is complicated and can only be applied in the scenario where a new operator is established and wants to open one or several dry ports besides existing dry ports that are operated by other peer operators. What's more, when evaluating the performance, the research totally relies on quantitative analysis but ignores the qualitative analysis, wanting comprehensive considerations.

Some improvements had been made by Wang (2004) pertaining to the dry port location model at the regional network level. Three Concerns related with application scope, complexity and comprehensive considerations, however, still exist. In essence, the paper is only dedicated to polishing the model created by Xu (1999).

In a word, some problems also lie in the existing dry port location model at the regional network level. By and large, there are three prominent concerns. One is that the application scope of the model is narrow to the extent that only scenario where a new operator wants to open one or several ICDs besides existing competitive ICDs can be solved. Secondly, the model is deemed to be complicated although several assumptions that seldom happen in reality have already been made. Last but not least, in the absence of qualitative analysis, other important factors affecting dry port location are not taken into account.

1.4 Research Objectives

In order to enhance the competitiveness and future development capability of Ningbo port, the strategy of establishing dry ports connected with Ningbo port is a must. However, the appropriate approach and reliable models have not been found to achieve the goal, which is indicated in the existing literature. With a view to helping decision-makers of Ningbo port to construct dry port network, the following research objectives are set:

- Clear the misunderstandings of dry port and fully understand the real concepts and qualification of dry port through a literature study, which is the foundation of the continued in-depth research.
- Study the specific scenario of Ningbo port and point out the significance for Ningbo port to boost dry port development as well as the problems encountered in dry port location decision.
- Identify the main criteria and sub-criteria for locating a dry port
- Put forward the potential dry port locations that cater to the selection requirements in circumstances of Ningbo port
- Make the final dry port location decision of Ningbo port with the help of the appropriate model that evaluates the preliminary dry port candidates.

1.5 Research Methods

This dissertation mainly applies Analytic Hierarchy Process (AHP) to analyze and address the dry port location decision of Ningbo port. In the context of locating a dry port, apart from quantitative factors, qualitative elements are also involved in; therefore AHP, which deals with both quantitative factors and qualitative factors, emerges as a powerful tool to achieve the purpose.

In addition, for the sake of bringing forward the dry port location criteria which tie in with the preliminary dry port location selection and AHP dry port location decision model, research efforts were made on the Internet and in library for relevant existing literature. Thirty summarized criteria on the basis of literature were chosen out and recorded after the brainstorming session in which the author, one academic port expert and one manager of Ningbo port participated. With a view to identify the most important factors influencing the decision-making on dry port location, the initial recorded criteria were narrowed down to 11 most critical dry port location criteria by two rounds of Delphi surveys conducted among experts from shipping industry, academia and government, who are sufficiently knowledgeable and experienced.

1.6 Organization & Structure of the Dissertation

The organization of this dissertation is as follows. Chapter 1 is the introduction of the thesis where the background, dry port development, literature review on dry port problem, research objectives, methods and creative points are covered. Chapter 2 highlights the basic concepts and classifications of dry port in which the functions and characteristics of dry port are given by means of literature study. Chapter 3 elaborates the current situation and circumstances of Ningbo port, placing emphasis on pointing out the necessity and possibility for Ningbo port to establish dry ports. Meanwhile, the problems encountered in dry port location decision of Ningbo port are raised. Chapter 4 proposes dry port location criteria through literature review and Delphi surveys. What's more, potential candidate sites of dry ports for further evaluation are chosen out. Chapter 5 determines that Analytic Hierarchy Process (AHP) would be the appropriate approach to solve the problem of dry port location decision. Most importantly, it creates the AHP dry port location decision model of Ningbo port that can be applied in Ningbo port's scenario in the hope of helping top managers of Ningbo to make the right decision. Finally, chapter 6 summarizes the conclusions drawn from the research.

The structure of the dissertation is displayed in figure 1.1.

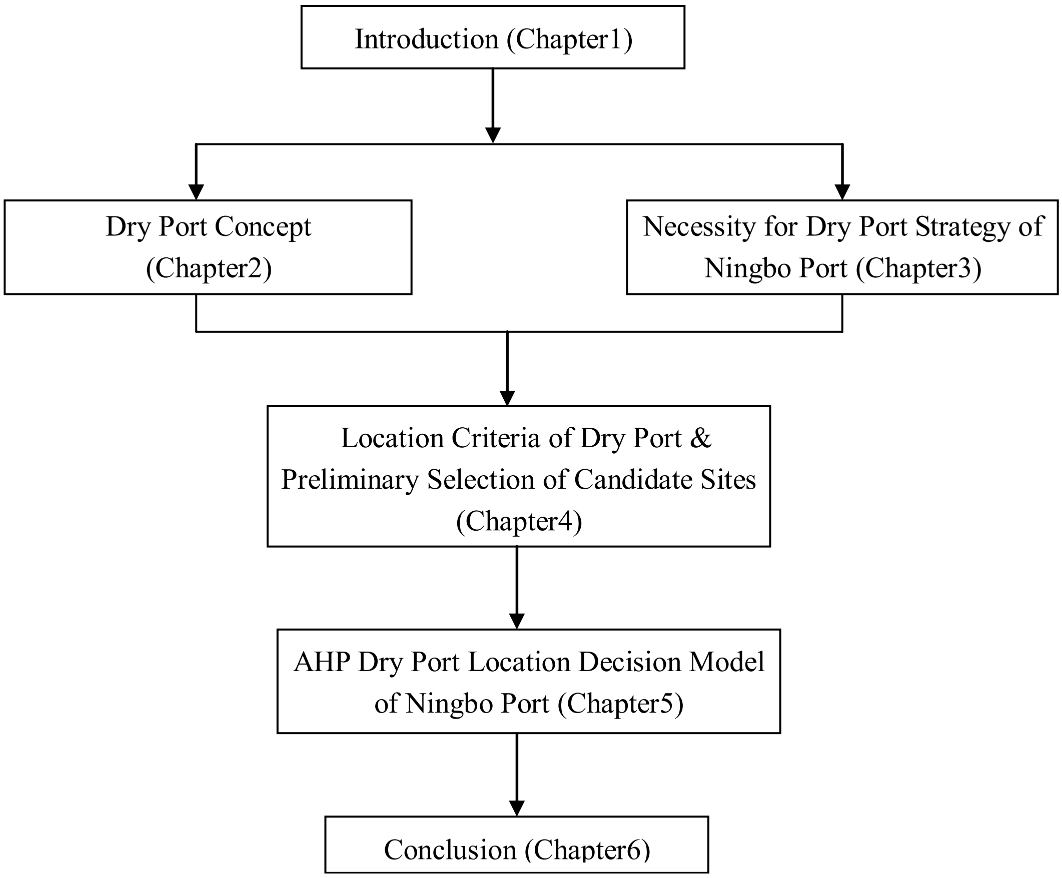

Figure 1.1 - Structure of the Dissertation

1.7 Creative Points of the Dissertation

There are three creative points in this dissertation. Firstly, although dry port strategy is sometimes mentioned in numbers of articles as a constructive train of thought in the development of Ningbo port, no research work has been done to probe the real potential and problems in developing dry ports in the hinterland of Ningbo port. This dissertation scrutinizes the circumstances of Ningbo port, finding out the preliminary candidate sites that need further pondering and investigation.

Secondly, comprehensive dry port location selection criteria are proposed partly based on literature review and partly based on Delphi technique, which the previous research has never touched. Also, recorded criteria are grouped into four main categories, enabling the construction of the hierarchy much more convenient.

Last but not least, it is the first time that Analytic Hierarchy Process is applied in the dry port location problem. AHP dry port location decision model of Ningbo port is built to evaluate candidate sites of dry ports, thus helping the top managers of Ningbo port to arrive at the satisfactory outcome.

2. Dry Port Concept

2.1 Dry Port Definition

Before 1990s, there was little mention of dry port in the available literature. Beresford and Dubey might be the first ones that referred to dry port concept. According to Beresford and Dubey (1990), 'dry ports' are specific sites to which imports and exports can be consigned for inspection by Customs and which can be specified as the origin or destination of goods in transit with documentations such as a multimodal transport bill of lading (B/L). United Nations Conference on Trade and Development (UNCTAD) 1991 adopted such concept and later United Nations (1992a) worked out a detailed definition, supplementing the concept of dry port. Also, UN believed that the dry port which performs the same function as a port is, in principle, the vivid synonym of ICD. Particularly, United Nations (1992a) defines ICD as follows:

> Inland Container Depots (ICD) may be generally defined as facilities located inland or remote from port(s) which offer services for the handling, temporary storage and customs clearance of containers and general cargo that enters or leaves the ICD in containers. The primary purpose of Inland Container Depots is to

> allow the benefits of containerization to be realized on the inland transport leg of international cargo movements. ICD may contribute to the cost-effective containerization of domestic cargoes as well, but this is less common. Container transport between the port(s) and an ICD is under customs bond, and shipping companies will normally issue their own bills of lading assuming full responsibility for costs and conditions between the incountry ICD and a foreign port, or an ICD and the ultimate point of origin/destination.

However, United Nations (2001) presented another simple definition of dry port in its publication, that is, a dry port is “inland terminal which is directly linked to a maritime port”. This definition indicates that dry port is in fact one kind of inland terminals that has direct link with maritime port. As to inland terminals, OECD (2000, p134) contended that:

> Inland terminals may be considered as “extended gates” for sea ports, through which transport flows can be better controlled and adjusted to match conditions in the port itself. In this way, inland terminals can help to improve land access to ports in both physical and psychological terms.

Clearly, direct link can be physical and/or administrative. Yet European Commission tends to favor the physical aspect of link. Compared to United Nations (1992a)’s definition which focuses on the function of dry port, United Nations (2001)’s definition is in a sense associated with intermodality and inland accessibility.

What is worth mentioning is that in the same year, one investment report of PDCOR Limited, an infrastructure project development company in India, considered the dry port as a multi-modal logistic hub having both rail and road based connectivity and catering to the export and import traffic, functioning as an entrepôt for the landlocked states for export and import cargo being transacted with the gateway ports.

The next year experienced great improvement in the understanding of dry port concept. Bert (2002) pointed out that in reality dry ports, sometimes referred to as inland customs container terminals, are used to reduce port congestion by allowing arriving containers to be moved quickly and efficiently to a secure container yard under Customs control located some distance from the seaport. Besides he emphasized that dry ports normally offer traders complete Customs clearance services. Many credits are given to Roso & Leveque, who had assimilated the achievements of other scholars and made surveys on the companies or other organizations involved, advanced the following definition of dry port in their master thesis entitled *Dry Port Concept for Seaport Inland Access with Intermodal Solutions*: "A dry port is an inland terminal directly connected to seaport(s) with high capacity transport mean(s), where customers can leave/pick up their standardised units as if directly to a seaport." In accordance with this definition, three criteria should be fulfilled, namely, direct connection to seaport, use of high capacity mean(s) and availability of customer services that may be found in a seaport.

In recent literature concerning dry port research, Roso & Leveque's dry port definition is widely accepted. For example, Woxenius, J., Roso, V. & Lumsden, K. (2004), Kania, M.& Podsiadly, M. (2005), Roso, V. (2005), Roso, V., Woxenius, J., & Olandersson, G. (2006) and Woxenius, J., Kania, M., & Podsiadly, M. (2006) all take the dry port definition created by Roso & Leveque as their foundation of the further research.

When it comes to the dry port concept research in China, the available literature has been few and far between. Among a relative plethora of publication just mentioning the dry port name rather than explaining the concept, two papers can only be found that deal with dry port concept in depth. One is Wang (2004), who, in the master thesis, rendered a new definition to dry port. The definition has three key points. Firstly, dry port is different from container freight station and terminal in that dry port is the inland pivot of container transport; therefore the scale of dry port should be large. Secondly, dry port is well equipped, offering the same services except for shore to ship services. In other words, dry port extends the gates of the seaport inland and no wonder shippers are encouraged to transport large volumes of cargoes to dry ports as they have a feeling of dealing directly with the seaport. Thirdly, dry port expedites the movement of cargoes, thus improving the total logistic chain for domestic and international trade emanating in the hinterland.

Another article named *Construction of Dry ports in the Inland Area* written by Ye (2005) defined dry port as inland container transshipment hub served for shipping lines and local customers. Dry port performs the same function as seaport excluding the operations of loading for shipments and discharging from the ships. Shipping lines issue their own multimodal Bill of Lading and provide door-to-door services, considering dry ports as the critical nodes in the whole intermodal transport networks.

2.2Function and Quality of Dry Port

Container cargoes are classified into Full Container Load (FCL) and Less than

Container Load (LCL) by tariff and operations. A container of goods with the shipper being responsible for the packing and the consignee being responsible for the unpacking of the container at his own premises is called FCL container. By the same token, cargoes in any quantities (usually loose cargo) intended for carriage are loaded in LCL containers. The carrier is responsible for packing and unpacking the container at the carrier's premises.

As far as the traditional functions of dry port are concerned, basics of CFS and CY are supposed to be understood because dry port is borne out of advanced CFS and CY. CFS is short for Container Freight Station, a place where consignments are consolidated as a number of TEUs, which may be accommodated on board a ship. CY is the abbreviation of Container Yard, a place to which full container loads are delivered by the shipper to the ocean carrier and to which empty containers are returned. As a general rule, CFSs and CYs are situated within or close to port and they mainly perform the following functions according to UN, ILO (1995):

- to receive, sort, and consolidate export break-bulk cargoes from road vehicles, rail wagons and inland waterway craft;
- to pack export cargoes into containers ready for loading aboard a vessel;
- to unpack import containers, and sort and separate the unpacked cargoes into break-bulk consignments ready for distribution to consignees;
- to deliver import cargoes to inland transport –road vehicles, rail wagons and inland waterway craft;
- to store import and export cargoes temporarily, between the times of unloading and loading, while various documentary and administrative formalities are completed (e.g. customs inspection, settling of charges for packing, unpacking and storage, arranging transport).

- to store container boxes, both loaded and empty.

Dry port also possesses such traditional functions as CFS and CY. In addition, some other functional elements need to be added on account that dry port is the advanced form of CFS and CY. To sum up, there are seven functions in relation to dry port.

First of all, dry port is the hub for transshipment of units between different modes. Dry port can take advantage of its intermodal capability to attract cargoes from surrounding areas, hence becoming the convergence point of export and import cargoes in the region. Small shippers are especially interested in this because they are in a comparatively weak position.

Dry port also provides storage services of containers, both empty and waiting units, thus serving as a temporary storage space for containers that are between two journeys on carriers. It not only facilitates the intermodal transport and brings convenience to customers, but also benefits the improvement of container transport imbalance phenomenon.

Sometimes, dry port functions as an inland logistics center where a much broad range of value-added services are tendered, including stripping/stuffing, repackaging, customization, equipment maintenance, security services and so on. Such inland logistics center performs all logistical operations that are not strictly required to be carried out in the seaport itself, thereby easing the pressure of the seaport and speeding up the movement of export and import cargoes.

Customs clearance availability might be one of the eminent functional elements of dry port. In some cases dry port corresponds to inland customs clearance depot offering services for handling and temporary storage of any kind of goods, including containers carried under Customs transit by any applicable modes of inland surface transport, placed under Customs control and with Customs and other agencies competent to clear goods for home use, warehousing, temporary admission, re-export, temporary storage for onward transit and outright export. Particularly this regulatory arrangement with customs greatly harmonizes the import container transport. Quick removal of imported goods from the seaport is allowed with final clearance procedures taking place at the dry port or even at the receiver's place, helping to decrease the dwell time of containers in seaports and alleviate congestion. Therefore, it goes without saying that shippers are inclined to use dry ports. Figure 2.1 demonstrates transportation options of containerizable cargoes for shippers.

