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The evaluation of iron ore logistics efficiency of the port based on the DEA model

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Abstract

In recent years, with the continuous development of China's economic and infrastructure construction, the demand of steel is also increasing. The number of iron ore imports and iron ore port throughput also continues to rise. The use of iron ore in the steel factories in our country mainly rely on imports, Iron ore are bulk cargo and the main mode of transport of iron ore is shipping. Therefore, the port is bound to become an important link in the chain of supply of iron ore. The improvement of the iron ore port logistics efficiency plays an important role in enhancing the entire iron ore supply chain logistics efficiency.

The paper decide to use data envelopment analysis to assess the iron ore port logistics efficiency after comparing the respective advantages of the efficiency evaluation method and absorbing the existing port efficiency research achievements. Principal component analysis model is the auxiliary model. Principal component analysis method has the advantage to make up for the limitations of the data envelopment analysis. This allows the analysis of the data envelopment analysis more accurate results. And then by the introduction of major iron ore ports on the north, principal component analysis method is used to extract the main ingredient among the raw input and output data. 2011 iron ore production data of these ports is the evaluation sample and raw data. This paper uses data envelopment analysis model to assess the iron ore ports logistics efficiency and determines the relative effectiveness of the logistics efficiency of each port to provide a theoretical basis for the ports to improve their management efficiency.

Key words: iron ore, DEA (data envelopment analysis), principal component analysis, the efficiency of port logistics

Content:

1. Introduction

1.1 Background and Significance

With the rapid development of Chinese economy, as well as various infrastructure projects, modernization and urbanization in our country and a large number of constructions, the steel demand is huge. In recent years, the number of China's imports of iron ore and iron ore port throughput also continue to rise. In 2011, the completion of the national port throughput of iron ore is 1.235 billion tons, an increase of 6.83%. The total imports of iron ore is 686 million tons, an increase of 10.9%[1]. Due to the huge domestic market, China has a huge demand for iron ore, but iron ore required for Chinese steel industry mainly rely on imports. Thus, iron ore ports become an important part of the transport of iron ore. Iron ore port logistics efficiency has a significant impact on the entire iron ore supply chain efficiency.

Therefore, improving the efficiency of port logistics of iron ore with the conception of modern logistics has become an important factor to improve service levels, and enhance the competitiveness for iron ore ports. To improve the efficiency of logistics of iron ore, the first scientific evaluation should be conducted on the various ports of iron ore logistics efficiency, but currently there are relatively few studies on the evaluation of the efficiency of the iron ore port logistics, so the research paper has strong reality guidance. 2011 Bohai Sea in northern China port unloading 436 million tons of iron ore, accounting for 62.5% of the total in the country with a large proportion of the ports in all our country[2]. The iron ore logistics efficiency of ports around northern Bohai is important for the country to improve the efficiency of logistics of iron ore. In this thesis, the evaluation and analysis of iron ore port logistics efficiency of the main port in northern Bohai provide a theoretical basis for the ports to improve their management efficiency.

1.2 Research status

1.2.1 Research status of port logistics efficiency theory.

To analyze the efficiency of port logistics, early studies of port logistics efficiency is usually by means of a single or multiple indicators. Performance Evaluation of harbor terminal usually only measure the efficiency of cargo handling operations (Bendall and Stent, 1987; Australian Bureau of Industry Economics, 1993; Tabernacle, 1995), or by measuring a single factor productivity (DeMonie, 1987), etc., or by calculating the optimal throughput levels of a period of time, and comparing actual levels with optimal levels to evaluate the efficiency of port logistics (Sachish, 1996), or the measure of all ports in factor productivity (Kim and Sachish, 1986) with a single indicator, or Chou and Lee (2004) using a single measure of efficiency indicators - profit dollars per unit to measure the performance of port cargo throughput of the port. This method by using single indicators to measure the efficiency of port logistics is too one-sided. Although it can evaluate, compare and analyze the efficiency of port logistics, it's only a measure of the value of a particular aspect of their efficiency, and it doesn't reflect the overall efficiency of the situation. Since it is not a very comprehensive description of the characteristics of the port logistics efficiency and the pursuit of a more accurately assess the efficiency of port logistics, stage efficiency of port logistics comprehensive evaluation studies began to turn the research stage.

Efficiency of port logistics including scale efficiency, technical efficiency, consolidated total efficiency. Port logistics efficiency can be investigated from the micro and macro aspects. From the micro-level visits, port logistics efficiency refers to various ports in the allocation of resources to achieve the optimal level of completion. From the macro level to examine, port logistics efficiency is the port's contribution to national economic growth rate. Port logistics efficiency refers to the relative efficiency of seaports, in comparison with other ports in the resulting efficiency.[3]

1.2.2 Research Status of port efficiency evaluation method

Currently, the methods of researches on port logistics efficient evaluation are various. Research methods are two major categories: one non-parametric analysis and the other is the parameter analysis. Among them, the data envelopment analysis method is often used in non-parametric analysis and stochastic frontier analysis is often used in parametric analysis.

In recent years, representative of the literature on the efficiency of the port logistics by using data envelopment analysis (data envelopment analysis, referred to DEA) is Banker and Charnes, who have established technical efficiency and scale efficiency evaluation model for the port by the use of DEA. Vanden Broeck studied the efficiency of the Port of Singapore in 1994 with the DEA model. Tongzon studied the advantages of large international ports in 1996 and 2001 with DEA model through studying the international ports logistics efficiency, 4 in Asia and 12 in other regions among the ports. The results indicate that the level of efficiency and scale port logistics port have no very clear relationship.

Stochastic frontier analysis method is also adopted in recent years by more and more scholars among port logistics efficiency evaluation methods. The so-called stochastic frontier analysis refers to measuring the degree of deviation of certain port to be investigated from the efficiency frontier to measure the efficiency of the port. Efficiency frontier port refers to the port who achieves the best performance by using the given technical conditions and external market conditions[4]. Efficiency frontier port does not exist in reality, it is the port of the best efficiency, relative to the other port, through the analysis of the efficiency of the process, and it is a different set of samples by which the port is changed.

Aigner and Schmidt (1977) firstly proposed the stochastic frontier approach efficiency evaluation. This stochastic frontier technical efficiency is a very convenient method of testing and is widely applied to various fields. However, this method is not widely applied in the port industry.