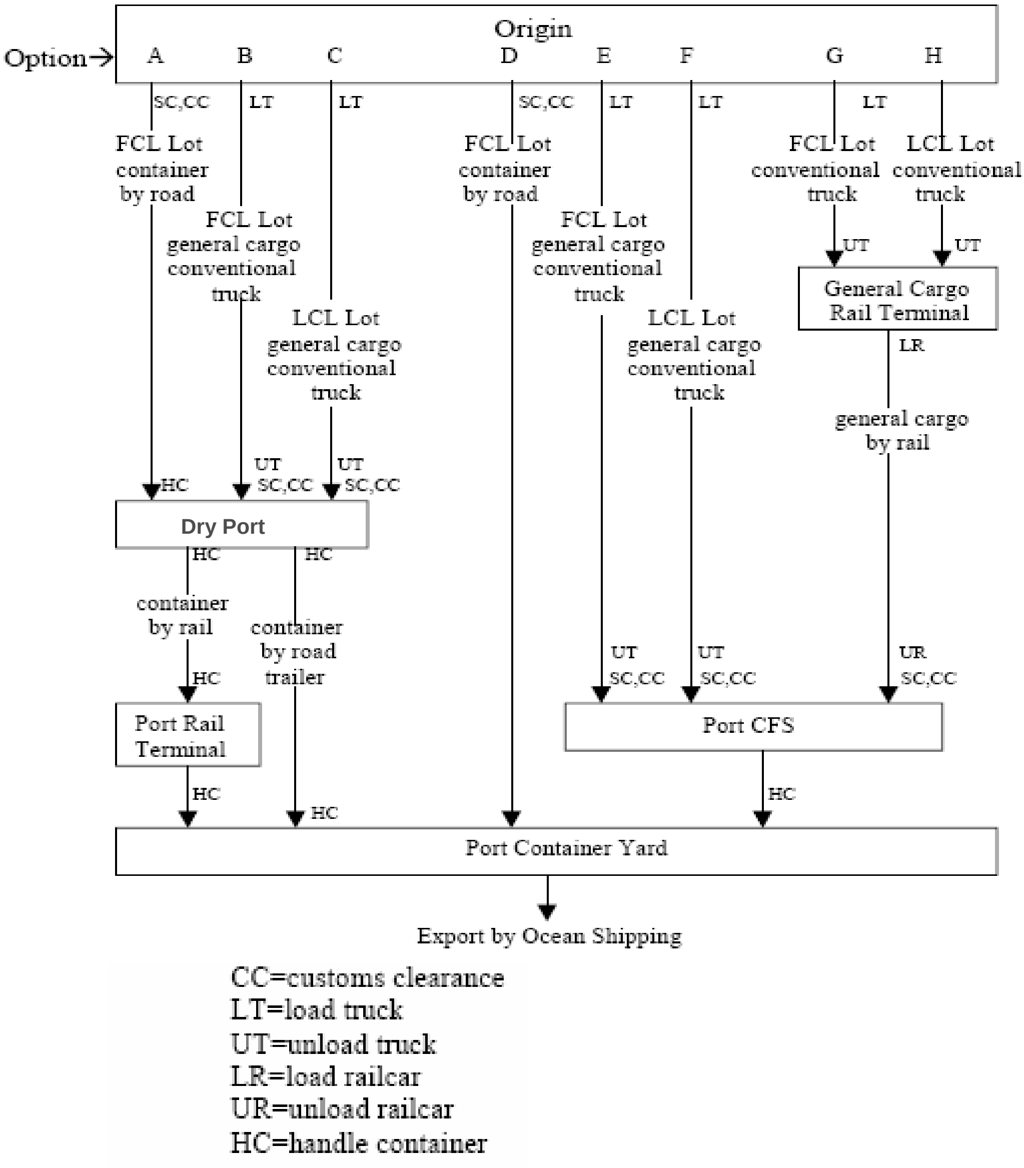

Figure 2.1 - Typical transportation options-exports (reverse order for imports)

Source: Xu, Y. Q. (1999). *A discrete choice based facility location model for inland container depots.*

To be well-functioned, the quality of basic components of dry port is of great significance. Attention is usually paid to available land size, infrastructure and equipment, intermodal connectivity, information technology employed and availability of customs declaration and other administrative support.

The size of the land for building the dry port must be large enough for operations. Generally speaking, dry port is composed of five parts, namely, warehouse or shed for temporary storage of cargoes and stuffing/stripping of containers, internal roadways for vehicle circulation and equipment movement, yard for stacking of loaded and empty containers, gatehouse for checking in and out cargoes and containers and offices for dry port personnel and inspection agencies.

Infrastructure and equipment in dry port are very much like those in seaport. Yet there is no quayside handling equipment since dry port is situated inland. Usually, there exist different container handling systems between stuffing/stripping points and container yards stacking heavy and empty containers. Examples are chassis system, lift-truck system, straddle carrier direct system, straddle carrier relay system, rubber tired gantry (RTG) system and rail mounted gantry (RMG) system, the choice of which depends on many factors, such as traffic volumes, distance, equipment purchasing and maintenance cost and land area utilization.

In most cases, quality of access to the dry port and the quality of intermodal interface may determine the quality of dry port performance. As a result, the need for dry port to have strong multimodal capability in the form of highway, rail, air, and/or waterway access is essential. On the contrary, there is no hope for a remote site with little intermodal connectivity to grow into a dry port.

Electronic means of information exchange, for instance, Electronic Data Interchange (EDI) are becoming more and more popular and vital in the facilitation and promotion of trade and transportation. As a critical point in the supply chain, dry port should be equipped with powerful information system to be productive and efficient. With the application of advanced information technology, Forrester

Effect or Bullwhip Effect first advanced by Forrester (1958), which means the variance of buyer demand becomes increasingly amplified and distorted at each echelon upwards throughout the supply chain, can be greatly reduced, resulting in better customer services. Nevertheless, because such information platform connects all the information systems of different actors involved, compatibility of these information systems is really a technical problem to be addressed.

Government agencies engaging in services like customs declaration, commodity inspection, animal/plant inspection and quarantine inspection should be contacted with in the dry port. However, in reality this is not always the case for various reasons. As is well known, the framework of customs in China is complex and distinctively Chinese. Customs houses are often unwilling to establish offices in the dry ports connected with seaports due to regional protectionism.

2.3 Dry Port Classification

From literature study, dry ports have mainly three kinds of classifications for different research purposes. Based upon different transportation modes, dry ports are classified under two types, namely, rail dry ports and highway dry ports. In the light of scale of operations, dry ports may be categorized as first level dry ports, second level dry ports, third level dry ports and forth level dry ports. According to different functions and locations, dry ports can be divided into three categories, viz distant dry ports, middle-range dry ports and close dry ports.

Xu (1999) mentioned two types of dry ports when he introduced dry port layouts. Rail dry ports, as the name implies, own sophisticated rail connections and use the rails as the main line haul mode. Highway dry ports, which might be more common, are known to use highways as the main line haul mode.

Wang (2004), a Chinese scholar, presented four levels of dry ports based on their different scale of operations, each level of which exists both international and domestic standards. The description and details with regard to four levels are as follows:

First level dry port: (1) International first level container dry port which is located in the vicinity of land transport hub with annual container transport volume reaching above 30,000 TEUs or storage volume over 9,000 TEUs per annum. (2) Domestic first level container dry port which is located in the vicinity of land transport hub with annual container transport volume reaching above 20,000 TEUs or storage volume over 6,000 TEUs per annum.

Second level dry port: (1) International second level container dry port which is located in the vicinity of land transport hub with annual container transport volume ranging from 16,000 TEUs to 30,000 TEUs or storage volume varying between 6,500 and 9,000TEUs per annum. (2) Domestic second level container dry port which is located in the vicinity of land transport hub with annual container transport volume ranging from 10,000 TEUs to 20,000 TEUs or storage volume varying between 4,000 TEUs and 6,000TEUs per annum.

Third level dry port: (1) International third level container dry port which is located in the vicinity of land transport hub with annual container transport volume ranging from 8,000 TEUs to 16,000 TEUs or storage volume varying between 4,000 TEUs and 6,500 TEUs per annum. (2) Domestic third level container dry port which is located in the vicinity of land transport hub with annual container transport volume ranging from 5,000 TEUs to 10,000 TEUs or storage volume varying between 2,500 TEUs and 4,000TEUs per annum.

Fourth level dry port: (1) International forth level container dry port which is located in the vicinity of land transport hub with annual container transport volume ranging from 4,000 TEUs to 8,000 TEUs or storage volume varying between 2,500 TEUs and 4,000 TEUs per annum. (2) Domestic forth level container dry port which is located in the vicinity of land transport hub with annual container transport volume ranging from 2,000 TEUs to 5,000 TEUs or storage volume varying between 1,000 TEUs and 2,500TEUs per annum.

Woxenius et al (2004) divided dry ports into groups of close, mid-range, and distant dry ports, all of which bring great benefits in contrast to conventional hinterland transport without the implementation of dry ports.

As the figure 2.2 illustrates, conventional hinterland transport relies most on road rather than on rail. What changes this situation is the implementation of three types of dry ports. Distant dry port which has the longest history among the three is located several hundreds kilometers from seaport. Apart from the reduced external environmental effects along the route, the implementation of a distant dry port can acquire new hinterland for the seaport by providing shippers with low cost and high quality services. To the seaport that shares the common hinterland with its competitors, the existence of dry ports that strengthen the competitive advantage of the seaport is therefore extremely important.

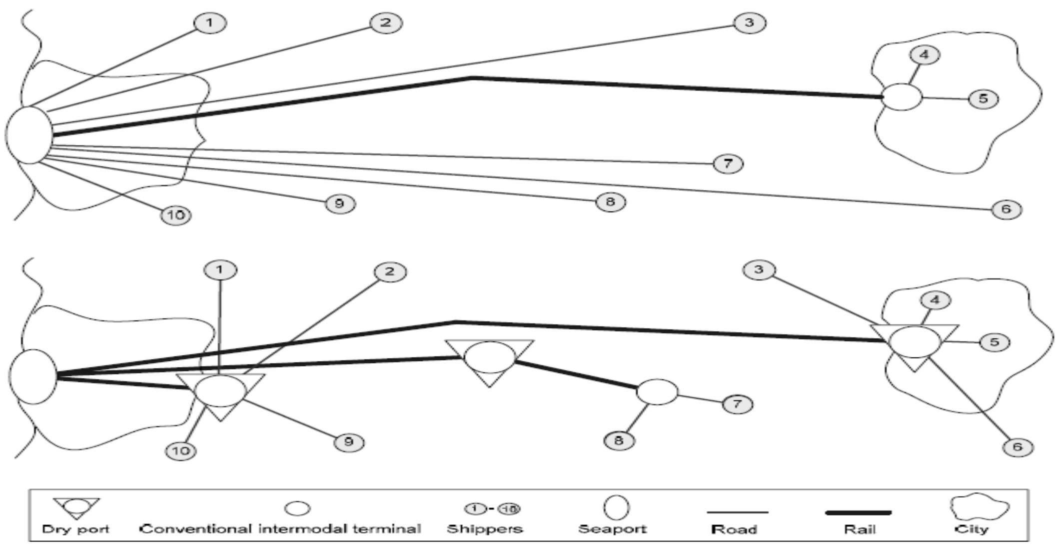

Figure 2.2 - Comparison between conventional hinterland transport and implemented dry port concept (close, mid-range and distant dry port).
Source: Woxenius, J., Roso, V. and Lumsden, K. (2004). *The Dry Port Concept-Connecting Seaports with their Hinterland by Rail*, in proceedings of the 1st International Conference on Logistics Strategy for Ports, ICLSP, Dalian, China.

Closer is middle-range dry port serving as a consolidation point for rail services. It is worth remarking that besides gaining the similar benefits as the distant dry port, middle-range dry port can also act as a buffer that relieves the pressure of seaport's stacking areas. For those cost-sensitive shippers with comparable distance to the seaport and the dry port, they are probably to transport goods in large quantities to dry port when there is a strain on the availability on stacking space in the seaport.

The last category, close dry port, whose distance to the seaport is the shortest, is usually set up in the immediate hinterland of seaport or at the rim of the seaport city. Owning to the trend of containerization, one headache seaports facing today is limited terminal capacity or lack of space. The establishment of close dry ports seems to be a proper way to resolve this situation because close dry port helps further ease the burden of tight capacity with a reliable rail shuttle to the seaport.

3. The Necessity for Ningbo Port to Boost Dry Port Development

3.1 Container Traffic Development in Ningbo Port

China has experienced a rapid growth in container transportation, with annual port throughput growth rate over 29％ in the last decade. Ports such as Shanghai and Shenzhen have caught the eye of the whole world, as they have grown to be the world-class mega ports just in few years. Besides these mega ports, there are also some smaller and less famous ports that have the same ambitious and enormous potential in the mainland of China. Ningbo port is no doubt the most brilliant one of them. Compared with other main ports in China, Ningbo port started later in container transportation, but it is doing its best to catch up, especially in the last decade. From 1999-2004, for 5 years running, it has been taking the first place for its increase rate among the chief container ports of Mainland China. Up to now, there are more than 156 lines calling at Ningbo port as shown in table 3.1, with monthly 600 services.

Table 3.1 - Weekly liner services in Ningbo port in year 2006

Destination of Line	Number of Weekly Service
Europe	14
Mediterranean	12

West America	16
East America	4
Middle East	12
Red Sea	1
South America	9
Australia and New Zealand	4
West Africa	1
India	3
Southeast Asia	11
Russia	2
Korea	6
Korea and Japan	4
Japan	15
Taiwan	4
Hongkong	2
Domestic Feeder	22
Domestic Trade	14
Total	156

3.1.1 The Advantages of Ningbo Port in the Development of Container Traffic

The amazing growth rate achieved by Ningbo port is mainly attributed to the following four factors:

First is the rapid development of outbound economy in its hinterland. The hinterland of Ningbo port mainly lies in Yangtze River Delta (YRD), including Shanghai Municipal city, Jiangsu Province and Zhejiang Province. The outbound economy in YRD has been regarded as a miracle in recent years. As showed in figure 3.1, the annual growth rate of export in YRD reached 28.3% from 1998 to 2003, while the national growth rate in the same period was 19.0%. The proportion of YRD in nation's export rose from 23.5% to 34.2%. The rapid development in outbound economy has spurred container transportation, which is the major transportation mean of China's foreign trade. The container throughput in the same period recorded an annual growth of 32.5%.