1.3 Technology roadmap of the thesis

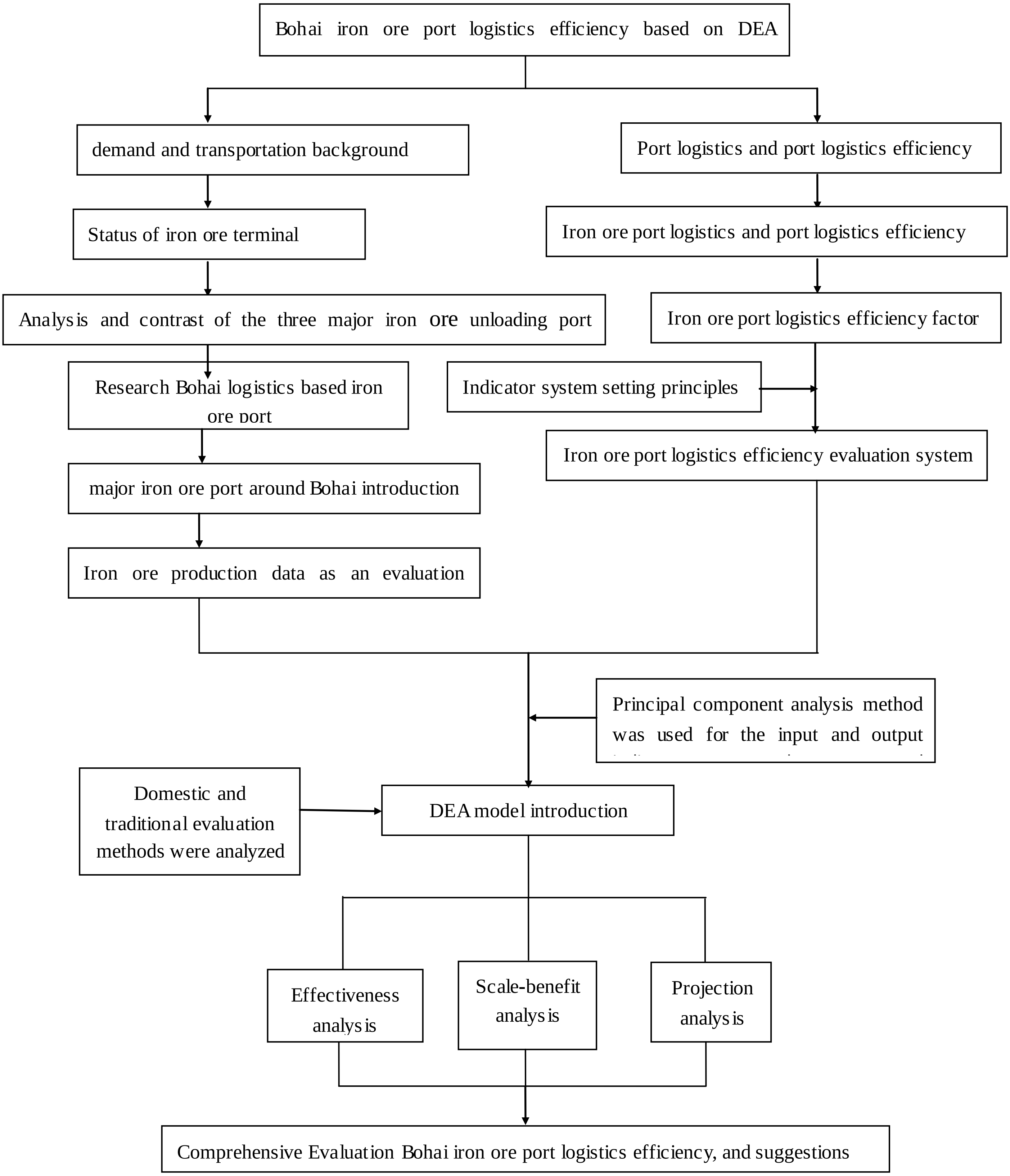

Figure 1.1 Technology roadmap of the thesis

2. Iron ore port logistics efficiency and its influencing factors

2.1 Iron ore port logistics efficiency connotation

2.1.1 The concept of port logistics

Port logistics is to transport and the port converted the as the main function, and realizing cargo transport, warehousing, distribution, processing, modification, packaging, customs clearance, commodity inspection, insurance, and information exchange and other goods throughout the supply chain services. Port areas according to their geographical advantages, the characteristics of the economic environment, use modern logistics concept, through goals, development plans, to format a wide range of radiation as a target area of integrated logistics services network[5].

Logistics of ports not merely have cargo handling simple function. The use of modern communication technology and automated warehousing, transportation technology, will build all the modern modes of transport to the port in order to transport the goods to the vast hinterland to go overseas and inland. At this point, the port as a hub of transportation plays a transport function. Then with a modern transport main line, warehousing, packaging, distribution, processing, information services and other integrated logistics functions make the transition from the port transport hub for the wider connotation, a higher level logistics network nodes. Smooth flow of goods not only in the logistics network flow, and can be based on customer requirements, customer service at the same time, to carry out distribution processing services through value-added processing services enable cargo port functions so as to enhance the purpose of transit in the port process. Therefore, port logistics is an integrated system, including content information technology, automation, networking and other aspects.

2.1.2 Port Logistics Efficiency

Modern port with cargo handling, storage, transportation, business and information services, has comprehensive cover the modern logistics activities for centralized control, instant messaging and transport efficiency requirements, so the overall efficiency of port logistics is reflected in cargo handling in storage, transportation, and logistics services of value-added logistics and other aspects of efficiency.[6]

In modern logistics system, the port became an important node of the entire logistics supply chain. Port logistics efficiency affects the whole process of logistics activities as well as other aspects of logistics systems, thus affecting the efficiency of the entire logistics network. Therefore, in order to improve the efficiency of the port logistics and maintain the sustainable development of ports and competitive advantage, we need to understand what factors affect the efficiency of the port logistics and the horizontal comparison with other ports in order to come up with strategies of development, so that we can seize the advantage in the new round of competition in the port field and improve the international competitiveness of the port logistics.

2.1.3 Iron ore port logistics

For the definition of the logistics of iron ore, the current domestic and international academia and the entire logistics industry has not yet been systematically described and defined. According to the meaning of port logistics, this paper in order to facilitate research on iron ore port logistics defined as follows: Port Logistics refers to the iron ore from the supplier to make high efficiency of various types of iron ore to receive their products, low planning, implementation and process control cost storage, handling, processing and conducted in accordance with the characteristics of various types and sizes of iron ore, iron ore transportation, storage, distribution, handling, distribution processing, information processing and other basic functions to achieve effective integration. To be specific loading of iron ore from the ship began to prepare to enter, after unloading berth, storage, transport and other sectors, iron ore shipped out of the port until the whole process. This process iron ore transshipment port handling and stockpiling at the core, in addition to mainly related to iron ore port, but also involves a number of relevant units of steel companies, traders, logistics intermediary service units, local government and port inspection departments.

The main content of iron ore logistics research was to determine the logistics system, logistics operation, logistics, operations and logistics systems methods and means of the network structure and size and so on according to the principles of logistics rationalization.

2.1.4 Port iron ore logistics efficiency

Combined port logistics, port logistics efficiency and iron ore port logistics analysis, we define iron ore port logistics efficiency: iron ore port logistics efficiency refers to carry iron ore port logistics activities during a given period, in creating logistics the value of the process through the effective and rational use of resources and the organization of its iron ore port logistics systems and other systems, combine the iron ore transportation, storage, distribution, handling, distribution processing, information processing and other basic functions to complete resources optimal configuration . Port iron ore logistics efficiency is to measure the degree.

2.2 Iron ore port logistics efficiency influencing factors

Iron ore port logistics efficiency is impact by many factors, both ports own factors, such as location advantages, hinterland economy, waterway conditions, berths conditions, the library field storage capacity, machinery and equipment conditions, collection and distribution capabilities, management services level, the degree of information, etc., and also factors associated with port other units, such as shipping companies which need to pay various fees to the port is more concerned about the time in the port, despatch, demurrage and other issues[7]. Bulk cargo such as coal and iron ore, have higher requirements on the port channel, berth water depth, specialized handling machinery and equipment, transport capacity, stacking yard, etc.

2.2.1 Port natural geographical and environmental conditions

Port regional conditions and natural conditions composite the harbor natural geographical environmental conditions determined mainly by the Port of natural geographic. They are the foundation of port planning and are prerequisite for port development and construction. They includes the port geographic conditions, Minato-water land area and shore line conditions, weather and other integrated natural hydro geological conditions. It is a prerequisite for imported iron ore port logistics operations, not only provides the basic operating environment for the iron ore port logistics system operation, but also in enhancing port bi-directional radiation to ensure smooth access to the ship and other aspects of the role of port. In large professional ship transport trends, iron ore port terminals have become more specialized. The quality of the natural conditions of the port determines the value and size of the port development and port development potential.

2.2.2 Port infrastructure equipment condition

Port infrastructure equipment condition is the material basis of port logistics manufacturing operations conducted by the iron ore port. Logistics operations necessary infrastructure composed of various machinery and equipment, infrastructure equipment including port channel facilities, anchorage basin, quay length, number and stopping ton berth, yard stockpiling transfer facilities, ship loading and iron ore transport machinery, etc. These infrastructures determine the overall production of iron ore through the port terminal capacity, affecting the production capacity and the reality of the port development potential. They are the material basis for the operation of the port logistics activities. Infrastructure conditions better, there are more conducive to improve the efficiency of port logistics. Improved port facilities can speed up the flow of goods; improve the efficiency of port logistics operation.

2.2.3 Management and production levels of port operations

Port management and production operation level is the core activity of the iron ore port logistics. Port logistics activities are primarily for the completion of planning, control and implementation process, as opposed to the soft ambient conditions harbor port infrastructure facilities in terms of this hard environment. In iron ore port, logistics activities also have a crucial role. According to the production process constitutes of iron ore port handling and port logistics system through the integrated use of a variety of advanced information technology and logistics, port logistics optimize operational processes. Iron ore production operations as a core logistics, port logistics operation is the central link, largely determine the capability and efficiency of the port logistics operations. Port logistics is an important factor to improve the level of service. Iron ore port logistics is a service provided by large specialized transport vessels will certainly take into account the level of port management and a variety of soft environmental conditions, in order to shorten the time in port, efficient completion of loading and unloading tasks. Technical service personnel and experience in port production, teamwork has a direct impact on the production of port operations.

2.2.4 Collection and distribution of iron ore port capacity

Port transport system is interrelated with the port, the port cargo throughput concentration and evacuation transport system, mainly composed by the convergence of waterways and ports branch, road transport lines and rail transport lines, etc.. They play an integral role in the collection and distribution of port logistics. Port channel is necessary linkages with its vast hinterland. It directly affects the operational efficiency of the port logistics, and is the important external conditions for the existence and development of port. Therefore, any professional modern iron ore port must have a perfect and smooth collection and distribution system, in order to become an important iron ore transportation transit network of land and water transportation hub. Currently, iron ore as low bulk cargo, in the domestic transportation by sea and rail transport, and distributing mainly by waterway and rail transport.

2.2.5 Port social and economic infrastructure conditions

Port hinterland economic situation is the decisive condition of port logistics formation. The demand of port economic hinterland, industrial base and other constraints affect the structure and scale of port logistics. Relying on the status of the port city will produce the same effect, whether relying on big cities and urban agglomerations is an important factor in promoting the development of port logistics. Around Bohai there are Angang, Tangshan Iron and Steel, Shougang and other large steel companies. The demand for iron ore is large, which makes the timely transport of iron ore from the port yard out to reduce the time of iron ore on the port stockpiling. iron ore harbor can avoid serious stock pressure, so that the entire iron ore port logistics become smoother.

3. Iron ore port logistics efficiency evaluation system and selection methods and establish indicator system

3.1 Select the evaluation system and method

3.1.1 Common port logistics efficiency evaluation method

(1) Analytic Hierarchy Process，AHP

Analytic Hierarchy Process，AHP, is a multi-criteria decision making qualitative and quantitative analysis method of combining[8]. The Features of AHP is the basis of the nature of complex decision problems, factors such as in-depth analysis of its intrinsic relationship on the structural analysis of a hierarchical model, with less quantitative information to make decisions mathematical thinking process, thus to solve the multi-objective, multi-standard or non-structural properties of the complex issues simple decision making methods. It is especially suitable for decision-making results difficult to directly and accurately measure the occasion. Specifically, it refers to the relevant elements of the decision problem is decomposed into goals, guidelines, programs and other levels, objectively quantified using a certain scale of people's subjective judgment, decision-making methods of qualitative and quantitative analysis on this basis. AHP is suitable for people of qualitative judgment plays an important role for decision-making is difficult to directly measure the results of the occasion.

However, AHP determines the impact of the related elements of heavy through expert scoring drill. it still could not escape the application of uncertainty and ambiguity in understanding the randomness of the evaluation process and evaluation by experts on subjective. This makes the evaluation the credibility of the process may have a greater subjective nature and the accuracy of the results fall.

(2) Fuzzy Comprehensive Evaluation，FCE

Fuzzy Comprehensive Evaluation，FCE is a comprehensive evaluation method based on fuzzy mathematics[9]. The comprehensive evaluation method based on the theory of fuzzy mathematics degree of membership of the qualitative evaluation into quantitative evaluation, which uses fuzzy mathematics subject to many factors thing or object to make an overall assessment. It has a clear result, systematic and strong features. It can solve vague, the problem difficult to quantify and is suitable for solving the problem of non-deterministic.

FCE evaluation methods cannot solve the underlying cause of duplication of evaluation information, when determining the weights of each factor with a certain degree of subjectivity. in some cases, the membership function is somewhat difficult to determine, especially in multi-objective evaluation model, to each goal, each of these factors to determine the membership function to calculate more cumbersome.

(3) Grey Comprehensive Evaluation Method

Grey comprehensive evaluation method is a gray relational analysis theory, a comprehensive evaluation method based on expert evaluation[10]. Grey system theory is a departure from the non-completeness of information, research and treatment of complex systems theory system. It is not from within the system to discuss a special law, but rather to the system through a mathematical treatment level observational data, to understand the trends of internal systems at a higher level, interrelated mechanisms. Grey comprehensive evaluation method based on gray correlation is to use the correlation between the size of the programs and the optimal solution, the evaluation system to compare. The process is: the establishment of gray comprehensive evaluation model, the evaluation factors of various weights choice, a comprehensive assessment.

The amount of data required of evaluation system gray comprehensive evaluation is not too high; you can analyze no matter the data more or less. It is a non-mathematical method of statistical methods. The data need not be normalized. It can directly calculate a raw index with strong reliability. In less data which cannot meet the statistical requirements and conditions of the situation, it is more practical. But the drawback is requested sample data must have the time series properties. In addition, the calculation of gray correlation coefficient also needs to determine the resolution, but the resolution did not choose a very reasonable standard. Each of the above methods are summarized in table 3.1.

Table 3.1 Comparative analysis and summarizes the various evaluation methods

Evaluation Method	AHP	Fuzzy Comprehensive Evaluation Method	Grey Comprehensive Evaluation Method
Advantage	According to the model will be easy to separate the levels of various factors. The treatment is simple and intuitive. It can weaken the human factor.	The result is clear, systematic, and can solve vague, difficult to quantify the problem, suitable for solving the problem of non-deterministic	Evaluation system is not too high for the amount of data required; availability of the original index is calculated directly, in the case of less data, more practical
Disadvantage	Need to drill through expert scoring way to determine the impact of the related elements of the weight, randomness and uncertainty exists subjective evaluation process	Evaluation of repeat problems cannot be solved between the indicators related to the evaluation of information resulting from, and more difficult to determine the weight of each factor is determined with a certain degree of subjectivity, the membership function	Required sample data with time-series characteristics; computing gray relational coefficients determined resolution, and the resolution is not very reasonable selection criteria
Evaluation Index Weight	Need to identify	Need to identify	Need to identify
Whether the improvement program	No	No	No
Subjective factors	Strong	Strong	Strong
For the applicability of Dynamic Logistics Systems	Poor	General	General

Through the above analysis we can see these assessment methods are not very suitable for the evaluation of the efficiency of port logistics. So we use a widely used method, namely data envelopment analysis.

3.1.2 Data envelopment analysis (DEA) Introduction

Data Envelopment Analysis，DEA is a special tool based on linear programming methods used to evaluate the relative effectiveness of different types of organization (or project) work performance, such as schools, hospitals, banks and other branches. They each have the same or similar inputs and outputs. Measures the level of Performance of such organizations usually use input-output ratio of this indicator. When the respective input and output can be converted into the same unit of measurement, it is easy to calculate the respective input-output ratio sorted according to their size of performance[11].

But when the same type of tissue being measured has a number of inputs and multiple outputs, and cannot be converted into a unified unit, you cannot calculate numerical input-output ratio. Most organizations operating units have a variety of input factors, such as staff size, the number of wages, operating hours and advertising, as well as a variety of output elements, such as profits, market share and growth rate. In these circumstances, it is difficult to let business owners know that when the amount of input convert into output, which operating units have high efficiency, which operating units have low efficiency. Thus, we need to adopt a new approach to performance comparisons. This packet is to produce the late 1970s envelope analysis (DEA).

DEA approach has an absolute advantage when solving multi-input, multi-output problem. DEA method is based on the concept of relative efficiency. It is particularly suitable for evaluation of the relative effectiveness of multi-input and multi-index of output indicators DMUs. Its advantages and characteristics embodied as: DEA model is based on optimization as a tool to put in the right multi-multi-index index of output weighting factor for the decision variables. It was evaluated in the sense optimization. It avoids determining the index weight coefficient in the statistical sense with inherent objectivity. Assuming it does not have any weight, the actual decision-making unit of input and output data obtain the optimal weight. It excludes a lot of subjective factors, with strong objectivity. Correlation between inputs and outputs and mutual restraint, each input is associated to one or more output, and exist a link between input and output. But the DEA method does not require any form of determining the relationship of dominant expression, with black-box type of research method characteristics.

Decision Making Unit referred to as the DMU. Were evaluated Departments, enterprises or enterprises with the same type in the same relative efficiency of different periods. These departments, enterprises or period were decision making units. Evaluation is based on a set of index data into the decision-making unit and a set of output indicators data.

The amount of input indicators is the economic amount that decision-making units consume in the social, economic and administrative activity, such as fixed assets, number of employees, occupying land.

The amount of output indicators of economic decision-making unit at a certain combinations of input factors is the effectiveness of economic activities, such as output value, sales revenue, production value profit margins, etc.

Index data is the actual observations, data evaluation of the relative efficiency of decision making units, namely the evaluation of the relative effectiveness between departments, enterprises or period based on the data input indicators and output indicators. DEA is to evaluate multi-input and multi-output index unit of output relative effectiveness of the decision-making multi-objective decision making.

3.1.3 The basic principles of the model C^2R

The model is used to evaluate the relative effectiveness of the decision-making between units, so called DEA efficient. There are n departments (business), called the n decision units, each unit has a p kind of investment decision and q kinds of outputs, each with different economic indicators expressed. This multi-input and multi-index output index evaluation system constituted by n DMUs, you can use Table 3.2 indicates.

Let n be a decision-making unit（ j = 1，2，…，n）

Each unit has the same decision-term investment p（input）（i = 1，2，…，p）

Each unit has the same decision-q outputs（output）（r = 1，2，…，q）

Xij——Item i input j DMUs

Yrj——Item j output j DMUs

Table3.2 C^2R model of multi-input and multi-index output index evaluation system

WEI GHTS	DMU		1	2	…	n
V1	INPUT	1	X11	X12	…	X1n
V2		2	X21	X22	…	X2n
…		…	…	…	…	…
Vp		p	Xp1	Xp2	…	Xpn

1	2	…	n	DMU		WEIGHTS
Y11	Y12	…	Y1n	1	OUTPUT	U1
Y21	Y22	…	Y2n	2		U2
…	…	…	…	…		…
Yq1	Yq2	…	Yqn	q		Uq

Let input indicators and output indicators were right coefficient vector：

$$V=(v_1, v_2, \ldots, v_{p)})^T, \quad U=(u_1, u_2, \ldots, u_q)^T$$

For each decision making unit k, define an efficient evaluation：

$$h_k=\frac{u_1\cdot y_{1k}+\cdots+u_q\cdot y_{qk}}{v_1\cdot x_{1k}+\cdots+v_p\cdot x_{pk}}=\frac{\sum_{j=1}^{q}u_j\cdot y_{jk}}{\sum_{i=1}^{p}v_i\cdot x_{ik}}, \quad k=1,2,\cdots,n \qquad \text{(Formula 3-1)}$$

That efficiency indicators h_k equals the weighted sum of outputs divided by the weighted sum of inputs, which means that economic efficiency k-th decision making unit multi-input and multi-index of output targets achieved. The weight coefficient may be appropriately selected U, V, so that $h_k \leq 1$.