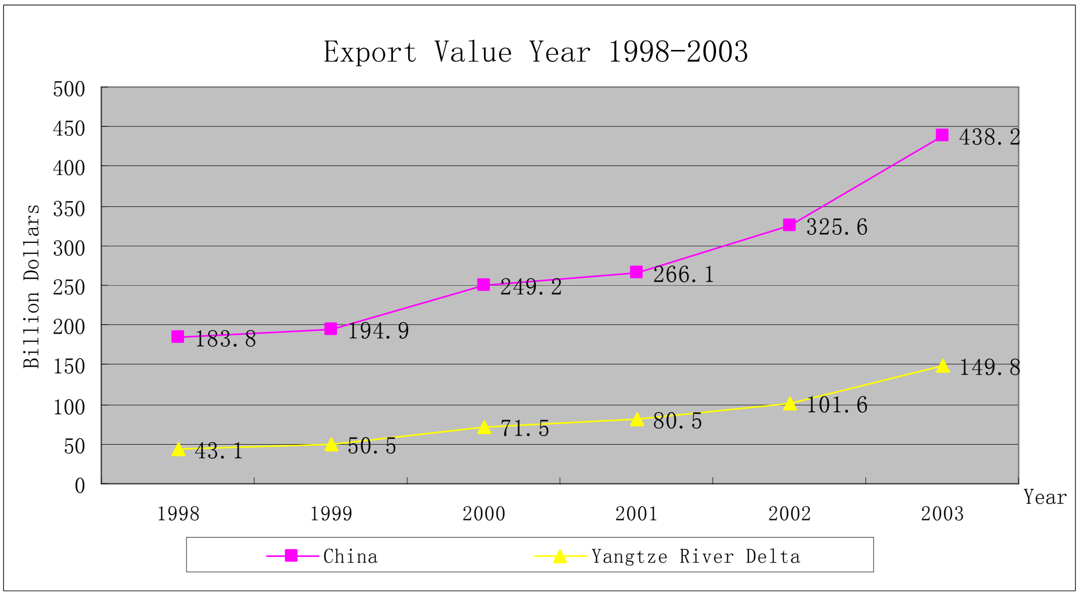

Figure 3.1 - Annual growth rate of export in YRD and China
Source: National Bureau of Statistics of China

Second is its geographic location and outstanding natural conditions. Geographically, Ningbo port is well situated in the middle of China's coastline, at the T-shaped joining point of China's coastline and the Yangtze River. It enjoys unique natural conditions with convenient traffic reaching in all directions. Outwardly the port links East Asia and the whole round-the-Pacific region. It's within 1000 sea miles to Hongkong, Gaoxiong of Taiwan, Pusan, Osaka and Kobe. It connects inwardly China's coastal ports and covers directly the whole East China and the economically developed Yangtze River Valley by river-sea through transport via the Yangtze River and the Grand Canal. It's therefore an ideal place for developing ocean-going transport to the ports of America, Europe, the Middle East and Oceania.

In terms of natural conditions, sheltered by Zhoushan Archipelago, the port area of Ningbo is free from strong winds and waves, with workable days more than 350 in a year. The entry channel is normally over 18.2 meters deep. Large ships of 250,000 up to 300,000 tonnage can come and leave at tide.

Third is the significant improvement in transportation infrastructure. An all-positioned, stereoscopic transport network of collection and distribution has taken an initial shape at Ningbo Port with expressways, railways, airway, river-sea through transport and water-to-water transfer as showed in figure 3.2.

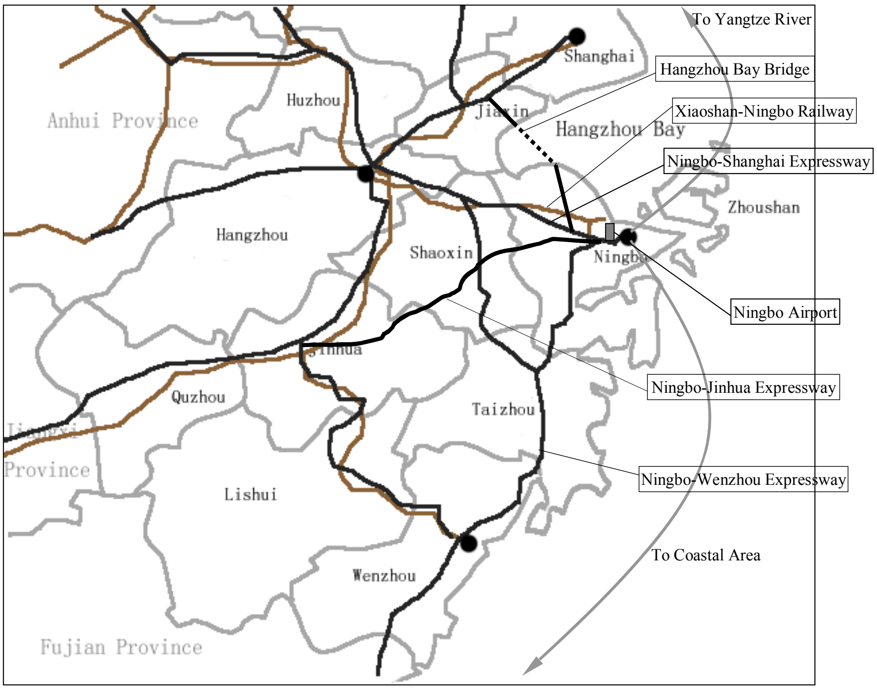

Figure 3.2 - Transportation network of Ningbo port

Water to water transshipment: Ningbo Port connects inwardly China's coastal ports and covers directly the whole East China and the economically developed Yangtze River Valley via the Yangtze River and the Grand Canal. Cargoes may reach directly Wuhan and Chongqing by river-sea through transport.

Highway: Shanghai-Hangzhou-Ningbo Expressway, Hangzhou-Nanjing Expressway, Ningbo-Taizhou-Wenzhou Expressway and Ningbo-Jinhua Expressway have all been open to traffic. The great bridge across Hangzhou Bay is expected to be completed in 2007. Once completed, the traffic time from Ningbo to Shanghai by land will be reduced to 2 hours. The deep-water advantage of Beilun Port Area will be further brought into play.

Railway: In-dock railways stretch to the port apron and link with the national railway network via Xiaoshan-Ningbo Railway, making it easier for inland provinces and cities to conduct export trade through the port. Sea-railway through transport of containers has formally started at the rail CFS of Beilun Port Area.

Airway: Regular flights from Ningbo to Hongkong have been opened at Lishe Class B International Airport of Ningbo.

Fourth is the convenient and normative port inspection system. There are complete port inspection set-ups in Ningbo, which are speedy and efficient in work. From May of 1996, all the inspection and service set-ups of Ningbo entered the port area and worked together, undertaking coordinated services of customs declaration, inspection, finance, insurance, ship agency and cargo agency for customers. From the end of June of 1999, approved by the Customs Administration General, the business of through clearance between Hangzhou and Ningbo was formally started, facilitating cargo owners in Hangzhou district to go through locally the formalities of customs declaration of international containers, exchange settlement and drawback. The through container transport between Hangzhou and Ningbo reduced transshipping links greatly. At the same time, storage yards for international containers were built at the industrial park of Jinhua City and a commodity inspection organ was set up at the through supervising spot from Jinhua to Ningbo Customs House, providing an economic and convenient passage to the sea for the inland areas of Zhejiang Province.

3.1.2 Container Throughput Forecast and the Corresponding Infrastructure Development

The government of Ningbo Municipal City has carried out a series of forecast research on container transportation, the result of which is encouraging. It is expected that in year 2010 the container throughput in Ningbo port will reach 11 million TEUs. To meet the demand in 2010, a number of container terminal projects have been planned. Table 3.2 gives a whole picture of container terminals in Ningbo port before year 2010. From the table, it can be seen that currently there are 4 terminals and 13 berths in service. To year 2010, there will be 5 terminals and totally 26 berths. Obviously, the capacity will double from 2006 to 2010.

Table 3.2 - The number of container berths in Ningbo port before year 2010

Terminal	**Completed year**	**Number of berth**	**Depth**
Beilun International Container Terminal	1992	3	-13.5
Beilun 2rd Container Terminal	2001	4	-15
Beilun 3rd Container Terminal	2004	2	-17
	2005	2	-17
	2006-2007	5	-17
China Merchants international Terminal	2005	2	-17
	2006	2	-17
Yongjin Terminal	2007	2	-18
	2010	4	-18

Source: Ningbo Port Group Ltd.

3.1.3 The Problems that Hinder the Further Development of Ningbo Port

It goes without saying that Ningbo port is confronted with the fierce competition from Shanghai Port. A recent picture of container throughput at both Shanghai and Ningbo container ports reveals that the port of Ningbo now constitutes a significant threat to Shanghai's position as the leading container port on the Central Eastern Seaboard of Mainland China. As can be seen in figure 3.3, the (largely international) container throughput to the hinterlands of the two ports has continued to expand at a very high average annual growth rate of approximately 30% over the period 1997-2005. In addition, the graph reveals that Ningbo's market share of the two ports' total international container throughput has been consistently increasing over this period at the expense of Shanghai. Thus port of Ningbo has been regarded as the main threat to port of Shanghai.

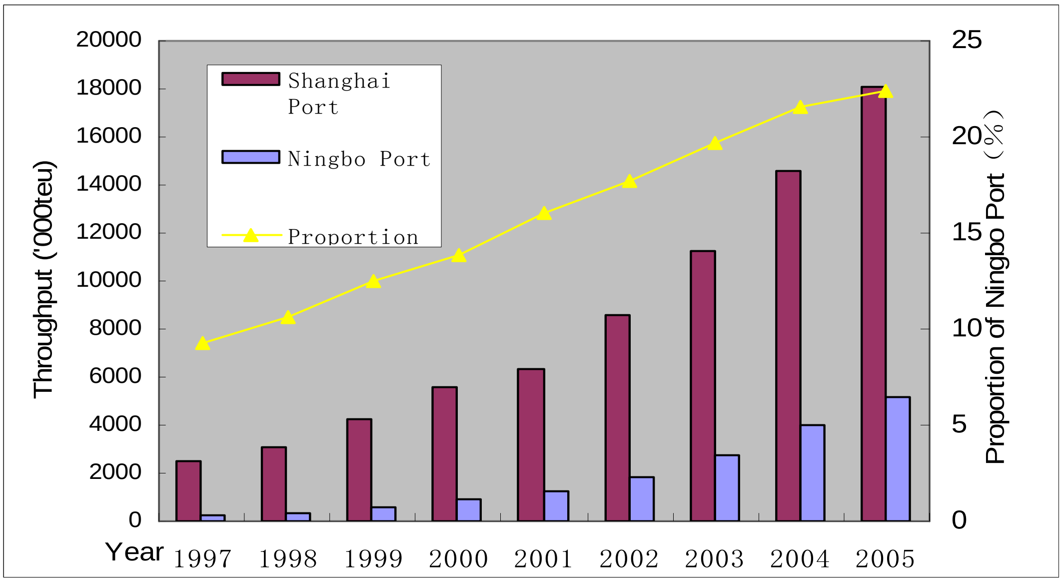

Figure 3.3 - The container throughput in the port of Shanghai and Ningbo from year 1997 to 2005.

During 2003-2004, as China deepened its reform, the former port authorities, acting as both operators and administrators of ports, were divided into two parts: port administration bureaus and enterprises, thus the former monopoly state in port industry was broken and a relatively free market has been set up. This change, of course, brought great impact on port competition, especially in the development of container transportation. Depending on its stronger position in finance and market, Shanghai port took a very aggressive competition strategy. It has set up joint ventures at the key points of the Yangtze River, such as Wuhan and Chongqing, and also in coastal feeder ports, such as Wenzhou, to build up an integrated network of container transportation and consolidate its dominated status in the Yangtze River Delta and consequently squeezes the development space of Ningbo port.

In the process of hinterland extension, Ningbo port is gradually gaining its advantages. To some destinations, especially in Zhejiang Province, Ningbo Port has the advantage in land transportation. Meanwhile, the freight rates on the major lines in Ningbo port, such as China to Europe and North American, have already declined to the same level as Shanghai’s or even lower, as liner services have increased dramatically in recent years in Ningbo port. However, currently the catchment of Ningbo port is still limited in the east and south of Zhejiang province, as showed in figure 3.4, according to the previous research work by Ningbo Port Group Ltd. On balance, there are still two obstacles that prevent the shippers from using Ningbo port as their export or import port.

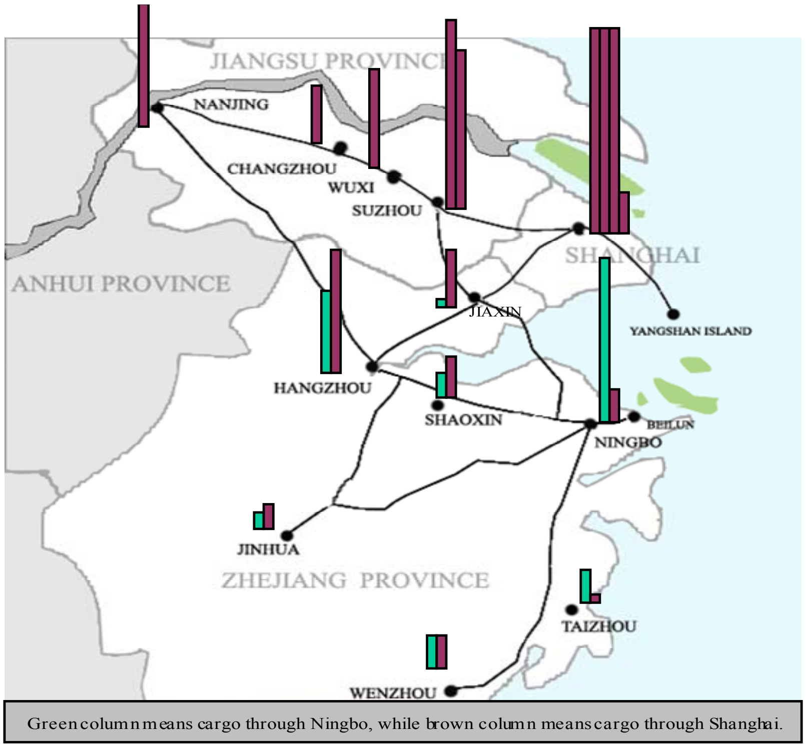

Figure 3.4 - The distribution of container cargo sources in the Yangtze River Delta.

The first obstacle exists in the freight forwarders. As the container traffic grows too fast in Ningbo port, its freight forwarders can hardly keep the pace in hinterland extension to set up their branches and networks in the region that used to be the domain of the forwarders in Shanghai.

As to transact customs business in seaport, inland forwarders have long-term mutual trust relationship with Shanghai forwarders. Currently, in China, the individual relationship between forwarders and shippers is still very crucial in business, and clients' information is sensitive in forwarders' circle. Therefore it will be cautious for the inland forwarders to do business with their counterparts in Ningbo port. For the cost advantage in choosing Ningbo port is limited, many inland forwarders aren't willing to take the risk of client loss to change the former business routines. It will take a long time for the inland forwarders to build up a trusting relationship with the forwarders in Ningbo, while the development of Ningbo port cannot afford such a waiting.

Second obstacle lies in customs. Ningbo Customs District is directly under the administration of China Customs just as Hangzhou, Shanghai and Nanjing Customs Districts are. If containers come from outside Ningbo, the inland forwarders must come to Ningbo for customs declaration, quarantine inspection, commodity inspection, animal/plant inspection, etc, which will consequently increase the cost of inland forwarders. New operation model has appeared, named through clearance, which allows cargoes to be cleared in the inland customs, but it is still experimental and in small scale.