Establish k_0 decision-making unit of the relative effectiveness of C^2R model. Set the k_0 decision making unit vector inputs and outputs are $X_0=(x_{1k_0},x_{2k_0},\cdots,x_{pk_0})^T$, $Y_0=(y_{1k_0},y_{2k_0},\cdots,y_{qk_0})^T$ and efficiency indicators $h_0=h_{k0}$. In the efficiency evaluation index $k \leq 1$ (k = 1,2, ..., n) constraints, select a set of optimal weights U and V, so that h_0 reaches maximum. Then structure optimization model (fractional programming), as shown in formula 3-2 and formula 3-3.

$$Max\,h_0 = \frac{\sum_{j=1}^{q} u_j \cdot y_{jk_0}}{\sum_{i=1}^{p} v_i \cdot x_{ik_0}} = \frac{u_1 \cdot y_{1k_0} + u_2 \cdot y_{2k_0} + \cdots + u_q \cdot y_{qk_0}}{v_1 \cdot x_{1k_0} + v_2 \cdot x_{2k_0} + \cdots + v_p \cdot x_{pk_0}} \quad \text{(Formula 3-2)}$$

$$s.t. \begin{cases} \dfrac{\sum_{j=1}^{q} u_j \cdot y_{jk}}{\sum_{i=1}^{p} v_i \cdot x_{ik}} = \dfrac{u_1 \cdot y_{1k} + u_2 \cdot y_{2k} + \cdots + u_q \cdot y_{qk}}{v_1 \cdot x_{1k} + v_2 \cdot x_{2k} + \cdots + v_p \cdot x_{pk}} \le 1, \quad (k = 1,2,\cdots,n) \\ u_j, v_i \ge 0,\ j = 1,2,\cdots,q; i = 1,2,\cdots,p \end{cases} \quad \text{(Formula 3-3)}$$

This model is called C^2R model. And it is also the basic of the DEA model. It is relative to the other by using C^2R model to evaluate the validity of the $k_{0,}$ in terms of decision making units. So it is called the DEA model which can evaluate the validity of decision making units.

In the above model, the x_{ik}, y_{rk} are known number. It can be obtained by the historical data or predicted data. And v_i, u_j are variable. The meaning of this model is that the variables are the weight coefficient v_i, u_j and constraint is all of the efficiency of decision making units h_0 and the target is the efficiency index of decision making units $k_{0.}$ So whether the production efficiency of decision making units k_0 is valid or not, is relative to the case of all decision making units.

Let $X_k = (x_{1k}, x_{2k}, \cdots, x_{pk})^T$, $Y_k = (y_{1k}, y_{2k}, \cdots, y_{qk})^T$, then we can get a Matrix type like the formula 3-4.

$$Max\,h_0 = \frac{U^T \cdot Y_0}{V^T \cdot X_0}$$

$$s.t. \begin{cases} \dfrac{U^T \cdot Y_k}{V^T \cdot X_k} \le 1, \quad (k = 1,2,\cdots,n) \\ U, V \ge 0 \end{cases} \quad \text{(Formula 3-4)}$$

Then, we make a Charnes - Cooper transformation, turning Into an equivalent linear programming model.

Let $t = \frac{1}{V^T \cdot X_0}$, $t \cdot V = \omega$, $t \cdot U = \mu$, then

$$MaxV_p = \mu^T \cdot Y_0$$

$$\text{(p)} \quad s.t. \begin{cases} \omega^T \cdot X_k - \mu^T \cdot Y_k \geq 0, & (k = 1, 2, \cdots, n) \\ \omega^T \cdot X_0 = 1 \\ \omega, \mu \geq 0 \end{cases} \qquad \text{(Formula 3-5)}$$

The dual programming is

(D) $MinV_D = \theta$

$$\begin{cases} s.t. \quad (x_{11} \cdot \lambda_1 + \cdots + x_{1n} \cdot \lambda_n) \leq x_{1k_0} \cdot \theta \\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ (x_{p1} \cdot \lambda_1 + \cdots + x_{pn} \cdot \lambda_n) \leq x_{pk_0} \cdot \theta \\ y_{11} \cdot \lambda_1 + \cdots + y_{1n} \cdot \lambda_n \geq y_{1k_0} \\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ y_{q1} \cdot \lambda_1 + \cdots + y_{qn} \cdot \lambda_n \geq y_{qk_0} \\ \lambda_k \geq 0, k = 1, 2, \cdots, n; \theta \text{ are the independent variables} \end{cases} \qquad \text{（Formula 3-6）}$$

In the reality, it is not very easy to make the judgment whether you use (P) or (D)

In order to make sure whether the decision unit is effective more easily, Check and Cooper used the concept of the Archimedes dimensionless, Which can make use of the simplex method to solve linear programming problems and judge the DEA validity of decision making unit.

ε is infinite small Archimedes. In the generalized real field, ε means a number which is smaller than the number of any positive and greater than zero, considering with the C^2R model of Archimedes dimensionless ε:

(P_ε):

$$s.t. \begin{cases} \omega^T \cdot X_k - \mu^T \cdot Y_k \geq 0, & (k = 1, 2, \cdots, n) \\ \omega^T \cdot X_0 = 1 \\ \omega^T \geq \varepsilon \cdot \hat{e}^T \\ \mu^T \geq \varepsilon \cdot e^T \end{cases} \qquad \text{（Formula 3-7）}$$

$$(D_{\varepsilon}):\quad MinV_{D_{\varepsilon}} = [\theta - \varepsilon(\hat{e}^T \cdot s^- + e^T \cdot s^+)]$$

$$\begin{cases} s.t.\ \sum_{k=1}^{k} X_k \cdot \lambda_k + S^- = \theta \cdot X_0 \\ \sum_{k=1}^{n} Y_k \cdot \lambda_k - S^+ = Y_0 \\ \lambda_k \geq 0, k = 1,2,\cdots,n; S^+, S^- \geq 0 \end{cases} \qquad \text{(Formula 3-8)}$$

In the formula, the $\hat{e}^T$=(1,1, …,1) is p dimensional vector which the elements equal to 1. And e^T=(1,1,…,1) is q dimensional vector which the elements equal to 1. It is easy to determine the effectiveness of decision making units by using the D_ε model which has ε. And what is more, we can get the following theorems:

ε is infinite small Archimedes and the optimal solution of linear programming (De) is λ^0，s^{0-}, s^{0+}，θ^{0}. Then we can say that:

① If θ^0 =1, then the decision making unit k_0 is weak DEA effective.

② If θ^0 =1 and s^{0-}=0，s^{0+} =0, then the decision making unit k_0 is DEA effective.

Using the formula 3-8 to make a calculation can determine whether the decision making units is DEA effective. In the actual operation, as long as you take ε is small enough, for example, take ε = 10^{-6}, you can use the simplex method to solve it. Usually you can use linear programming software in mathematical software such as Lingo，Lindo ，Matlab to do it in the computer.

The economic meaning of DEA validity is as follows[12]

Technology effectively: Output has reached its maximum relative to input, that is, the decision making units is located in the curve of the production function.

Scale of effective: Refers to the inputs is neither slants big, also not small and it is between scale income gains from increasing to decreasing state, which is in a state of constant return to scale.

Production function: Production function y = f (x) is the best ideal state, when the inputs for x can get maximum output. Therefore, the points (X stands for input, Y stands for output) on the image of the production function which correspond the decision making units is in a state of "technical efficiency" from the point of view of the production function. The general production function of the image is shown in figure 3.1

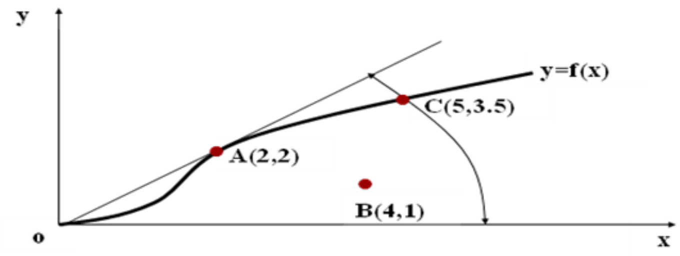

Figure 3.1 Production function image

In the figure 3.1, point A and point C is in a state of technology effectively. The curve is divided into two parts by point A. At the left of the point A, y'＞0， y''＞0. The curve is downward convex in the convex section of the production function, which means once increase the volume of input, the amount of the output could increase the speed of increment. This is called increasing returns to scale. That is to say the investment of the decision-making unit is motivated. On the right of point A, y'＞0，y"＜0, the curve is convex. In this interval, once increase the volume of input, the amount of the output could decrease the speed of increment. It is called the decreasing returns to scale. The decision-making unit has been no increase incentives to invest. So point A is the inflection point of the curve and point A corresponding decision unit not only is technological efficiency, but also the scale efficiency. Because at that point corresponding to the scale of production, whether the decision-making unit is decreased in volume or increased in volume, it is not the best production point. The point C is on the production function curve, but it is located on intervals of diminishing returns to scale. The corresponding decision unit is technology effectively, but it is not scale effectively. The point B is not on production function curve, and it is located in the region of decreasing returns to scale. So the corresponding decision making unit is neither technical nor effective scale.

Let optimal solution of the model (De) is λ^0、s^{0-}、s^{0+}、θ^0. Then make further discussion in three different conditions.[13]

1. Let $\theta^0 = 1$ and $s^{0-} = 0$、 $s^{0+} = 0$, so the decision making units k_0 is DEA efficient.

Its economic significance is that the decision-making unit k_0's production activities (X_0， Y_0) is both the technology effectively and efficiently scale. The so-called technology effective means for production activities (X_0， Y_0), from a technical point of view, is to get the full use of resources, to achieve the best combination of input factors, and output results achieves maximum and efficiency evaluation h_0= 1.

2. Let $\theta^0 = 1$, but at least there is a $s_i^{0-} > 0$, or at least there is a $s_j^{0+} > 0$, then the decision making units k_0 is weak DEA efficient.

Its economic significance is that the decision-making unit k_0's production activities (X_0， Y_0) is the technology effectively or efficiently scale. If there is a $s_i^{0-} > 0$, it means that there is s_i^{0-} of the kind of input indicators of i which have not fully utilized. If there is a $s_j^{0+} > 0$, that is to say there is a gap which is s_j^{0+} between the output indicators of j and the largest output value.

3. Let $\theta^0 < 1$, then the decision making units k_0 is not DEA efficient.

Its economic significance is that the decision-making unit k_0's production activities (X_0， Y_0) is not the technology effectively or efficiently scale.

E.g. $\theta = 0.9 < 1$. The constraints of D_ε model is that:

$$\sum_{k=1}^{k} X_k \cdot \lambda_k^0 + S^{0-} = 0.9 X_0, \sum_{k=1}^{n} Y_k \cdot \lambda_k - S^{0+} = Y_0$$

It means that to get the volume of output Y_0 the input is only up to $0.9X_0$. That is to say, the production activities (X0, Y0) investment scale is too large, and the technical efficiency and the scale gains do not reach to the top at the same time.

3.1.4 Eliminate the limitations of DEA

Although there are many advantages of DEA method, but using DEA method has some limitations.[14]

(1) The number of input and output indicators of DEA model should not be excessive. If the input and output indexes is too many, it will lead to increased number of valid active units, reducing the accuracy of DEA. Therefore, the number of indicators should be as concise as

possible to meet the purpose.

(2) There may be a strong correlation between the evaluation indicators. And there are overlaps between indicators, resulting in redundant indicators, leading to inaccurate results of the evaluation.

(3) DEA model requires data input and output indicators must all be non-negative, if there are negative data, it will affect the results of the evaluation to a large extent.

So this paper selects the principal component analysis to eliminate the limitations of DEA.

Principal component analysis, PCA, is also known as principal weight analysis. It aims to use the idea of dimensionality reduction, to transform the multi-index into a few composite indicators[15]. During the study of practical problems, in order to comprehensively and systematically analyze the problem, we must consider many factors. These involved factors are usually called indicators and it is also known as variable in the multivariate statistical analysis. The number of indicators is too many, and there is some degree of correlation between the indexes in multi-objective decision making. Since each variable in some extent, gives the different information in the research, and there are certain correlation between indicators each other, thus there are overlaps in reflected information from the resulting statistics to some extent. When use the statistical methods to analyze the multivariate issue, too many decisions will increase the amount of computation and complexity analysis of the problem, but also directly affect the validity and reliability of decision-making. It is hoped that during the process of quantitative analysis, the variables is as few as possible and get as much information as possible. Principal component analysis is a practical method in multivariate statistical and the unique in this approach is that it can eliminate the correlation index between samples, under the premise of maintaining the main amount of information in samples to extract a small amount of a representative of the main indicators. Meanwhile, get the key indicators reasonable weight in the analysis process and use the main ingredient as a comprehensive index value in decision unit.

The basic principle of principal component analysis is as follows.

Assuming there are n samples, and each sample has the p variables, constituting an matrix of n × p order data.

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1p} \\ x_{21} & x_{22} & \cdots & x_{2p} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{np} \end{bmatrix}$$

When p is large, the there is too much trouble for the study in p-dimensional space. Dimensionality reduction is to use several comprehensive indexes of variables to instead the original indicators, and use these several comprehensive indexes to reflect information of the original variable indicators as much as possible, and at mean time they are independent.

Let x_1, x_2, …, x_P be the original variable index and z_1, z_2, …, z_m ($m \le p$) be the variable new index.

$$\begin{cases} z_1 = l_{11}x_1 + l_{12}x_2 + \cdots + l_{1p}x_p \\ z_2 = l_{21}x_1 + l_{22}x_2 + \cdots + l_{2p}x_p \\ \vdots \\ z_m = l_{m1}x_1 + l_{m2}x_2 + \cdots + l_{mp}x_p \end{cases}$$

Determine the principles of the coefficient l_{ij}:

1. There are no relationship between the z_i and z_j ($i \neq j$; i, j=1, 2, …, m)

2. z_1 is the greatest variance in linear combination of x_1, x_2, …, x_P. z_2 is the greatest variance in linear combination of x_1, x_2, …, x_P which has no relationship with z_1. The rest can be done in the same manner. z_m is the greatest variance in linear combination of x_1, x_2, …, x_P which has no relationship with z_1, z_2, ……, $z_{(m-1)}$.

The new indicator variables z_1, z_2, …, z_m are called the first, second, ..., m-th principal component of the original indexes variable x_1, x_2, …, x_p.

As the analysis above, the essence of principal component analysis is to determine the load l_{ij} (i=1, 2, …, m; j=1, 2 , …, p) of all the main components z_i (i=1, 2, …, m) in the basis of the original variable x_j (j=1, 2 , …, p) .

It can be proved mathematically that load larger l_{ij} are the corresponding eigenvectors of the correlation matrix of number m bigger special values.

The procedure of principal component analysis is as follows:

1. Calculating a correlation coefficient matrix

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1p} \\ r_{21} & r_{22} & \cdots & r_{2p} \\ \vdots & \vdots & \vdots & \vdots \\ r_{p1} & r_{p2} & \cdots & r_{pp} \end{bmatrix}$$

r_{ij}（i，j=1，2，…，p）is the correlation coefficient of the original variables x_i and x_j. And $r_{ij}=r_{ji}$. The formula is

$$r_{ij} = \frac{\sum_{k=1}^{n}(x_{ki}-\bar{x}_i)(x_{kj}-\bar{x}_j)}{\sqrt{\sum_{k=1}^{n}(x_{ki}-\bar{x}_i)^2\sum_{k=1}^{n}(x_{kj}-\bar{x}_j)^2}}$$

2. Compute eigenvalues and eigenvectors

First to work out the equation $|\lambda I - R| = 0$, and arrange them in order of size after get the eigenvalues: $\lambda_1 \geq \lambda_2 \geq \cdots, \geq \lambda_p \geq 0$, then compute each eigenvalue λ_i and its eigenvector $l_i(i=1,2,\cdots,p)$, demand that $\|l_i\|$=1, and l_{ij} shows the jth vector of l_i.

3. Calculate contribution rate of main factors and accumulative contribution rate

Contribution rate: $\frac{\lambda_i}{\sum_{k=1}^{p}\lambda_k} \quad (i=1,2,\cdots,p)$,

Accumulative contribution: $\frac{\sum_{k=1}^{i}\lambda_k}{\sum_{k=1}^{p}\lambda_k} \quad (i=1,2,\cdots,p)$,

Generally we choose first, second…and the “m”th (m<=p) main element which match up with eigenvalues $\lambda_1, \lambda_2, \cdots, \lambda_m$ of which accumulative contribution range from 85%-95%.

3.2 Establish evaluation index system

3.2.1 Design principle of index system

Selection and confirmation of evaluation index is the premise to carry on scientific evaluation activities. A scientific rationality of evaluation standard is a requirement of fair and reasonable evaluation result. So we should set up principles of establishing evaluation index system in order to provide guidance for the selected indexes. According to evaluation purpose and structural characteristics of port logistics system and status of port logistics and shortage of previous evaluation, we should comply with principles below when establish evaluation index system.[16]

(1) purpose principle

The choice of indexes is subject to the purpose of the evaluation system, selecting evaluation index need to consider the realization of evaluation purpose. In this paper, from the point of the port facility utilization to evaluate its logistics efficiency, therefore from the investment of port facilities and investment bringing to the port throughput, loading and unloading and transportation level as output to determine the index system.

(2) System principle

Port logistics system is a system which inner structure is complex, therefore, when establish its evaluation index system, all evaluation indexes are required to form a system with internal connection. The establishment of evaluation index system of port logistics system should be based on the structure analysis of port logistics system, using system analysis method, to conduct a comprehensive and gradation analysis of port logistics subsystem.