3.2 The Importance of Dry Port and its Development in Ningbo Port

3.2.1 The Development of Transport Logistics and its Influence on Modern Ports

From JIT (just-in-time) in early 1970s to the latest CPFR (Collaborative Planning, Forecasting & Replenishment), the trend in supply chain business model is the integration of organizations from upstream to downstream. CPFR is a business model that engages manufacturers and retailers into exchanging marketplace information in order to come up with a customer specific plan that can substantially reduce inventory, with forecasts force sharing of promotion schedules, POS data, and inventory data enabling shorter lead-times and integration between forecasting and replenishment processes. The influence on transport logistics sector relating to such trend is that customers become more demanding in terms of services. The shipments become more frequent, less in volume but stricter on the delivering time. All of these lead to the integration in transport logistics, since successfully integrated logistics management ties all logistics activities together in a system, which works simultaneously to minimize total distribution costs and maintain desired customer service levels (Kenderdine & Larson, 1988; Gustin et al., 1995). Through integration 3PLs not only extract costs and efficiency but also find more chances in delivering value to the end customer and gain competitive advantage (Robinson, 2001). The integration trend is also reflected by the customers' demand. According to the survey carried out by Containerisation International (2001) on global shippers, about 39% of the total respondents said they were in favour of "one-stop" shop, and required their logistics partners to provide warehousing and secondary distribution services as well.

The impact of logistics integration on the quality of a modern port can be concluded into three points. Firstly, it puts a challenge to the port operation, because there still exist some gaps between the organizations in the maritime sector. Avery (2000) pointed out that ports need to do more in co-operation with carriers' diversified service strategies. For example, port should stow the import containers in a concordant way with customers' demand on timeliness. Secondly, the land accessibility will be emphasized in the quality of a modern port. Considering the large scale of hinterland, and long distance in land transportation, the gain in the high quality liner service may be upset by poor intermodal operation and inland transportation. The cost and time consumed in intermodal operation will be a determinant factor of the port's penetration ability into the inland market. Thirdly, the integration of logistics also changes the structure of maritime community. The introduction of integrated transport model such as door-to-door or point-to-point transport has been shifting the choice of port from the shipper to the shipping lines (Marti, 1988). The major port clients consider ports merely as a sub-system in the logistics chain and port choice becomes more a function of network costs (Notteboom & Winkelmans, 2001).

Mourão et al. (2002) argued that ports compete not only in terms of transshipment efficiency and tariffs, but also in terms of speed and reliability of shipments to destinations on the continent. That competition requires seaports to focus on transport links, on the demand for services in their traditional hinterlands and also on development in areas outside their immediate market.

As China gradually opens its market, which it promised to WTO, the giant international logistics providers, such as DANZAS, Maersk Logistics, Schneider Logistics, etc., have entered china's freight market in recent years. They are more demanding on logistics services than the traditional Chinese freight forwarders. To keep those giant clients, ports in China must face the challenges that brought by logistics development.

3.2.2 The Merits of Dry Port

Considering the functions of dry port that mentioned in chapter 2, and also the successful experience in various regions, establishing dry ports in hinterland has been regarded as an important strategy of port development. In the scenario of Ningbo port, dry port has following merits:

1. It provides a platform for logistics services to cope with the rapid logistics development in hinterland and fulfill the need of international freight forwarders. With the dramatic growth of container cargoes, the space around port area is taking great pressure to meet the need of terminal construction and its corresponding infrastructure development. As a result, there is less space left for the increasing amount and the broadening scope of logistics services. Table 3.3 illustrates the logistics services provided by 3PL. Diverting these services from seaports to dry ports will be a good solution.

Table 3.3 - The scope of 3PL's services

Transportation	Supply chain management	Information management	Cargo handling	Other service
Outbound transportation Inbound transportation	Logistics planning Inventory management Supply chain design Returns/reverse logistics	Web-based linking EDI Information system management	Labelling Packaging Cross-docking Track and trace Assembly and production Inspection and quality control Pick and pack Customs clearance Shipment consolidation Warehousing	Invoicing Factoring/financing Payment processing Management reports Order processing Fleet management Promotional support

2. It reduces the total logistics cost. Compared to CY and CFS in seaport area, dry port has its cost advantage to act as a logistics platform, as the land and labor costs in seaport area are significantly higher than the inland area. For example, the land cost for one hectare around port area for CY is about 0.75 million dollars in Ningbo in 2005, while it only costs 0.15 million dollars in Jiangxi Province, which is adjacent to the west side of Zhejiang Province. By establishing dry ports in inland, Ningbo port can cut down the total logistics costs of cargoes through them.

3. It secures the clients of inland freight forwarders and encourages them to use

optional seaport. With the existence of dry port, the inland freight forwarders may transact the customs and inspection business locally. The inland freight forwarders don't need to consign the freight forwarders in seaport to process the related formalities, thus avoiding the loss of client information as mentioned in chapter 3.1 and also saving the commission.

4. It speeds up the distribution of containers and facilitates the inspection and customs clearance. The local authorities, such as customs, commodity/animal/plant inspection bureaus, will provide better and more flexible services than their counterparts in seaports, as they know the local shippers or consignees better. Just as is referred to in chapter 2, quick removal of imported goods from the seaport avoids the usual congestion in seaport, helping to decrease the dwell time of containers. In the scenario of Ningbo Port, commodity inspection will usually take one or two days, and may be longer during the peak period of terminal operation. Figure 3.5 shows the whole process of commodity inspection operation in seaport. What impresses us is that by through container transport to dry port, the dwell time of containers can be reduced at least by one or two days.

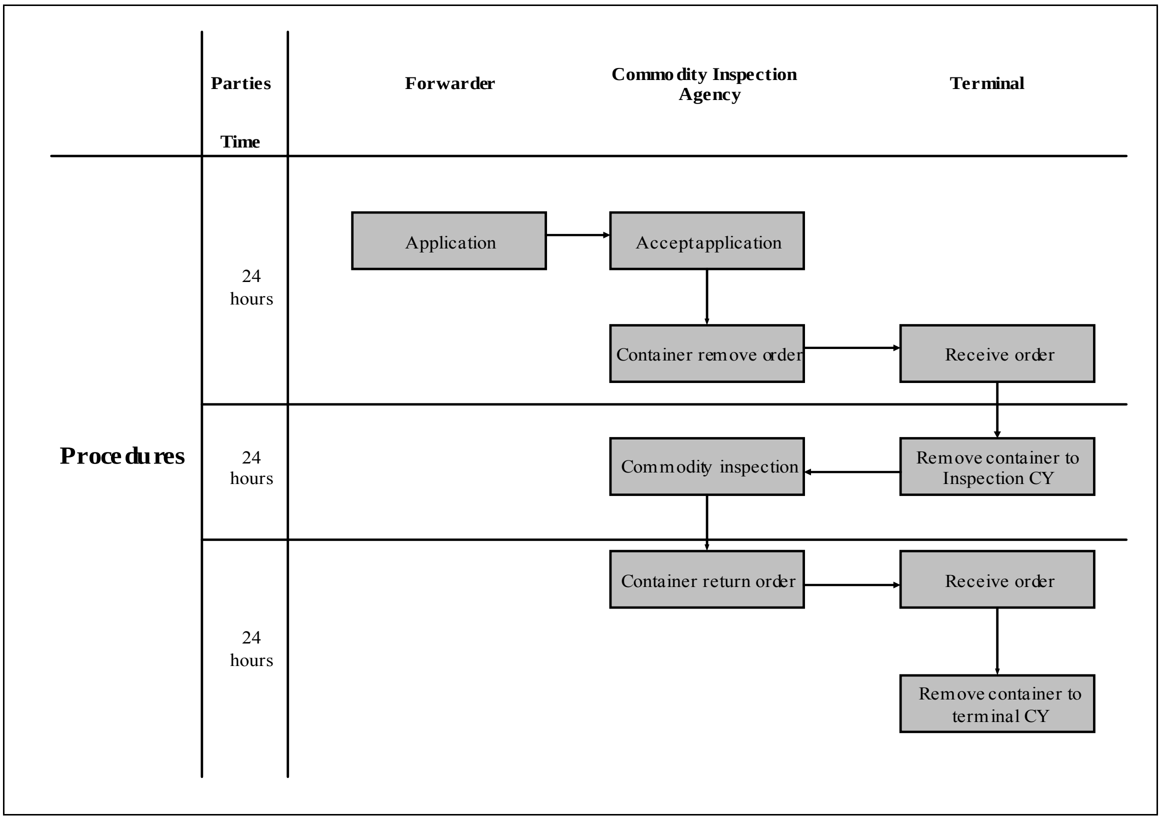

Figure 3.5 - Procedures of commodity inspection in Ningbo Port

5. It helps the carrier extend their transportation services to inland market. With customs clearance at dry port, the carrier can sign the bill of lading to or from the dry port.

6. It reduces the road haul freight rate. As mentioned in chapter 2, dry port provides storage service of containers, and the carriers store their empty container in it. Therefore, it provides the customers an option to use one-way haul rather than the conventional round-trip haul as showed in figure 3.6.

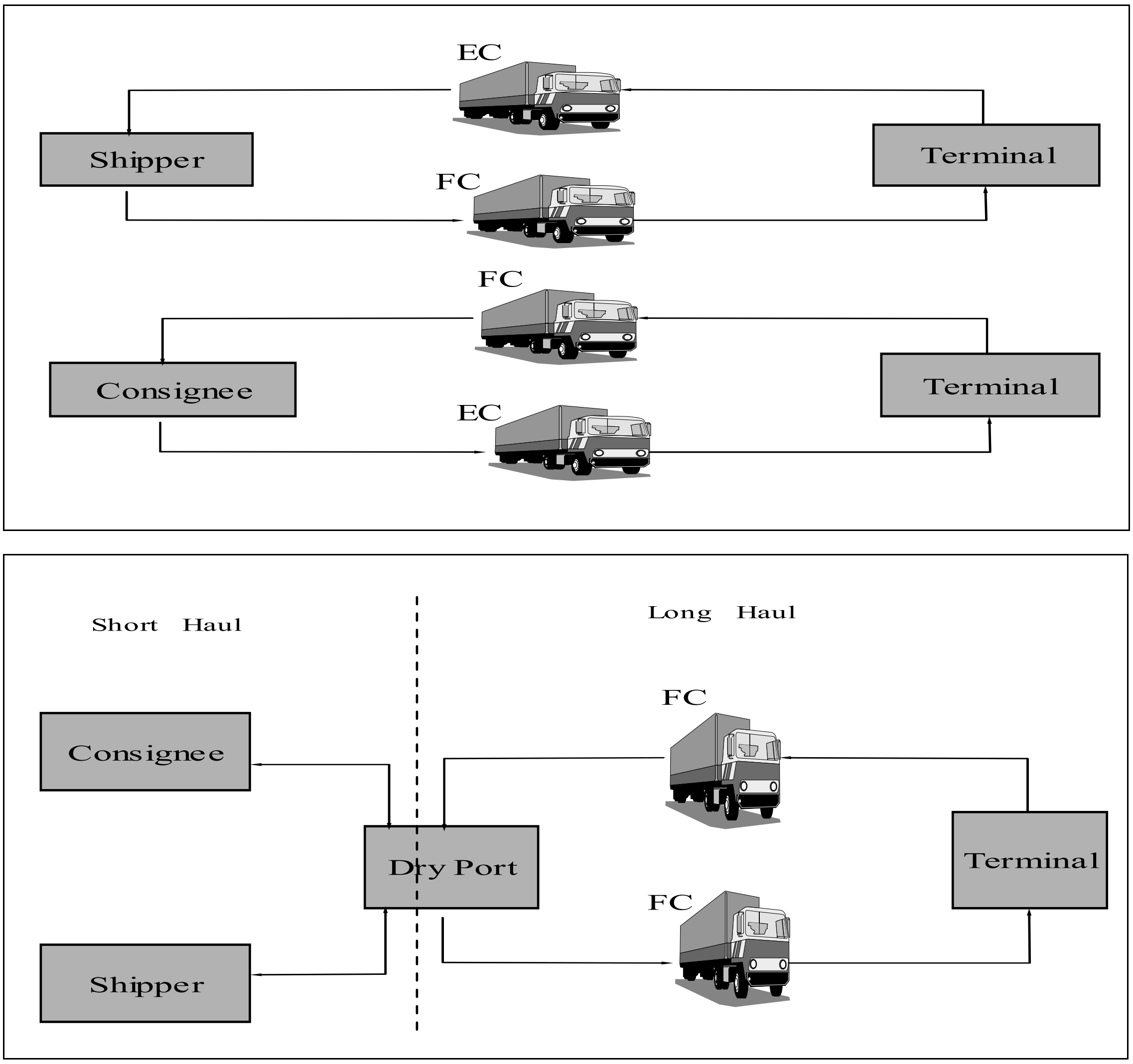

Figure 3.6 - Round-trip haul and one-way haul

3.2.3 Dry Port Development in the Hinterland of Ningbo Port

As described in chapter 1, worldwide development of dry port is not only initiated by the mega carriers, but also by ports and terminal operators. In Rotterdam, ECT (European Container Terminals), the largest container terminal operator participates in inland terminals in the Netherlands, Germany and Belgium, and enables an integrated transport services to these inland ports. (Peter & Ariane, 2004).

The development of dry port and its predecessors, CY and ICD, in Ningbo port have taken two courses. Under the first course, they are sponsored by the freight forwarders, carriers and related interest parties, while under the second course, they are sponsored by port administrations and inland local governments strategically aiming at stimulating local economy and improving the infrastructure.

To date, more than a dozen CYs and ICDs have been established around the port area of Ningbo port and in its hinterland. Table 3.4 shows the name, capacity, equipment, function of the existed CYs. Table3.5 shows the existed logistics centers or ICDs in the hinterland of Ningbo port. Figure 3.7 displays the geographic locations of the listed ICDs. From the data, we can see currently the development of dry ports in Ningbo port still remains at its early stage, characterized by focusing on the skirt area of the seaport. Though there are already nine ICDs, most of them are developing under the second course. Consequently they, to some degree, lack economic viability, and are doubtfully to be the optimal locations in the network. As a matter of fact, the locations of the ICDs are too close to the seaport. Those ICDs wholly rely on the benefits brought by inland customs clearance but cannot enjoy any benefits from intermodal transportation. Therefore, the profits gained from those ICDs probably cannot cover the costs raised by using them.