(3) Operationality principle

Operationality refers to that evaluation index system is moderate between complexity and simplicity, and calculation method of evaluation method should be easy and feasible. On the premise of meet the demand of port logistics efficiency evaluation, starting from the actual situation of port, we should pay attention to whether the conception is clear and the sources of the index system data is easy to collect when designing the evaluation index system. In addition, indexes should not be complicated, and its amount should not be overmuch lest we can’t grasp the essence due to much more details, thus will affect the guiding significance of the evaluation results.

⑷ General principle of comparability

Using evaluation index system to evaluate port logistics system, we often need to carry out longitudinal and horizontal evaluation of comparative analysis. Therefore, the establishment of evaluation index system must reflect generality and comparability. Meanwhile in order to make objectively evaluation of comprehensive situation of the port logistics system, in the process of index set, it should be centered on quantitative indexes and scale the indexes as far as possible to establish highly comparative and operable evaluation index system.

⑸ Goal oriented principle

Comprehensive evaluation of port logistics system, the aim is not just simply evaluate its advantage or disadvantage, but more important is to guide and encourage port logistics system to develop in the right direction and goals.

3.2.2 Design of initial index system in this paper

The selection of input and output indexes is a basic premise work of applying the DEA method. We should consider the following factors when selecting input and output indexes: First selection of input and output indexes should serve and subject to the fitted study goal, second should fully consider the relationship between input and output indexes, and finally consider the diversity of input and output index system. Integrate the above analysis, this paper has carried on primary induction and screening, combined the actual situation which impact on efficiency of iron ore port logistics and port iron ore decks in our country, eventually determine the efficiency evaluation index system of port iron ore logistics, and the specific evaluation indexes is shown in table 3.3.

Table3.3 iron ore port logistics efficiency evaluation index system

Objective level	criterion layer	index level
Iron ore logistics efficiency evaluation index system	natural conditions	depth of navigable channel
		The main channel width
		the average water depth of forefront berth
	iron ore logistics infrastructure	berth length
		berth number
		the berth number of 0.15million tonner
		yard area
		stockpiling ore quantity in one time
		Iron ore handling machinery
	Iron ore logistics scale	Iron ore throughput
		Iron ore throughput rate
		Iron ore port total design capacity
	Iron ore logistics transportation ability	rail line length within the port
		single loading efficiency
		Ore discharge efficiency

In this article, through the above analysis, the reference for related research, taking into account the data availability and the general standard of the selection of indicators, selection of channel depth and width of the main channel, iron ore berth front average water depth, the total length of ore berth, number of ore berth, the number of 150,000 tons ore berths, the general design capacity, ore yard area, one-time can be stockpiling ore, the port rail line length and number of the ore handling machinery within other elements as input index, selecting ore throughput, ore throughput rate, efficiency of shipment by single wire for iron ore, ore discharge efficiency elements as the output indexes, build the port logistics efficiency evaluation of input and output index.

Table3.4 input and output index of Iron ore port logistics efficiency evaluation

Iron ore logistics efficiency evaluation index system	Input	X1：depth of navigable channel
		X2：The main channel width
		X3：the average water depth of forefront berth
		X4：berth length
		X5：berth number
		X6：the berth number of 0.15million tonner
		X7：Iron ore port total design capacity
		X8：yard area
		X9：stockpiling ore quantity in one time
		X10：rail line length within the port
		X11：Iron ore handling machinery
	Output	Y1：Iron ore throughput
		Y2：Iron ore throughput rate
		Y3：single loading efficiency
		Y4：Ore discharge efficiency

4. Empirical research of Bohai Sea region main port iron ore logistics efficiency evaluation

4.1 Port iron ore terminal and the present situation of iron ore logistics in our country

At present, the layout of port iron ore transportation system is: the Bohai Sea region is centered on Dalian, Yingkou, Tianjin, Tangshan, Qingdao, Yantai, arrange large, specialized ore transfer storage and transportation facilities. The northern Bohai Sea region distribution is of Shougang, Angang, Tanggang, Handan and other national key iron and steel enterprises, is also China's important steel production bases. Imported iron ore transport system of Yangtze river delta is given priority to Ningbo - Zhoushan port, Lianyungang, corresponding auxiliary layout of Shanghai, Suzhou, Nantong, Zhenjiang, Nanjing and other port, the middle and lower reaches of the Yangtze river region centered big steel companies such as Baosteel, Wisco, Chongqingsteel, is also a key layout area iron and steel industry in our country. Restricted by the Yangtze estuary channel depth, iron ore transport ship in east China in Ningbo – Zhoushan is centered on port transshipment or lightening shipment directly into the river, the Pearl River Delta region transit transport system is given priority to with Guangzhou & Zhuhai. Coastal areas of southwest import iron ore transporting system is made up of Zhanjiang and Fangcheng. Iron and steel enterprises in the Pearl River Delta area of south China are scattered, and large enterprises include Guanggang, Liugang and Kungang in southwest area and so on[17].

Our main import countries are Australia, Brazil, South Africa and other countries, and transportation distance is far, generally we use the large-scale professional ore transport ship. In order to meet the requirement of large ore shipping, each port in China speeds up the pace of the construction of the large loading dock. In 2011, coastal ports ore transportation system complete pilot programs amounting to total 4 new discharge berths, new capacity of 58 million tons. By the end of 2011, coastal area has 45 iron ore discharged berths which are more than 100 thousand tons, and the total discharge capacity is about 551 million tons.[18]

In 2011, the capacity of discharging iron ore in northern Bohai Sea Region port is 436 million tons, taking 62.5% of total in our country. Northern ports large ore terminal of the discharge capacity increased to 319 million tons, the shortfall is 157 million tons, slightly less than the previous year, but the capacity gap is still the largest in the ports group[19]. With new built large ore terminals begin to put into production, it can alleviate the shortage of discharge capacity, and the gap will also be smaller.

Discharge capacity of iron ore of Yangtze River port is 200 million tons, accounting for 28.89% of the total of country[20], but large ore terminal capacity has no change, and the overall ability has changed from the rich into a shortfall of 23.41 million tons, mainly caused by shortfall of Ningbo-Zhoushan Port and Lianyungang port.

The discharge capacity of main ports in Pearl River Delta amount to 59.93 million tons, accounting for 8.59% of the total of our country[21], and the discharge amount and proportion changed little.

As analyzed from the above, the northern Bahai Sea account for lager proportion of discharge capacity in national ports, so research on northern Bohai Sea ports on the efficiency of the logistics of iron ore is of great significance to improve logistic efficiency of iron ore. This article mainly also studies the northern Bohai Sea ports on the iron ore logistics efficiency.

4.2 The basic situation of main ports in Bohai Sea Region

(1) Yingkou Port

The iron ore business of Yingkou port is mainly complete by the third branch of Yingkou Port Co., LTD., the company is a professional stevedoring company, responsible for unloading, storage and dredging.

The company has 200 thousands tons, 150 thousands tons of ore berth and 30 thousands tons of automatic unloading coal berth one in each, the new 30 tons berth wharf has been put into use in October 2010, the total capacity may reach 50 million tons. The port is equipped with total 19 large handling machines in which there are 6 bridge-type grab ship unloaders, 9 bucket-wheel stacker reclaimers and 4 car loaders. Single biggest ship loading efficiency is 7000 tons/hour. Company has a ore yard which area is 1 million square meters, can be a one-time stockpiling 6 million tons of ore. Company also has 5 rail loading lines, and the biggest loading quantity can reach 18 trains.[22]

The company's using modern management information system has realized all automation management of production control, business process and management work as well as formed a fully functional and advanced port service system.

In 2010, company has completed 35.07 million tons of throughputs, increasing 8.38 million tons compared with last year, growing 31.4% from a year earlier.

(2) Dalian Port

Dalian Port iron ore business is mainly done by the Dalian Port Ore Terminal Company. The company is mainly engaged in iron ore handling services as well as warehousing and logistics services to steel mills. The design throughput capacity of Dalian Port Ore Terminal is 28 million tons. It consists of a both 300,000-ton and 400,000-ton professional ore berths and a both 70,000-ton and 150,000-ton transfer berths, large pier is trestle type, and its lead length is 465m, berth length is 450m, and alongside depth is -24.5m, vessel swirling depth is -23/6m, can accommodate 5 to 400,000 tons of ore ship. The lead length of water transfer dock is 220m, its berth length is 437m, and alongside depth is -18.6m, can meet up to 20-25 ton ship tank cleaning operations, down to 0.5-2.0 ton ship docked for the transfer of water shipment. In 2011, there add a 3rd berth which depth is -18.6m and length is 209m.[23]

The wharf is equipped with 4 bridge grab ship unloaders which load is 64 tons, and its single nominal loading efficiency is 2750 tons per hour. The second transfer dock is equipped with 2 bridge grab ship unloaders which nominal loading efficiency is 1800 tons per hour, and it also equipped with a path movable ship loader of which capacity is 4500 tons per hour. The stock yard is equipped with total 10 stacker-reclaimer, of which efficiency of stacking is 5000 tons per hour and reclaiming is 4500 tons per hour. In the port area there are 3 850m length of railway lines, 2 loading floors. The loading capacity of single railway can reach 4500 tons per hour, and it spend only 48 seconds loading a car, loading a train with 60 cars will spend less than an hour. All kinds of facilities in the wharf are has implemented automatic control, the function and advanced length is leading domestic. The valid stocking area of 4 stock yard is 540,000 m^2, can stock 3.82 million tons of ore one time. At present, company has bonded yard of which area is 20,000 m^2, can develop international trade transit service delivery of import and export goods. The yards has a backward transport between each other, can develop a service of ore stowage, maximum to meet customer's individual requirements. The reserved back planning yard is 1 million m^2, its stocking capacity is 10 million tons. In 2010, the port ore throughput 28.4 million tons, 190 thousand tons more than last year, and the growth is 0.9%.