Table 3.4 - Existed CYs around Ningbo port

Name of Yard	Total area ('000 m²)	Capacity of Empty Container (TEU)	Capacity of Full Container (TEU)	Warehouse (m²)	Rail-mounted Gantry Cranes	Rubber-tyred Gantry Cranes	Frontloader	Reachstacker	Business Scope
New Century Logistics	63	3500	2877	2918	1	2	1	2	Inspection, warehouse, packing/unpacking, container stack, container repair, bonded logisitics
Dagang Container Yard	51	9800	2500	6000	1	—	1	2	Inspection, warehouse, packing/unpacking, container stack, container repair
Tongda Container Yard	190	18900	2300	5952	2	—	4	5	Inspection, warehouse, packing/unpacking, container stack, container repair, PTI inspection
Taiping Container Yard	35	3000	500	6500	—	—	2	2	packing/unpacking, container stack, container repair, bonded logistics
Anxin Container Yard	35	6000	—	3000	—	—	—	4	warehouse, container stack, container repair
Changshen Container Yard	90	14000	—	4054	—	—	1	6	container stack, container repair, PTI inspection
Donghua Container Yard	38	5000	—	—	—	—	—	3	warehouse, container stack, container repair
Gaoxin Container Yard	80	4000	—	—	—	—	1	2	warehouse, container stack, packing/unpacking
Hongda Container Yard	135	11000	1500	2100	—	—	2	3	warehouse, container stack, packing/unpacking, customs sealing
Lingrong Container Yard	50	4700	1000	5200	—	—	2	3	inspection, warehouse, container stack, packing/unpacking, bonded logistics
Tianxiang Container Yard	40	6000	—	3000	—	—	—	2	warehous, container stack, PTI inspection
Xunda Container Yard	30	3600	576	5100	—	—	2	1	warehouse, container stack, packing/unpacking
Xinhe Container Yard	37	6400	—	3000	—	—	1	3	warehouse, container stack, packing/unpacking, PTI inspection
Zhongya Container Yard	55	5300	—	5200	—	—	1	2	container stack, packing/unpacking, container repair

Table 3.5 - The existed logistics centers in the hinterland of Ningbo port

No.	Name of Dry Port	Yard under Custums Supervision(m²)	Total Yard (m²)	Throughput in 2004(TEU)
1	Hangzhou Internation Logistics Center	8400	40015	11239
2	Xiaoshan Inland Internation Logistics Center	5863	86710	11000
3	Fuyang Internation Logistics Center	8000	50000	83828
4	Shaoxing Internation Logistics Center	5600	30000	11776
5	Jiaxin Internation Logistics Center	3000	50000	15600
6	Huzhou Internation Logistics Center	2000	118725	9500
7	Yiwu Internation Logistics Center	50000	213440	8500
8	Jinhua Internation Logistics Center	7150	172750	2079
9	Yuyao Internation Logistics Center	2000	88711	12000

Source: http://zjeco.zei.gov.cn/2005/0506/13.htm.

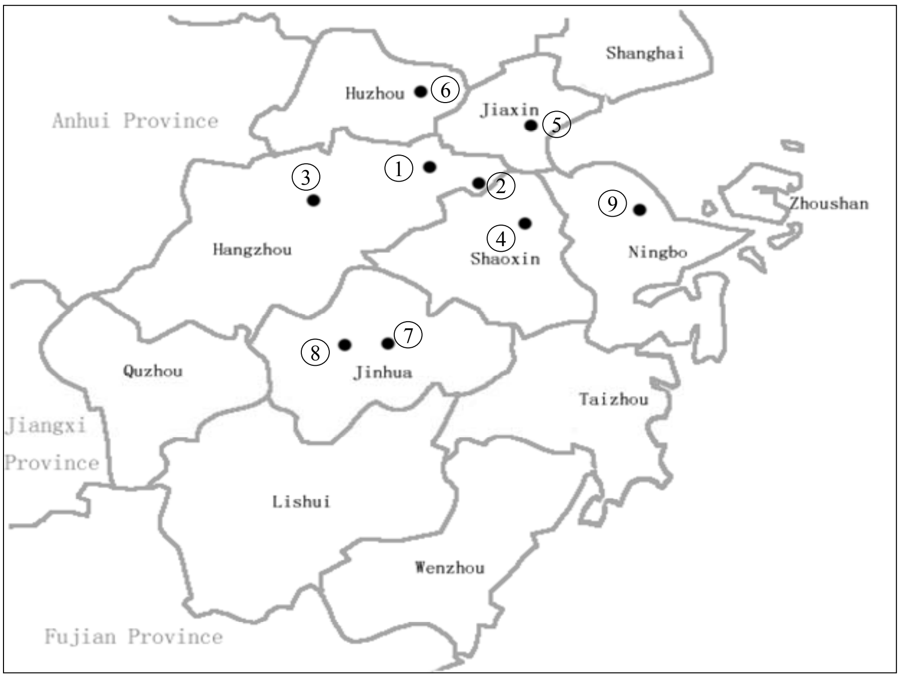

Figure 3.7 - Geographic locations of existed ICDs in the hinterland of Ningbo port.

Although the situation is not satisfying, Ningbo port has possessed the conditions for dry port development. As indicated in table 3.4, some of the CYs have been well equipped and functioned, just as the typical dry ports, except for their locations and intermodal transshipment capability. Those nine ICDs are the attempts of Ningbo port on dry port development. They are hardly to be regarded as successful projects; nevertheless, they are experimental and provide valuable experiences.

Today, as the outbound economy in inland regions is booming and more and more FDI go to inland regions, the potential of the provinces like Jiangxi, Anhui, Hunan and Hubei cannot be underestimated, evidenced by the export volume of these four provinces as showed in figure 3.8. Noticeably the time has come to establish dry ports in these regions to facilitate the transportation and trim the logistics costs.

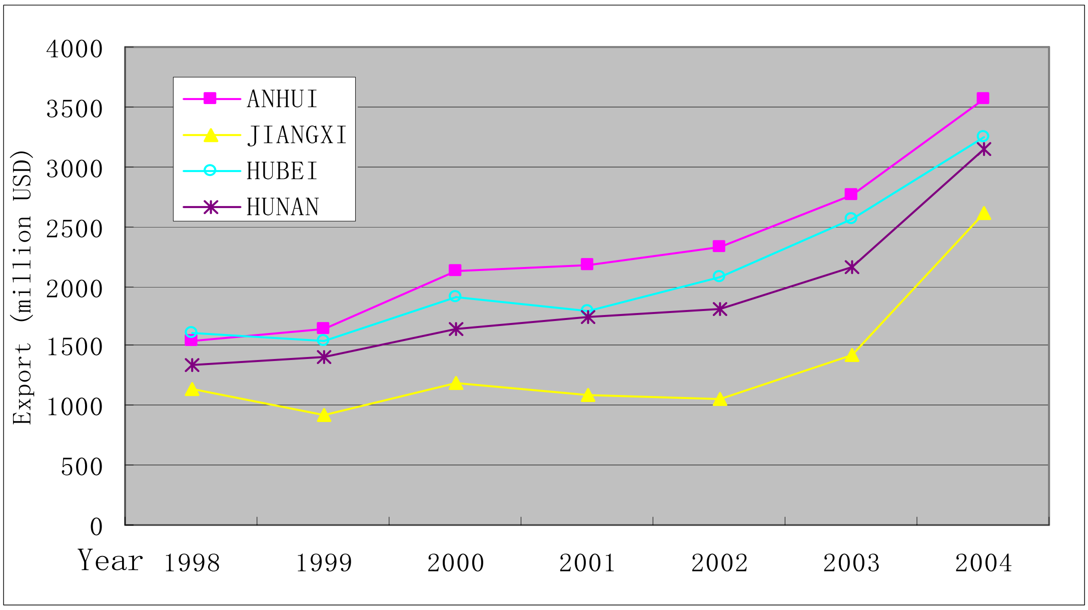

Figure 3.8 - The export value in four inland provinces from year 1998 to 2004

3.3 The Problems Encountered in Dry Port Location Decision in the Circumstances of Ningbo Port

The literature reviewed in chapter 1 and 2 theoretically discussed location decision and the factors such as inland transport cost, labor cost etc, have been emphasized. However, in reality the problem is more complex, hence in the case of Ningbo port, based on the experiences from the existed ICDs, more factors must be taken into account.

Firstly, local government initiative is recognized to be an important factor. To meet the functions as mentioned in chapter 2, such as storage of empty container, warehousing, container repair, and other logistics services, dry port will occupy large amount of land. Accordingly, acquirement of a land with suitable size and in right site is crucial to a project of dry port, especially when the central government tightened the control of land use. Besides, local government also sets the price of land and offers favorable tax policy.

Secondly, collaboration of local customs and inspection agencies must not be ignored due to its significance in practice. To carry out the business such as customs clearance and commodity inspection, dry port should be an area under the supervision of customs, and need to be authorized by customs administration, which sometimes depends on the willingness of local customs and seaport customs. Currently, through clearance mode is still experimental in China. The customs in seaports are, however, reluctant to accept and promote the development of through clearance, as it will divert customs revenue that is supposed to be their most important performance measurement.

Thirdly, Port competition is a special factor on which emphasis should be placed. Ningbo and Shanghai are located very closely, both of which need larger hinterland to sustain the ever growing container throughput and solidify their status in the chief ports of mainland. Numerous projects have been allocated by Shanghai port along the Yangtze River and coastal area to facilitate the container transportation. Hence it is of little sense for Ningbo port to establish a dry port where its rival possesses overwhelming advantages. Concerning Ningbo port's scenario, dry port's location decision should not only consider the optimal candidate sites to Ningbo port, but also their location attractiveness to Shanghai port.

Fourthly, infostructure is an indispensable factor, as dry port is deemed as the node point in logistics network. The use of information technology to form a consolidated logistics network has become an inevitable trend. Information technology (IT) has been regarded as a logistics resource as well as a competitive weapon (Closs et al., 1997). New conceptions such as 'Virtual Logistics', which creates many powerful new possibilities in the design of logistics systems and means that major improvements in efficiency become possible, are totally based on information technology. According to Berglund et al. (1999), IT skills are at the base of the total four value creation ways of logistics. These include operational efficiency, sharing resources, development of a network of service providers, and use of conceptual logistics skills to improve the customers' supply chains.

With above factors in mind, the location decision of dry port in the hinterland of Ningbo port is so complicated that only a typical quantitative analysis cannot be solved, for example, cost-effectiveness analysis. A solution that combines quantitative and qualitative factors ought to be sought.

4. Location Selection Criteria of Dry Port & Preliminary Selection of Candidate Sites

4.1 Location Selection Criteria of Dry Port

In this section, a comprehensive set of factors that may exert the influence on the dry port location decision are at first identified from an analysis of the relevant existing literature. Then a Delphi study is carried out to investigate the factors influencing dry port location decision, with the participation of a panel of experts from marine-related organizations. The final selection criteria for dry port location are at last presented and discussed.

4.1.1 Literature Review

Unlike general facility location problems, there is limited literature on dry port location selection criteria. Roso et al (2006) made the claim that a dry port is specific to each location depending on traffic volume, traffic pattern, special trade requirements and local conditions. According to Beresford and Dubey (1990), the factors to consider in the location analysis for a dry port site are: traffic flows between centres of production and consumption and the ports; modes of transport available and network capacities; transport infrastructure in the vicinity of the site; existing auxiliary transport related services in the vicinity of the site; possible reduction in tonne-km by road transport with the introduction of the dry port; the actual functions of the dry port, such as road haulage, stuffed and empty container storage, shunting, customs clearance; scope for future site expansion, etc. One investment report of PDCOR Limited, entitled *Multi-modal Logistic Center (Dry-Port) at Bhiwadi Region, Rajasthan*, proposed the following dry port location parameters: inter-modal connectivity; number of port services provided at the facility itself; total costs involved in export/import of cargoes; dwell time of export/import containers; repair facilities for containers; customs facility available; information technology employed, including EDI; type of handling equipment provided; availability of banks, communication facilities and other administrative and support facilities; availability of warehouse and availability of reefer points.

This author also refers to numerous papers on general facility location criteria which can be served as the initial pool of criteria on dry port location criteria in order to supplement the inadequate literature on dry port location factors. A comprehensive list of general facility location factors that are relevant to dry port are listed in table 4.1.

Table 4.1 - Factors considered in facility location decisions

Factors	Studies
Area's business climate	Galbraith and De Noble (1988); Hekman (1992); Schemenner (1979)
Attitudes of local and state governments	Galbraith and De Noble (1988); Schemenner (1979)
State and local government incentives	Blair and Premus (1987); De Noble and Galbraith (1992); Galbraith and De Noble (1988); Stonebraker and Leong (1994)
Transportation costs	Blair and Premus (1987); De Noble and Galbraith (1992); Fulton (1971); Hekman (1992) Stonebraker and Leong (1994)

Availability of transportation facilities	Blair and Premus (1987); De Noble and Galbraith (1992); Galbraith and De Noble (1988); Stonebraker and Leong (1994)
Labor productivity and attitude toward productivity	Fulton (1971); De Noble and Galbraith (1992); Galbraith and De Noble (1988); Hekman (1992); Schemenner (1979); Stonebraker (1994)
Cost of labor	De Noble and Galbraith (1992); Galbraith and De Noble (1988); Hack (1984); Hekman (1992); Schemenner (1982); Schemenner et al. (1987) Stonebraker and Leong (1994)
Availability of labor	Blair and Premus (1987); Galbraith and De Noble (1988); Stonebraker and Leong (1994)
Land availability for building and expansion	Galbraith and De Noble (1988); Hekman (1992); Schemenner (1982); Stonebraker and Leong (1994)
Cost of land	De Noble and Gailbraith (1992); Fulton (1971); Hekman (1992); Stonebraker and Leong (1994)
Cost of construction	Hekman (1992); Schemenner et al. (1987); Stonebraker and Leong (1994)
Proximity and access to markets	Blair and Premus (1987); Galbraith (1985, 1990); Galbraith and De Noble (1988); Hack (1984); Hekman (1992); Schemenner (1982); Stonebraker and Leong (1994)
Tax structure and rates	Blair and Premus (1987; Fulton (1971); Galbraith and De Noble (1988); Schemenner (1982); Schemenner et al. (1987)
Insurance considerations	Fulton (1971)

Financing opportunities	Blair and Premus (1987); Fulton (1971); Schemenner (1982)
Banking services	Stonebraker and Leong (1994)
Local and physical infrastructure	Blair and Premus (1987)

Source: Adapted from Fahri Karakaya and Cem Canel: Underlying dimensions of business location decisions. Industrial Management & Data Systems 98/7 [1998]

During the brainstorming session, the author, one academic port expert and one manager of Ningbo port discussed selection criteria from both literature of dry port and facility location decisions. As a result, 30 summarized criteria were chosen out. Nevertheless, what we need are the most critical factors that play the significant roles in dry port location decision. From this angle, 30 criteria might be too much. Hence, initial recorded criteria should be narrowed down in a systematic way, making sure that the most important criteria for choosing a dry port location are recognized and validated.

4.1.2 Delphi Study

The application of Delphi technique is deemed as the right approach to help investigate and identify the most important factors influencing the decision-making on dry port location.

Delphi technique was originally developed as a short-term forecasting approached by the Rand Corporation in the late 1940s (Benson et al, 1982; Klassen & Whybark, 1994). Owning to the fact that a single opinion may be incorrect, misinformed or narrow, Delphi technique uses a representative group of experts to generate a more accurate and more informed response rather than relying on one individual opinion. Unlike brainstorming or other group approaches, Delphi approach avoids face-to –face communication and interactions of individuals. Such anonymous nature of Delphi prevents a result that might be biased by one or more influential panelists.

This approach reduces the influence of dominant individuals and develops a consensus of expert opinions on subjective issues (Ray & Sahu, 1990; Azani & Khorramshahgol, 1990; Klassen & Whybark, 1994; Green & Price, 2000). Moreover, the power of the Delphi approach is that it provides more understanding of complex problems than other survey techniques. As Ray & Sahu (1990) stated, the Delphi method is a helpful tool to explore and judge miscellaneous future scenarios, and is likely to provide more information than other methods.

Delphi is primarily a qualitative knowledge elicitation approach that focuses on using an expert panel to arrive at a consensus of opinions. It is not designed for advanced statistical analysis and does not, in itself, show relationships or interactions between factors. Delphi studies must not be confused with conventional statistical sampling and inferences techniques. Instead of randomly surveyed, the panellists were selected based on their experience and knowledge pertaining to the subject being considered and on their willingness to participate. Panellists should be mutually anonymous. As a matter of fact, Delphi technique requires a minimum group size of about 20 participants to reduce the bias that could derive from individual opinions.