⑶ Tianjin Port

Tianjin port’s iron ore business is mainly completed by Tianjin Sailing Ore Terminal Co., LTD. The company is a large professional bulk cargo loading dock company which main business is comprehensive service including loading, warehousing, transportation, distribution, delivery and other modern logistics service of ore, coal, coke and other bulk cargo.

The company is located at east of south area of Tianjin Port, total length of the wharf is 806m, the design capacity of annual throughput is 24 million tons, and there are two berths named south number 11 and south number 12, and the south number 11 berth is a 200 thousand tons level, the south number 12 berth is a both 200 thousand and 250 thousand tons level. And there are still number 25 berth and number 26 berth in the north area of Tianjin Port, they are professional ore docks of which depth is 19m, length of berth is 466m, berthing capacity is 100 thousand tons and throughput capacity is 6 million tons[24].

The terminal company is equipped with 106 large loading facilities including 16 gantry cranes, 60 imported handling machines; 60 tons level dumping cars of engineer use, its discharge amount of day and night can reach more than 15 tons. In 2010, it completed 4054 tons of throughputs, and exceeded 4000 tons two years in a row.

(4) Rizhao Port

Rizhao port's iron ore business is mainly finished by the Second Harbor Company of Rizhao Port. This company is one of the major production units of Rizhao Port Group, and its main business is loading service of iron ore and other bulk cargo, outwards connecting with Australia, Brazil, South Africa, Peru, India and other major iron ore production areas around the world, inwards connecting with more than 30 large iron steel enterprises in our countries, it is one of the large imported iron ore transshipment base of which function is full, equipment is advanced, business network is extensive and service measures are thoughtful.

The wharf is located at east of Rizhao Port, its total length is 4010m, and there are 18 productive berths including 200,000 tons berth and 300,000 tons berth one in each. The average depth of approach channel is 18m which can meet the requirement of approaching of a 200,000-300,000 tons level of large vessel. Wharf is equipped with 16 large loading facilities among which there are 6 ship loaders, 6 stacker-reclaimers, and 4 car loaders. Its discharge amount of day and night can reach more than 480,000 tons and its average top discharge efficiency is 9876 tons per hour single vessel, all of those keep the world record[25].

Ore discharge should go pass the process of ship unloading and car loading from the front of wharf, and then it will be conveyed to stock yard by belt conveyor or directly evacuated by automatic car loader. From ship discharging to stacking and from reclaiming to loading on the car, the whole process system are all carried out automatic operation, and it is controlled by central control room, also it is one of greater professional ore discharge wharf in our country. The access railway in the port area directly reaches the front of the wharf and cargo yard, here it can conduct direct fetching work of ships and cars, and connect with the national railway network. The designed annual discharge capacity is 100 million tons, and ore discharge in 2010 was 93.21 million tons, has completed throughput of 103.29 million tons, and made a 20% growth than last year, that make it be the first 100 million tons port company in the national coastal port of which service is ore discharging, continually keep the second place of foreign import ore discharge in our country and the first share of the market of trade ore discharge.

⑸ Qingdao Port

The former branch of Qingdao Port Group Co., LTD is a professional wharf company which professionally engaged in ore business, it focuses on ore and auxiliary business is discharge of coal. At present the company has 4 wharfs and 9 deepwater berths, and its annual designed throughput is 55.2 million tons. In the Dongjiakou area of Qingdao Port, the depth of specialized ore wharf is 24.5m, and berth length is 510m, throughput is 25 million tons. The total area of Qingdao Port ore zone is about 2.4 square kilometers, area of storage yard is 1.7 million square meters, and the throughput of the yard is more than 17 million tons.

The port area is equipped with 48 large stevedoring facilities among which there are 3 bridge-type ship grab unloaders, 2 reloading machines, 8 bucket-wheel stacker reclaimers, 4 stackers, 2 taking machines, 24 gantry machines, 4 car loaders and one loading floor. The 200,000 level tons wharf has equipped with 3 ship grab unloaders which can discharge 2500 tons per hour, the discharging capacities day and night can reach more than 110,000 tons.

The ore wharfs of Qingdao Port are all carried out with process work and automatic management. In recent years Qingdao Port Group has roundly upgraded the former branch, and successively invests KF1 - KF10 belt machines and loading floors. The second train loading floor also has completed and ore loading capacity is 2200 cars per day.

4.3 Empirical process and the result analysis

4.3.1 The original data collection of logistics efficiency of Bohai Sea port iron ore

Combined with the former built port iron ore logistics evaluation index system, we find and make statistics on the statistical yearbook and other related materials as well as statistical data of related websites, then we can make the a collection of original data. In this paper, we collected the updated data of 2011[26][27], it is showed in table 4.1.

Table 4.1 DEA model input original data

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
Dalian	17.5	270	20	1177	3	2	2800	54	822	2550	17
Yingkou	22	140	18	1443	4	3	5000	100	600	1908	19
Tianjin	17.4	180	20	1741	4	2	3600	58	430	5818	106
Rizhao	18	280	16	4010	18	2	10000	65	290	3154	16
Tangshan	13.8	180	22	5304	7	6	10900	110	760	7580	47
Qingdao	21	300	14	1545	9	3	6620	170	1700	1360	48
Yantai	15	160	18	1026	2	2	1360	36	250	1557	12

The data is based on Port research center in association of port in China, 2011-2012 China's port development report and Chinese port yearbook newsroom. 2011 yearbook of Chinese port[M]

The indexes meaning is as follows:

X1: Channel depth (m)

X2: Main channel width (m)

X3: Front average depth of ore wharf berth (m)

X4: Total length of ore wharf berth (m)

X5: Berth numbers of ore wharf

X6: Number of 150,000 tons level ore berth

X7: Total design throughput (ten thousand tons)

X8: Ore yard area (ten thousand square meters)

X9: Stockpiling ore one-time (ten thousand tons)

X10: Total length of the railway line in the port (m)

X11: Number of ore discharging machines

The output data is in table 4.2.

Table 4.2 Indexed output original data

	Y1	Y2	Y3	Y4
Dalian	2840	0.9	6550	5500
Yingkou	3507	30	7000	4600
Tianjin	4054	2	6300	4700
Rizhao	10329	20	9780	4000
Tangshan	9580	4	5000	5500
Qingdao	9800	5	7600	6000
Yantai	2710	4	3000	3200

The indexes meaning is as follows.

Y1: Ore throughput (ten thousand tons)

Y2: Growth rate of ore throughput (%)

Y3: The biggest ore discharge efficiency of single vessel (ton per hour)

Y4: Operation efficiency of transportation machine (ton per hour)

4.3.2 Make principal component analysis on original data

By using DEA model to evaluate, the number of input and output index should not be too much, and considering there are a lot of information overlaps of the original data and the accuracy of the analysis results, so we should use principal component analysis method to transfer the original data into several unrelated indexes which also retain the most information of original data.

In this paper, we made principal component analysis on original data by SPSS and got a analysis result.[28]

Correlation matrix between original indexes data in the result from SPSS analysis as showed in table 4.3

Table 4.3 Correlation matrix between original indexes data

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
X1	1.000	.227	-.644	-.464	.127	-.336	-.095	.480	.433	-.598	-.061
X2	.227	1.000	-.542	.052	.587	-.234	.269	.327	.540	-.273	-.120
X3	-.644	-.542	1.000	.307	-.487	.435	-.027	-.427	-.403	.742	.248
X4	-.464	.052	.307	1.000	.591	.707	.914	.168	-.122	.716	.051
X5	.127	.587	-.487	.591	1.000	.015	.758	.233	.021	.039	-.139
X6	-.336	-.234	.435	.707	.015	1.000	.651	.502	.272	.627	.094
X7	-.095	.269	-.027	.914	.758	.651	1.000	.474	.159	.489	.008
X8	.480	.327	-.427	.168	.233	.502	.474	1.000	.873	-.054	.143
X9	.433	.540	-.403	-.122	.021	.272	.159	.873	1.000	-.208	.123
X10	-.598	-.273	.742	.716	.039	.627	.489	-.054	-.208	1.000	.587
X11	-.061	-.120	.248	.051	-.139	.094	.008	.143	.123	.587	1.000

Lager the correlation matrix is, the stronger the correlation between the variables will be, and more information overlaps will generate, it can be found in the above table, there is much information overlaps between original data.[29]

The analysis result of eigenvalue and main component contribution rate from SPSS analysis is showed in table 4.4

Table 4.4 Eigenvalue and main component contribution rate

Total Variance Explained

Component		Initial Eigenvalues			Extraction Sums of Squared Loadings		
		Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
dimension0	1	3.826	34.780	34.780	3.826	34.780	34.780
	2	3.426	31.147	65.927	3.426	31.147	65.927
	3	1.772	16.108	82.035	1.772	16.108	82.035
	4	1.021	9.277	91.312	1.021	9.277	91.312
	5	.700	6.368	97.680			
	6	.255	2.320	100.000			
	7	2.163E-16	1.966E-15	100.000			
	8	1.218E-16	1.107E-15	100.000			
	9	8.160E-17	7.418E-16	100.000			
	10	-6.724E-17	-6.113E-16	100.000			
	11	-2.004E-16	-1.822E-15	100.000			

Extraction Method: Principal Component Analysis.