In order to gain the major location criteria of choosing a dry port, the panel was designed to have representatives from shipping industry, academia and government who are sufficiently knowledgeable and experienced. In particularly, the panel was composed of 22 experts, three from shipping lines, five from freight forwarding companies, eight from Ningbo Port Group Ltd., four from academia and two from government organizations, such as local customs and inspection agencies. The study was conducted in strict confidence throughout and anonymity was guaranteed to respondents. Two rounds of Delphi surveys were carried out to achieve the purpose.

In the first round, the Delphi panelists were asked to rate major criteria that are considered to be important in locating a dry port using a seven-point scale ranging from 1 (not important) to 7 (very important). The cut-off method for mean ratings at a value of 5.0 will be used to scale factors down. The reason for cutting off at 5.0 is that at this point it can be considered that the factors are relatively important to the decision process as key determining factors. The first round responses were combined and analyzed in order to statistically collate and summarize the results for another round of the process. In the second round, the interim report which summarizes the group response of the initial survey was sent back to panallists. A general agreement was reached at the end of the second round. Overall, it was felt that a third round would not do anything more to the result provided by the first two rounds and thus the study was concluded. The results of the study derived from two rounds conducted are presented below.

4.1.3 Results

Eleven dry port location criteria are remained as they were rated equal to or more than 5.0 (round off). They are proximity to the source of container cargoes; proximity to high capacity transport system; location to other competing seaports; transportation infrastructure; infostructure; collaboration of local customs and inspection agencies; local government initiatives; land potentiality and cost; construction cost; labor cost and availability of related business services.

Dry port location criteria, on balance, can be grouped into four categories, namely geographical location, cost, physical and technical infrastructure and business environment.

(1) Geographical location: This category is generally acknowledged as the most important one for locating a dry port. Three sub-factors such as proximity to

the source of container cargoes, proximity to high capacity transport system and location to other competing seaports are included.

(2) Cost: Cost in this study mainly refers to land potentiality and cost, construction cost for building specific dry port and labor cost.

(3) Physical and technical infrastructure: As the name indicates, this category comprises two sub-criteria; one is transportation infrastructure which is tangible while the other is infostructure that is intangible, like the availability of EDI.

(4) Business environment: With regard to dry port location decision especially in China, government attitude and incentive always catches public eyes. In addition, auxiliary business services have been receiving more and more emphasis. All these, specifically, collaboration of local customs and inspection agencies, local government initiatives and availability of related business services, constitute the whole business environment in which dry port is operated.

Dry port location criteria, based on the measurability, integrate both quantitative and qualitative elements. The quantitative elements can be measured in numerical values, such as the cost of land, construction cost and labor cost. The qualitative criteria, on the other hand, cannot readily be expressed in numerical values and evaluated by quantitative models. Rest of criteria excluding cost fall in this range and therefore certain model is needed to assess the importance of these evaluation criteria as well as the performances of potential candidates which firstly meet these criteria.

4.2 Preliminary Selection of Potential Candidate Sites

Before the appropriate evaluation model is established for helping selecting best dry port locations, potential candidate sites have to be found out as the decision alternatives of the evaluation model. In this section, the structure of the hinterland of Ningbo port is initially examined in order to pinpoint the intended market in which possible candidates exist. With the dry port location criteria educed from 4.1 in mind, some sites devoid of due qualification are washed out in the intended market. As a result the remainders are the preliminary dry port locations for further evaluation using the suitable model.

4.2.1 The Structure of the Hinterland of Ningbo Port

The hinterland of Ningbo port can be divided geographically into three parts as demonstrated in figure 4.1. The first part is mainly the area south of Hangzhou Bay, covering the most part of Zhejiang province. The second part is mainly the area north of Hangzhou Bay, covering the south of Jiangsu, north of Zhejiang province and Shanghai city. The third part includes the west provinces that close to Zhejiang, namely, Jiangxi province, Anhui province and other provinces in the center of China.

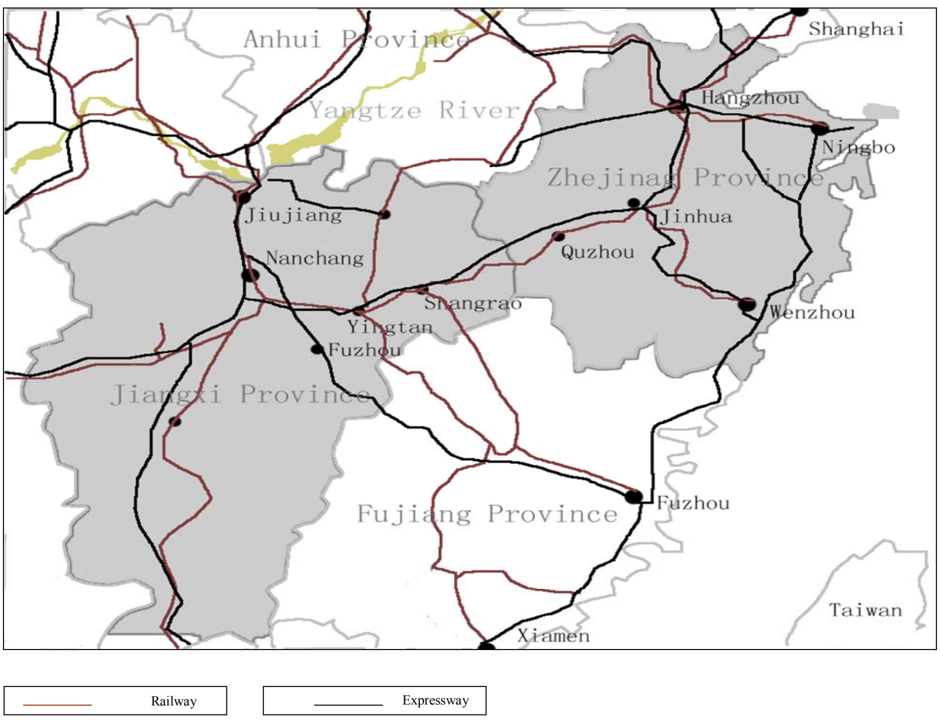

Figure 4.1 - Structure of the hinterland of Ningbo port and its inland tansportation

Currently, the first part of hinterland has been the main source of container cargoes of Ningbo port. The second part is a rich source but dominated by Shanghai port, as it has land transportation advantage over Ningbo port. Third part only accounts for a very small amount of container cargoes due to undeveloped outbound economy in the center of China. Nevertheless, the situation is changing as China opened the inner provinces to the foreign investors and the cost of manufacture in coastal area rose. In that case, container cargoes in these areas are growing rapidly and the upward momentum is estimated to be strong.

4.2.2 The Choice of Candidate Sites

The candidate sites for dry port locations in the whole hinterland are numerous. However, it is meaningless to compare the candidate sites in different parts of the hinterland facing different markets. Thus Jiangxi province is primarily chosen as the intended market where the potential candidate sites lie.

Jiangxi is a province adjacent to the west of Zhejiang province. From the figure 4.1, it can be seen that there are mainly three connections of inland transportation. First is the Chuangjin expressway connecting Nanchang, the capital of Jiangxi province, with Jinhua, and consequently with Ningbo port by Yongjin expressway. Second is the Zhegan railway, which crosses through Jiangxi province and connects the cities in Zhejiang province such as Quzhou, Jinhua, Hangzhou and Ningbo. Third is river-sea transportation through Yangtze River from the port of Jiujiang.

What is worth stressing is that a dry port should have strong multimodal capability in the form of highway, rail, or waterway access, which is also clarified in chapter 2 as one of the qualities of dry port. With this quality to be a precondition, the candidate sites for dry ports in Jiangxi Province are limited. By eliminate the cities without the connection of railway, expressway and waterway to Ningbo port, we eventually get 6 candidate sites of dry ports: Jiujiang, Nanchang, Fuzhou, Yingtan, Shangrao and Quzhou. On the whole, these six candidate sites comply with other dry port criteria, hence no one among six candidates should be got rid of. A general description of these places is given as follows:

(1) Jiujiang: a city located in the north of Jiangxi province and settled besides Yangtze River. It has connection with Nanchang by expressway and railway. Jiujiang port is one of the main ports on Yangtze River.
(2) Nanchang: the capital of Jiangxi province, with Zhegan and Jinjiu railway across it and five expressways connected with other provinces. It is regarded as the transportation pivot of Jiangxi province.
(3) Fuzhou: a city located in south of Nanchang, with Zhegan railway and Changfu expressway in connection.
(4) Yingtan: a city located in east of Jiangxi province, with Zhegan, Yingxia and Wangan railway crossing it and also connected by Changjin expressway.
(5) Shangrao: a city located in east of Jiangxi province, close to the border of Zhejiang province, connected by Zhegan railway and Changjin expressway.
(6) Quzhou: a city located in west of Zhejiang province, close to the border of Jiangxi province, connected by Zhegan railway and Changjin expressway.

5. AHP Dry Port Location Decision Model of Ningbo Port

5.1 Choice of Methodology

Just as the literature review on dry port location problem indicates, current dry port location models have some limitations. First, they lack application-oriented solution procedures that are practical to handle real-world problems. Selecting a dry port location, in most real world applications, is a complex process involving multiple sites to be considered, multiple criteria to be evaluated and multiple stages to be conducted. Second, under multiple criteria comparison, more often no single location site could dominate all other alternatives under consideration in a clear-cut fashion. Instead, each candidate site may have an appealing advantage in its favour, as such the ultimate selection will be the result of a compromise, other than an “optimal” decision. Finally, they are mainly concerned with quantitative factors, that is, qualitative factors are basically not incorporated in the majority of reported dry port location decision models. However, in many cases, qualitative factors are the primary concerns in the dry port location selection, such as land potentiality, intermodal capability and so on.

Hence, a framework that can present and organize all related dry port location factors, both quantitative and qualitative, into a solution structure is essentially needed. At the same time, a detailed analysis of dry port location factors with the selected sites is a must. Undoubtedly, Dry port location selection is a typical multi-criteria decision-making (MDM) problem in which managerial preference among performance criteria plays a key role in the final decision. To assess the decision-maker's preference explicitly with a preference model, many efforts have been made to develop the theory and methodology for preference assessment. In the current literature, the most preferred approaches are multi-attribute utility theory (MAUT) and analytic hierarchy process (AHP) (Falkner and Benhajla, 1990; Saaty, 1990). In the context of dry port location decision, AHP might be the suitable approach. As opposed to some traditional evaluation techniques, AHP is a multi-criteria decision-making technique well suited to derive collective judgements and account for not only quantitative but also for qualitative impacts, facilitating the quantitative comparison of alternatives.

The AHP methodology is a flexible tool that can be applied to any hierarchy of performance measures (Rangone, 1996), which enjoys many advantages. Saaty (2001) listed 10 advantages of AHP as a decision-making tool: unity, complexity, interdependence, hierarchy structure, measurement, consistency, synthesis, tradeoffs, judgement and consensus and process repetition. Although AHP has a successful track record regarding applications in the wider transport area following its introduction as a multiple criteria decision-making (MCDM) methodology in the late 1970s (Saaty, 1977), for example, Frankel (1992), Tzeng & Wang (1994), Poh & Ang (1999), Chang & Yeh (2001), Vreeker et al (2002), Lirn et al (2003), Yedla & Shrestha (2003), unfortunately there is no application of AHP in the field of dry port location problem up to now, which this dissertation is dedicated to bridge the gap.

5.2 Analytic Hierarchy Process

The analytic hierarchy process (AHP) was developed by Thomas L. Saaty in early

1970s in response to military contingency planning, scarce resources allocation, and the need for political participation in disarmament agreements (Saaty, 1980). The basic idea of AHP is to break down a complex and unstructed problem into a set of components organized in a multi-level hierarchic form so as to minimize the complexity. According to Saaty (1980), "a hierarchy is a particular type of system, which is based on the assumption that the entities, which we have identified, can be grouped into disjoint sets, with the entities of one group influencing the entities of only one other group". A salient feature of AHP is to quantify decision makers' subjective judgements by assigning corresponding numerical values based on the relative importance of factors under consideration. A conclusion can be reached by synthesizing the judgements to determine the overall priorities of variables (Saaty, 1994a)

AHP is one of the more widely applied multi-attribute decision-making methods, analyzing a variety of decisions with respect to complex technological, economical and socio-political problems. Up-to-date successful applications of AHP have been reported in marketing, finance, education, public policy, economics, medicine, and sports (Saaty, 1990, 1994a, 1994b).

The analytic hierarchy process is composed of five main stages: developing the hierarchy tree, constructing pairwise comparison matrices, getting relative priorities, checking for consistency and obtaining overall priority ranking of the decision alternatives.

The first step in AHP is to develop the hierarchy tree in terms of the overall objective, criteria and decision alternatives, which is the graphical representation of the problem. Initially, overall objective needs being broken down into subunits, on which the decision-maker can focus. Overall objective is always represented at the top level of the hierarchy tree, with criteria, sub-criteria, and alternatives represented at the subsequent lower levels. By this way, various criteria are grouped and structured in a hierarchical manner showing the relationship among them.

The key step in AHP is to construct pairwise comparison matrices by using Saaty's scale. Pairwise comparisons are fundamental building blocks of AHP. At the criteria level, decision makers specify judgements about the relative importance of each criterion in terms of its contribution to the achievement of the overall objective. Similarly, at the decision alternative level, AHP asks the decision makers to indicate a preference or priority for each decision alternative in terms of how it contributes to each criterion. The main advantage of this pairwise comparison method is that only two criteria are compared at any given time, revealing a clear inter-relationship between them. Moreover, given that the procedure focuses on two factors at a time and their relation to each other, decision makers will be more comfortable to offer relative than absolute preference information.

The relative importance of each item is rated by a measurement scale in AHP to provide numerical rating corresponding to verbal judgements. Such instrument in the construction of pairwise comparison matrices, developed by Saaty, is a nine-point ordinal scale, from 1 to 10 with 1 representing the equal importance of two factors and 10 being the highest possible importance of one factor over another. In other words, the degree of importance becomes higher while moving from one to nine. The nine-point scale expressing the intensity of importance for one criterion versus another is displayed in table 5.1. Research and experience have confirmed the nine-point scale as a reasonable basis for discriminating between the preferences for two items.

Table 5.1 - Pairwise comparison scale of relative importance

Intensity of Relative Importance	Definition
1	Equal Importance
2	Equal to Moderate Importance
3	Moderate Importance
4	Moderate to Strong Importance
5	Strong or Essential Importance
6	Strong to Demonstrated Importance
7	Demonstrated Importance
8	Demonstrated to Extreme Importance
9	Extreme Importance

Source: Anderson, D. R., Sweeney, D.J., & Williams, T. A. (1997). *An introduction to management science: quantitative approaches to decision making. (8th ed.).* West Publishing Company.

After constructing the pairwise comparison matrix, the next step is to arrive at the relative priority of each of the elements being compared. Three steps to calculate the relative priorities are listed below (Anderson, Sweeney & Williams, 1997, p. 650).

Step 1: Sum the values in each column of the pairwise comparison matrix.

Step 2: Divide each element in the pairwise comparison matrix by its column total; the resulting matrix is referred to as the normalized pairwise comparison matrix.

Step 3: Compute the average of the elements in each row of the normalized matrix; these averages provide an estimate of the relative priorities of the elements being compared.

In this way, priority vectors which are the column vectors giving the relative priorities for the various criteria are established. By looking at the priority vector values, relative rating of the various selection criteria is obtained.

An important consideration in terms of the quality of the ultimate decision relates to the consistency of judgements that the decision-makers demonstrate during the series of pairwise comparison matrices. Consistency of judgements refers to the consistency in the process of making judgments regarding the importance of one criterion over the other. In fact, the validity of the pairwise comparison matrix depends on the consistency in the process of assigning weights to the various criteria. Once the relative priorities have been evaluated, the consistency of judgements should be checked. This is done by calculating the consistency ratio. Inconsistent judgment leads to poor consistency ratio of the pair-wise comparison matrix, making the AHP output more non-realistic (Saaty, 1980). The recommended consistency ratio is less than or equal to ten percent, indicating a reasonable level of consistency in the pairwise comparison matrix and that the decision process can continue. If, on the other hand, the consistency ratio is greater than ten percent, then the pairwise comparison matrix is held to be inconsistent and the decision-maker should reconsider and possibly revise the pairwise comparison judgements before proceeding with the analysis.

Finally, the criteria priorities and the priorities of each decision alternatives relative to each criterion should be combined in order to obtain the overall priority ranking of the decision alternatives, which is the ultimate output of analytic hierarchy process. The procedure used to compute the overall priorities for each decision alternative can best be understood if the priority for each criterion is thought as a weight that reflects its importance. The overall priority matrix can be gained by summing the products of the criterion priority times the priority of its decision alternatives.

5.3 AHP Dry Port Location Decision Model

5.3.1 Evaluation Framework of AHP Dry Port Location Decision Model

In this section, a dry port location decision model using AHP which can be applied to Ningbo port scenario is developed. Quantitative factors as well as qualitative factors are taken into consideration in this model. With the help of the model, decision-makers are able to evaluate and compare the preliminary feasible candidate sites under both quantitative and qualitative factors with a view to getting the final dry port location selections. This model that incorporates managerial experience and judgements of decision-makers with dry port site characteristics is expected to be instrumental in untangling the dry port location problem of Ningbo port. A four-level evaluation framework of AHP dry port location decision model is displayed in figure 5.1.

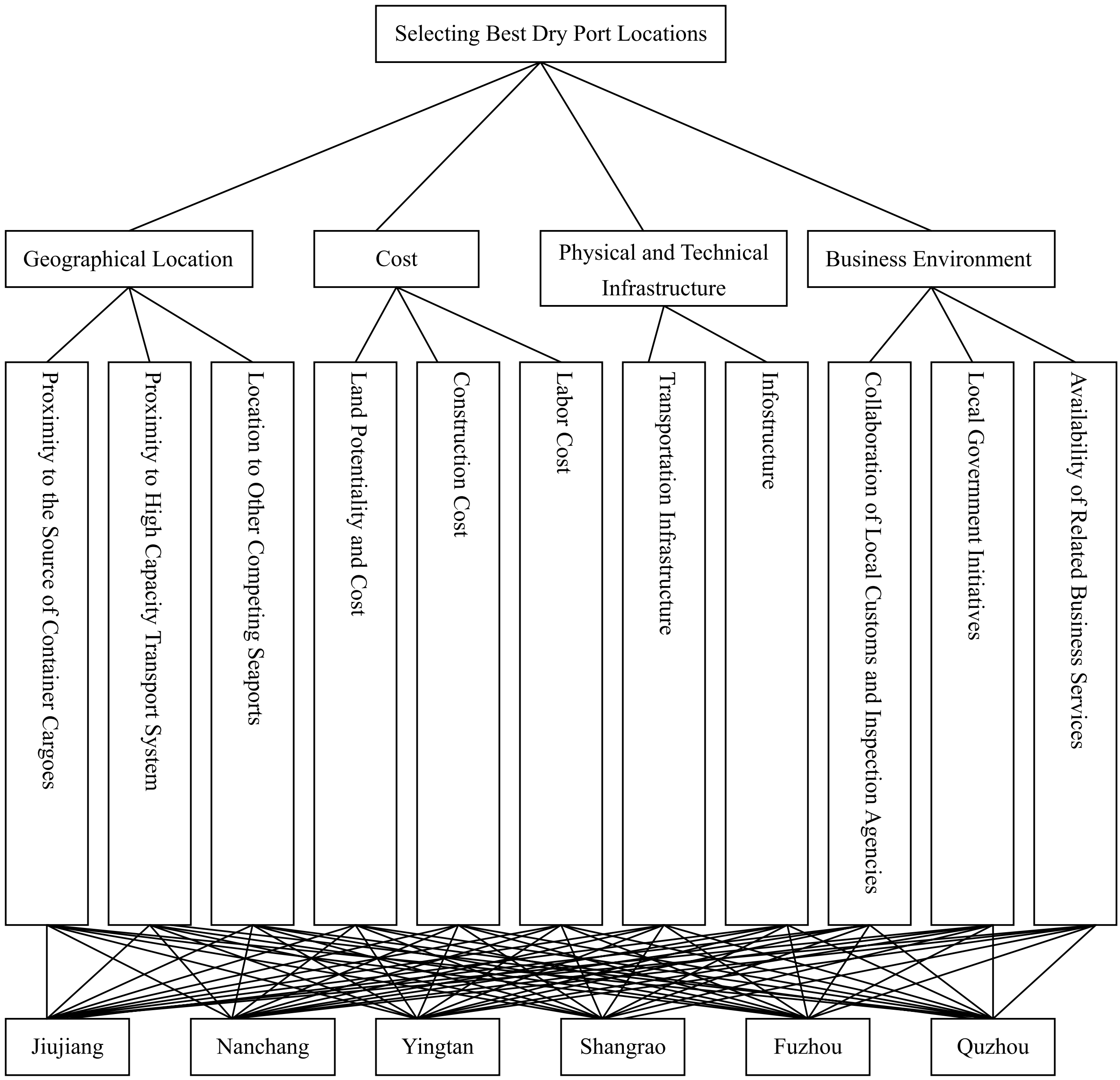

Figure 5.1 - Evaluation framework of AHP dry port location decision model

In essence, the evaluation framework of AHP dry port location decision model is shaped as a hierarchy tree in which four layers are formed. Below are the particulars of these four levels:

Level 1: Initially, the first level which is the top layer of the hierarchy tree presents the main objective or the overall goal of the decision. Specifically, in this case, the main objective is selecting best dry port locations.

Level 2: The second level encompasses four primary selection criteria that are most pertinent to the dry port location selection problem, namely, geographical location cost, physical and technical infrastructure and business environment. These four criteria, representing the basic requirements of a dry port, are identified from a number of sources and summarized by brainstorming in order to achieve the overall goal.

Level 3: Major sub-criteria affecting dry port location decision are demonstrated at the third level of the hierarchy tree. There are altogether eleven sub-criteria involved in this layer, viz. proximity to the source of container cargoes; proximity to high capacity transport system; location to other competing seaports; transportation infrastructure; infostructure; collaboration of local customs and inspection agencies; local government initiatives; land potentiality and cost; construction cost; labor cost and availability of related business services. All of eleven detailed sub-criteria are derived from relevant literature and chosen out by virtue of Delphi study, the process of which is portrayed in the section 4.1.

Level 4: Finally, it comes to the lowest level of the hierarchy tree, where the dry port location alternatives lie. Six decision options，i.e. Jiujiang, Nanchang, Fuzhou Yingtan, Shangrao and Quzhou are listed respectively through the investigation of the target market and the elimination of unqualified sites, which has already done completely in the section 4.2.

5.3.2 Evaluation Process of AHP Dry Port Location Decision Model

The purpose of this section is to illustrate the evaluation process of the model in which dry port location decision of Ningbo port is made. The evaluation process of AHP dry port location decision model applied in Ningbo port scenario is depicted in figure 5.2.

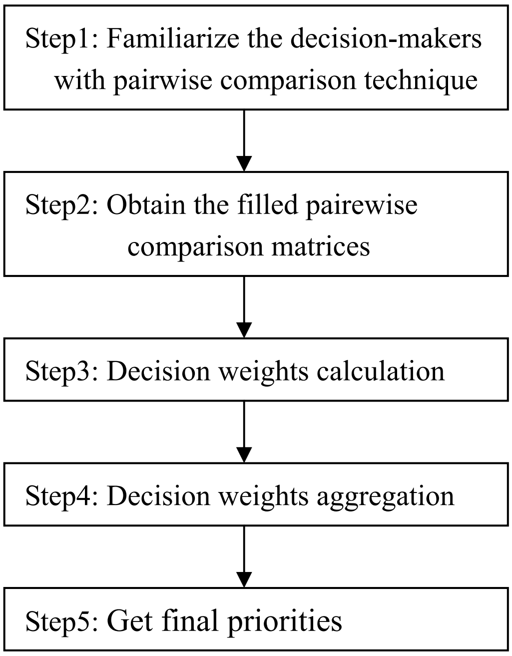

Figure 5.2 - Evaluation process of AHP dry port location decision model

Step1: Familiarize the decision-makers with pairwise comparison technique

In the case of Ningbo port, a particular questionnaire was designed, which is presented in the appendix, to distribute in the form of emails to the experts involved so as to attain the original data. 80 questionnaires in all were emailed to two groups, with half of them sent to one group and the rest sent to the other group. The first group comprises the experts from shipping lines, freight forwarding companies, trading companies, Ningbo Port Group Ltd., logistics companies and academia. Those experts have knowledge and experience in business associated with dry port. They were asked to complete part A of questionnaires, which is concerned with relative priorities for dry port location criteria. On the other hand, the second group was required to provide numerical ratings that reflect the relative importance of each item in part B of questionnaires, which is related with the outcome of the relative weights of decision alternatives. Because decision alternatives are places primarily in Jiangxi market, the second group is comprised of experts dealing with marine business in Jingxi market. It is certain that the experts in the second group are knowledgeable and competent enough to accomplish the task.

An introductory page (see the appendix) which offers some background information is included in the questionnaire. It is suggested that both groups of experts should have no problem in understanding the real meaning of the criteria and in applying the AHP's pairwise comparison technique. Therefore, an explanation of criteria, together with clear example of how to answer the questionnaire using pairwise comparison scale of relative importance, is elaborated in the introductory page. In that case, the decision-makers participated is thought to be familiarized with the pairwise comparison technique and terms after they read the introductory page information.

Step2: Obtain the filled pairwise comparison matrices

Of all the distributed e-mail questionnaires, 55 were received finally, with a reply rate reaching over 60 percent. Twenty-seven out of received fifty-five questionnaires came from the first group and the rest twenty-eight questionnaires with only part B finished undoubtedly stemmed from the second group. Such response rate is satisfactory in conducting further calculation and gaining the scientific results afterwards. It cannot be denied that the replies largely depend on people's willingness to participate in questionnaires. In fact, people don't always take the initiative to reply the questionnaires because it is really time-consuming and makes no difference to their business. However, in this case because Ningbo port

Group Ltd. has good relationship with those experts that are chosen, the reply rate is relatively high and gratifying.

Therefore, all the original data which the participants filled into the pairwise comparison matrices are gained. These filled pairwise comparison matrices are the foundations of the successive normalized pairwise comparison matrices. Moreover, relative priorities of both criteria and decision alternatives are eventually derived from the original data filled in the pairwise comparison matrices.

Step3: Decision weights calculation

Data in pairwise comparison matrices of fifty-five questionnaires are then needed to be processed with the implementation of certain tools. Microsoft Excel spreadsheet was chosen in that it is an excellent and powerful product for conducting complex and burdensome calculations. As is well-known, there are huge calculations in multi-criteria problems using AHP. The application of Excel spreadsheet effectively resolves it, avoiding excessively cumbersome calculations and ensuring the simplicity and convenience of the whole process.

Empty pairwise comparison matrices, initially developed on spreadsheet, were filled in with original data from one questionnaire, which brought the normalized pairwise comparison matrices into being. With the introduction of some formula in spreadsheet, all the calculations of filled-in matrices were well performed and consequently relative weights for criteria and decision alternatives came out. Due to the technical competency and user-friendliness of Excel spreadsheet, when all the judgements in 55 received questionnaires were entered into the cells of the spreadsheet, a series of new results were successfully obtained as well.

Also, spreadsheet calculated the consistency ratio, which evidences the validity of filled-in pairswise comparison matrices and subsequent relative priorities. The ratio is designed in such a way that values of the ratio exceeding 0.10 are indicative of inconsistent judgements, the cases of which the decision-maker would probably need to revise the original values in the pairwise comparison matrix. In reality, when answers were found to be inconsistent, the respondents would better be asked to revise their replies, as suggested by Selly & Forman (2002). Fortunately, all the consistency ratios in this case are less than 0.10, which is considered to be a reasonable level of consistency in the pairwise comparisons. Hence, no revision is required and all the returned questionnaires seem to be effective and valid.

Step4: Decision weights aggregation

Since AHP dry port location decision model of Ningbo port is used by application of questionnaires, the key question is how to synthesize the individual pairwise comparison matrices of the respondents. In other words, we must find some way to deal with multiple and most likely different judgements.

Traditionally, there are two ways to produce a group priority vector. First, group members could discuss each comparison and arrive at a consensus judgement. Second, all individual corresponding judgments are geometrically averaged to produce a single judgment for each comparison. The second approach is preferred in this study for several reasons. In the first place, it is relatively time-saving and much faster than reaching consensus. Second, it gives each participant equal voice. Third, the application of a geometric mean can reconcile conflicting judgements and reach an averaging effect. Last but not least, Aczél & Saaty (1983) also showed that under reasonable assumptions (reciprocity and homogeneity), the only synthesizing function is the geometric mean.

Once all the individual relative weights have been computed, the geometric mean can be calculated by averaging the group's individual responses. The calculated geometric mean of relative priorities with respect to each matrix or the group priority vectors are illustrated in the appendix. It is then recognized that the process of aggregation of the individual weight vectors, which accommodates the views and judgements of group participates, was completed.

Step5: Get final priorities

The last step is to obtain the overall priorities and ranking of the candidate sites. The overall priorities of the six candidate sites will represent the overall desirability of those choices in satisfying the overall objective of AHP dry port location decision problem of Ningbo port.

Before deriving the ultimate result, composite weights of sub-criteria which are deemed to be the bridge in the calculation process, need to be figured out. Composite weights of dry port location sub-criteria was computed by multiplying the group priority vector of main criteria by the group priority vector of sub-criteria, as displayed in table 5.2. Group priority vector of main criteria as well as the group priority vector of sub-criteria had already been reckoned in the forth step.

Table 5.3 presents the result of overall priorities calculation. The overall priority scores for candidate sites of dry ports were computed by multiplying composite weights of dry port location sub-criteria by group priority vector of candidate sites that was also gained from step four. What is worth noticing is that the numbers in parenthesis in the second column indicate the rank order of importance concerning the sub-criteria of dry port location while the numbers in the last row that are given in parenthesis denote the overall ranking of the candidate sites.

Table 5.2 - Composite priorities for criteria and sub-criteria

Criteria		Geographical location 0.482	Cost 0.158	Physical and technical infrastructure 0.088	Business environment 0.272	Composite priorities
Geographical location		0.482				0.482
	Proximity to the source of container cargoes	0.500				0.241
	Proximity to high capacity transport system	0.250				0.121
	Location to other competing seaports	0.250				0.121
Cost			0.158			0.158
	Land potentiality and cost		0.681			0.107
	Construction cost		0.216			0.034
	Labor cost		0.103			0.016
Physical and technical infrastructure				0.088		0.088
	Transportation infrastructure			0.500		0.044
	Infostructure			0.500		0.044
Business environment					0.272	0.272
	Collaboration of local customs and inspection agencies				0.595	0.162

	Local government initiatives				0.277	0.075
	Availability of related business services				0.129	0.035

Table 5.3 - Overall priorities of candidate sites *

	Composite priorities	Jiujiang	Nanchang	Yingtan	Shangrao	Fuzhou	Quzhou
Proximity to the source of container cargoes	0.241 (1)	0.268	0.311	0.119	0.074	0.159	0.068
Proximity to high capacity transport system	0.121 (3)	0.297	0.155	0.155	0.155	0.082	0.155
Location to other competing seaports	0.121 (3)	0.066	0.111	0.225	0.225	0.118	0.254
Land potentiality and cost	0.107 (5)	0.121	0.070	0.255	0.255	0.165	0.134
Construction cost	0.034 (10)	0.133	0.067	0.267	0.267	0.133	0.133
Labor cost	0.016 (11)	0.099	0.099	0.188	0.327	0.188	0.099
Transportation infrastructure	0.044 (7)	0.192	0.331	0.139	0.090	0.056	0.192
Infostructure	0.044 (7)	0.167	0.461	0.093	0.056	0.056	0.167
Collaboration of local customs and inspection agencies	0.162 (2)	0.171	0.341	0.066	0.040	0.040	0.341

Local government initiatives	0.075 (6)	0.161	0.323	0.090	0.052	0.052	0.323
Availability of related business services	0.035 (9)	0.212	0.424	0.117	0.065	0.065	0.117
Overall priorities		0.191 (2)	0.248 (1)	0.146 (4)	0.125 (5)	0.105 (6)	0.186 (3)

* Numbers in parenthesis in the second column are rank order of sub-criteria.
Numbers in parenthesis in the last row are rank order of candidate sites.

5.3.3 Results & Analysis

It can be clearly seen, from table 5.3, that two results of this study are drawn. For one thing, by looking at the composite priorities and ranking of sub-criteria in the second column of the table, the rank order of importance of the factors concerning the dry port location is self-explanatory. In particular, proximity to the source of container cargoes, collaboration of local customs and inspection agencies, proximity to high capacity transport system, location to other competing seaports and land potentiality and cost are the top fives in the list, among which proximity to high capacity transport system and location to other competing seaports are paralleled in the third place. The factor of local government initiatives ranks six by which transportation infrastructure and infostructure are followed side by side. The last threes in the list are, in turn, availability of related business services, construction cost and labor cost.

In general, such ranking result not only is consistent with some functional and quality elements of dry port that are described in section 2.2, but also truly embodies the particular circumstances or conditions of China under which dry ports are supposed to grow and flourish.

The obvious example is the factor of proximity to the source of container cargoes that tops the list, revealing that in China dry port which has much larger scale than container freight station and inland terminal might mainly function as the inland pivot of container transport. This understanding relating to dry port is popular in China at present, evidenced by Wang (2004) in his master thesis. It is understandable, therefore, that top container ports in China are aggressive on dry port strategy for canvassing cargoes, thus gaining competitive edge in the ever intensifying competition.

Another typical example boils down to the factor of collaboration of local customs and inspection agencies. This factor plays an extremely important role pertaining to dry port establishment and development in China, which may not be the case with foreign countries. This is partly because of the complexity of the local customs and inspection system with Chinese characteristics, and partly because of the concept of "guanxi", which takes root in the hearts of Chinese people. In the Chinese business world, "guanxi" is regarded as the network of relationships among various parties that cooperate together and support each other. Chinese people are inclined to conduct business with people they know and trust. With a strong relationship, you can be trusted and even be favored. It is the right "guanxi" in China that will make all the difference in ensuring business success. Therefore, it cannot be hardly understood that the extent of relationships of local customs and inspection agencies, which is one of the most essential elements of running dry port business successfully in China, will directly affect the dry port location decision of Ningbo port.

However, at the bottom of the list lies the factor labor cost. Compared with other dry port location criteria, it doesn't get many credits with respect to selecting best dry port locations. The reason might be quite simple. For one thing the labor cost in

China is relatively cheap and for another the gap between wages in different places that have the potential to grow into dry ports seems to be small.

The second result is demonstrated in the last row of the table. Obviously, Nanchang is the preferred dry port location since it has the highest weight (0.248) among the six candidate sites. Jiujiang is the second best choice with the second highest score (0.191), which is trailed closely by Quzhou whose priority weight arrives at 0.186. Yingtan and Shangrao are placed forth and fifth respectively while Fuzhou stays at the bottom of the list.

Considering the establishment and construction of a dry port is capital-intensive, it is impossible for Ningbo Port Group Ltd. to invest in all the six candidate sites once and for all. Therefore the second result is of great value to Ningbo Port Group Ltd., for it offers the investment priority order of establishing dry ports in the hinterland of Ningbo port. Ningbo port Group Ltd. can then decide specific numbers of dry ports in which it invested according to its financial capabilities.

In a word, the proposed AHP dry port location decision model of Ningbo port can provide a framework to assist top managers of Ningbo Port Group Ltd. in analyzing the importance of dry port location factors, evaluating dry port location alternatives and making the final location decision. Hence, dry port location problem facing Ningbo port can be successfully solved, and as a result, Ningbo port's capability of canvassing cargoes will be greatly strengthened via dry port netwok.

6. Conclusion

The competition among big ports in the Yangtze River Delta (YRD) is heating up, partly because the YRD has recently been experiencing the most bustling port production and fastest transportation infrastructure developments in China, and partly because the major ports that are geographically close share the common hinterland. In this context, Ningbo port, which enjoys the brilliant growth rate of container traffic but at the same time is challenged by the fierce competition from neighbouring container ports for canvassing cargoes, are sparing no efforts to build dry port network. However, up to now no appropriate dry port location decision model has been established to fit into the scenario of Ningbo port and help the top managers of Ningbo Port Group Ltd. make the right decision.

The main contribution of this dissertation is the establishment and application of the AHP dry port location decision model of Ningbo port. Dry port location factors, which were identified from relevant literature using Delphi technique, were structured into a hierarchy tree, with the main objective of selecting best dry port locations lying at the top level and the decision alternatives at the bottom level. Six decision alternatives, namely Jiujiang, Nanchang, Fuzhou Yingtan, Shangrao and Quzhou, were chosen out through the investigation of the target market and the elimination of unqualified sites at the preliminary selection stage of dry port locations.

80 particularly designed e-mail questionnaires were distributed to two groups of experts in the shipping industry so as to obtain the original data. Among them fifty-five were received effectively, indicating that the response rate is relatively high and satisfactory in carrying out further calculation with a view to gaining the scientific results. Microsoft Excel spreadsheet was then chosen to conduct burdensome decision weights calculation and decision weights aggregation, and finally the overall ranking of the candidate sites were gained.

As a result, Nanchang comes top of the list with the highest weight among the six. Jiujiang is the second preferred choice, closely followed by Quzhou. Yingtan and Shangrao are listed at the forth and fifth place respectively. Due to the lowest weight that has been got, Fuzhou is regarded as the least preferred site.

In a word, the proposed AHP dry port location decision model of Ningbo port offers managers of Ningbo Port Group Ltd. a powerful and flexible tool to make the dry port location decision. It not only tackles the complex dry port location decision process into a simple concept of hierarchy, which incorporates both quantitative factors and qualitative factors impinging on the decision alternatives in a systematic way; but also combines dry port location characteristics with managerial experience and judgements of decision-makers.

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Appendix: Questionnaire

Introductory Page of Questionnaire

Explanation of Criteria:

(1) Geographical location: Three sub-factors such as proximity to the source of container cargoes, proximity to high capacity transport system and location to other competing seaports are included.

(2) Cost: Cost in this study mainly refers to land potentiality and cost, construction cost for building specific dry port and labor cost.

(3) Physical and technical infrastructure: As the name indicates, this category comprises two sub-criteria; one is transportation infrastructure which is tangible while the other is infostructure that is intangible, like the availability of EDI.

(4) Business environment: Specifically, collaboration of local customs and inspection agencies, local government initiatives and availability of related business services, constitute the whole business environment in which dry port is operated.

Pairwise Comparison Scale of Relative Importance and Example Used:

(1) Pairwise comparison scale of relative importance

Intensity of Relative Importance	Definition
1	Equal Importance
2	Equal to Moderate Importance
3	Moderate Importance
4	Moderate to Strong Importance
5	Strong or Essential Importance
6	Strong to Demonstrated Importance
7	Demonstrated Importance
8	Demonstrated to Extreme Importance
9	Extreme Importance

(2) Example:

Goal	geographical location	cost	Physical and technical infrastructure	Business environment
geographical location	1			
cost		1		
Physical and technical infrastructure			1	
Business environment				1

The entry in row i and column j of the matrix is labeled $a_{ij,}$ indicating how much more or less important objective i is than objective j. For all objectives i, we use the convention that $a_{ii} = 1$. If you think criterion geographic location is moderate important than criterion cost in selecting best dry port locations, then $a_{12} = 3$. At the same time, it follows that $a_{21} = 1/3$, which is the reciprocal of $a_{12.}$ By the same token, if you think criterion physical and technical infrastructure is strongly less important than criterion business environment in selecting best dry port locations, then $a_{34} = 1/5$ while it can be inferred that its reciprocal, $a_{43} = 5$.

Part A

Table A1 - Pairwise comparison matrix and relative weights with respect to the goal

Goal	geographical location	cost	Physical and technical infrastructure	Business environment	Relative weights
geographical location	1				0.482
cost		1			0.158
Physical and technical infrastructure			1		0.088
Business environment				1	0.272

CR=0.0054

Table A2 - Pairwise comparison matrix and relative weights with respect to geographical location

geographical location	Proximity to the source of container cargo	Proximity to high capacity transport system	Location to other competing seaport	Relative weights
Proximity to the source of container cargo	1			0.500
Proximity to high capacity transport system		1		0.250
Location to other competing seaport			1	0.250

CR=0.0000

Table A3 - Pairwise comparison matrix and relative weights with respect to cost

Cost	Land potentiality and cost	Construction cost	Labor cost	Relative weights
Land potentiality and cost	1			0.681
Construction cost		1		0.216
Labor cost			1	0.103

CR=0.0025

Table A4 - Pairwise comparison matrix and relative weights with respect to physical and technical infrastructure

Physical and technical infrastructure	Transportation infrastructure	Infostructure	Relative weights
Transportation infrastructure	1		0.500
Infostructure		1	0.500

Table A5 - Pairwise comparison matrix and relative weights with respect to business environment

Business environment	Collaboration of local customs and inspection agencies	Local government initiatives	Availability of related business service	Relative weights
Collaboration of local customs and inspection agencies	1			0.595
Local government initiatives		1		0.277
Availability of related business service			1	0.129

CR=0.0053

Part B

Table A6 - Pairwise comparison matrix and relative weights with respect to proximity to the source of container cargoes

Proximity to the source of container cargoes	Jiujiang	Nanchang	Yingtan	Shangrao	Fuzhou	Ouzhou	Relative weights
Jiujiang	1						0.268
Nanchang		1					0.311
Yingtan			1				0.119
Shangrao				1			0.074
Fuzhou					1		0.159
Ouzhou						1	0.068

CR=0.0106

Table A7 - Pairwise comparison matrix and relative weights with respect to proximity to high capacity transport system

Proximity to high capacity transport system	Jiujiang	Nanchang	Yingtan	Shangrao	Fuzhou	Ouzhou	Relative weights
Jiujiang	1						0.297
Nanchang		1					0.155
Yingtan			1				0.155
Shangrao				1			0.155
Fuzhou					1		0.082
Ouzhou						1	0.155

CR=0.0015

Table A8 - Pairwise comparison matrix and relative weights with respect to location to other competing seaports

Location to other competing seaports	Jiujiang	Nanchang	Yingtan	Shangrao	Fuzhou	Ouzhou	Relative weights
Jiujiang	1						0.066
Nanchang		1					0.111
Yingtan			1				0.225
Shangrao				1			0.225
Fuzhou					1		0.118
Ouzhou						1	0.254

CR=0.0052

Table A9 - Pairwise comparison matrix and relative weights with respect to land potentiality and cost

Land potentiality and cost	Jiujiang	Nanchang	Yingtan	Shangrao	Fuzhou	Ouzhou	Relative weights
Jiujiang	1						0.121
Nanchang		1					0.070
Yingtan			1				0.255
Shangrao				1			0.255
Fuzhou					1		0.165
Ouzhou						1	0.134

CR=0.0134

Table A10 - Pairwise comparison matrix and relative weights with respect to construction cost

Construc -tion cost	Jiujiang	Nanchang	Yingtan	Shangrao	Fuzhou	Ouzhou	Relative weights
Jiujiang	1						0.133
Nanchang		1					0.067
Yingtan			1				0.267
Shangrao				1			0.267
Fuzhou					1		0.133
Ouzhou						1	0.133

CR=0.0000

Table A11 - Pairwise comparison matrix and relative weights with respect to labor cost

Labor cost	Jiujiang	Nanchang	Yingtan	Shangrao	Fuzhou	Ouzhou	Relative weights
Jiujiang	1						0.099
Nanchang		1					0.099
Yingtan			1				0.188
Shangrao				1			0.327
Fuzhou					1		0.188
Ouzhou						1	0.099

CR=0.0022

Table A12 - Pairwise comparison matrix and relative weights with respect to transportation infrastructure

Transporta -tion infrastructure	Jiu -jiang	Nan -chang	Ying -tan	Shang -rao	Fuzhou	Ouzhou	Relative weights
Jiujiang	1						0.192
Nanchang		1					0.331
Yingtan			1				0.139
Shangrao				1			0.090
Fuzhou					1		0.056
Ouzhou						1	0.192

CR=0.0155

Table A13 - Pairwise comparison matrix and relative weights with respect to infostructure

Infostruc -ture	Jiujiang	Nanchang	Yingtan	Shangrao	Fuzhou	Ouzhou	Relative weights
Jiujiang	1						0.167
Nanchang		1					0.461
Yingtan			1				0.093
Shangrao				1			0.056
Fuzhou					1		0.056
Ouzhou						1	0.167

CR=0.0052

Table A14 - Pairwise comparison matrix and relative weights with respect to collaboration of local customs and inspection agencies

Collaboration of local customs and inspection agencies	Jiu -jiang	Nan -chang	Yingtan	Shangrao	Fuzhou	Ouzhou	Relative weights
Jiujiang	1						0.171
Nanchang		1					0.341
Yingtan			1				0.066
Shangrao				1			0.040
Fuzhou					1		0.040
Ouzhou						1	0.341

CR=0.0044

Table A15 - Pairwise comparison matrix and relative weights with respect to local government initiatives

Local government initiatives	Jiu -jiang	Nanchang	Yingtan	Shangrao	Fuzhou	Ouzhou	Relative weights
Jiujiang	1						0.161
Nanchang		1					0.323
Yingtan			1				0.090
Shangrao				1			0.052
Fuzhou					1		0.052
Ouzhou						1	0.323

CR=0.0022

Table A16 - Pairwise comparison matrix and relative weights with respect to availability of related business services

Availability of related business services	Jiu -jiang	Nanchang	Yingtan	Shangrao	Fuzhou	Ouzhou	Relative weights
Jiujiang	1						0.212
Nanchang		1					0.424
Yingtan			1				0.117
Shangrao				1			0.065
Fuzhou					1		0.065
Ouzhou						1	0.117

CR=0.0030