As can be seen in table 4.4, the variance accumulate contribution rate of 4 main components has reached 91.3%, and the 4 main components can completely represent the original 11 indexes and show all the indexes information.

Analysis result of main component load is showed in table 4.5

Table 4.5 Main component load

Component Matrix[a]

	Component			
	1	2	3	4
X1	-.694	.378	.219	.022
X2	-.326	.660	-.250	.307
X3	.727	-.554	.194	-.063
X4	.843	.443	-.296	-.054
X5	.107	.722	-.631	.221
X6	.753	.354	.363	-.418
X7	.598	.749	-.229	-.054
X8	-.060	.823	.534	-.143
X9	-.276	.676	.603	-.048
X10	.941	-.038	.153	.288
X11	.310	-.041	.532	.766

Data in main component load matrix divided by eigenvalue of main component and get square root, and then we can get each coefficient matched up with the 2 main components, named as eigenvector. Eigenvector of input indexes that are worked out in this paper is as showed in table 4.6.

Table 4.6 Eigenvector of input indexes

eigenvalue	3.826	3.426	1.772	1.021
eigenvector	-0.355	0.204	0.165	0.022
	-0.167	0.357	-0.188	0.304
	0.372	-0.299	0.146	-0.062
	0.431	0.239	-0.222	-0.053
	0.055	0.390	-0.474	0.219
	0.385	0.191	0.273	-0.414
	0.306	0.405	-0.172	-0.053
	-0.031	0.445	0.401	-0.142
	-0.141	0.365	0.453	-0.048
	0.481	-0.021	0.115	0.285
	0.158	-0.022	0.400	0.758

When using SPSS to make a main component analysis, SPSS will automatically make a Z standardized processing to the original data, although the result will not be given directly, it can get the result after a Z standardized by a process from analysis to statistics analysis to description.

The specific result is worked out as follows in table 4.7.

Table 4.7 Original data after a Z standardized processing

ZX1	ZX2	ZX3	ZX4	ZX5	ZX6	ZX7	ZX8	ZX9	ZX10	ZX11
-0.107	0.832	0.637	-0.691	-0.672	-0.586	-0.817	-0.671	0.260	-0.365	-0.621
1.422	-1.160	-0.106	-0.530	-0.491	0.098	-0.209	0.334	-0.188	-0.635	-0.562
-0.141	-0.547	0.637	-0.350	-0.491	-0.586	-0.596	-0.584	-0.531	1.010	2.029
0.063	0.985	-0.850	1.020	2.041	-0.586	1.174	-0.431	-0.814	-0.111	-0.651
-1.363	-0.547	1.381	1.802	0.052	2.147	1.423	0.553	0.135	1.751	0.272
1.082	1.291	-1.593	-0.469	0.413	0.098	0.239	1.864	2.033	-0.866	0.302
-0.956	-0.853	-0.106	-0.782	-0.853	-0.586	-1.215	-1.064	-0.895	-0.783	-0.770

We can get the principal component expression after multiplying data standardized and eigenvector, and use the EXCEL MMULT function to multiply standardized matrix and eigenvector matrix, and then can get each value of main component of input matrix.

Table 4.8 Values of input data's main component

Main components	F1	F2	F3	F4
Dalian	-0.964	-0.968	-0.070	-0.106
Yingkou	-1.011	-0.370	0.601	-1.068
Tianjin	0.693	-1.562	0.878	1.910
Rizhao	0.154	1.550	-2.669	0.499
Tangshan	3.979	0.804	0.588	-0.710
Qingdao	-1.973	2.905	1.287	0.199
Rizhao	-0.879	-2.358	-0.615	-0.725

Considering that input and output number in DEA model can't be negative number, so we use e (about 2.7183) as a base, make a power transformation for the input main component analysis result, the transformation result is showed in table 4.9

Table 4.9 Input index data after power transformation

	F1	F2	F3	F4
Dalian	0.381	0.380	0.933	0.900
Yingkou	0.364	0.691	1.823	0.344
Tianjin	2.000	0.210	2.406	6.755
Rizhao	1.166	4.709	0.069	1.648
Tangshan	53.441	2.234	1.801	0.492
Qingdao	0.139	18.265	3.621	1.220
Yantai	0.415	0.095	0.541	0.484

In the same way, we can deal with the original data according to the above steps, that is

Then do the things with the original output data, in the same way, that is to say, Firstly, using SPSS statistics software to analysis main component to get load matrix, and calculating the characteristic vector. Secondly, using MMULT function in EXCEL to multiply the standardization of matrix of the raw output data Z and eigenvector matrix, then we get the values of the main component of the output data. Finally, transforming, the main component of the output data values into positive results by the power transformation, such as table 4.10.

Table 4.10 the output data by the power conversion

	E1	E2
Dalian	0.607	0.445
Yinkou	1.301	5.196
Tianjin	0.532	0.735
Rizhao	5.758	3.430
Tangshan	1.235	0.314
Qiandao	3.547	0.299
Yantai	0.094	1.826

Based on the analysis of the above, it is concluded that are in table 4.11.

Table 4.11final the input and output data of the final DEA model

Index / DMU	principal component of the input indicator				principal component of the onput indicator	
	F1	F2	F3	F4	E1	E2
Dalian	0.381	0.380	0.933	0.900	0.607	0.445
Yinkou	0.364	0.691	1.823	0.344	1.301	5.196
Tianjin	2.000	0.210	2.406	6.755	0.532	0.735
Rizhao	1.166	4.709	0.069	1.648	5.758	3.430
Tangshan	53.441	2.234	1.801	0.492	1.235	0.314
Qiandao	0.139	18.265	3.621	1.220	3.547	0.299
Yantai	0.415	0.095	0.541	0.484	0.094	1.826

4.3.3 The evaluation analysis process and results of Bohai sea port iron ore logistics efficiency based on DEA

According to the above analysis of the DEA model, as well as the introduction of main iron ore port logistics of the northern Bohai sea, now using the DEA model to evaluate iron ore port logistics efficiency of the northern bohai sea, verifying whether the decision making unit of the ports is the DEA efficient.

According to the formula 3-8, input each index data, this paper get a result in 4-10

To Dalian port：

$$
\begin{cases}
Min[\theta-0.000001(s_1^- + s_2^- + s_3^- + s_4^- + s_1^+ + s_2^+)] \\
0.381\lambda_1+0.364\lambda_2+2\lambda_3+1.166\lambda_4+53.441\lambda_5+0.139\lambda_6+0.415\lambda_7+ s_1^-=0.381\theta \\
0.380\lambda_1+0.691\lambda_2+0.21\lambda_3+4.709\lambda_4+2.234\lambda_5+18.265\lambda_6+0.095\lambda_7+ s_2^-=0.38\theta \\
0.933\lambda_1+1.823\lambda_2+2.406\lambda_3+0.069\lambda_4+1.801\lambda_5+3.261\lambda_6+0.541_7+ s_3^-=0.933\theta \\
0.9\lambda_1+0.344\lambda_2+6.755\lambda_3+1.648\lambda_4+0.492\lambda_5+1.22\lambda_6+0.484\lambda_7+ s_4^-=0.9\theta \\
0.607\lambda_1+1.301\lambda_2+0.532\lambda_3+5.758\lambda_4+1.235\lambda_5+3.547\lambda_6+0.094\lambda_7-s_1^+=0.607 \\
0.445\lambda_1+5.196\lambda_2+0.735\lambda_3+3.43\lambda_4+0.314\lambda_5+0.299\lambda_6+1.826\lambda_7-s_2^+=0.445 \\
\lambda_1,\lambda_2,\lambda_3,\lambda_4,\lambda_5,\lambda_6,\lambda_7>=0 \\
s_1^- ,s_2^-, s_3^-, s_4^-, s_1^+, s_2^+>=0,
\end{cases}
\qquad (4\text{-}10)
$$

To Tianjin port：

$$
\begin{cases}
Min[\theta-0.000001(s_1^- + s_2^- + s_3^- + s_4^- + s_1^+ + s_2^+)] \\
0.381\lambda_1+0.364\lambda_2+2\lambda_3+1.166\lambda_4+53.441\lambda_5+0.139\lambda_6+0.415\lambda_7+ s_1^-=2\theta \\
0.380\lambda_1+0.691\lambda_2+0.21\lambda_3+4.709\lambda_4+2.234\lambda_5+18.265\lambda_6+0.095\lambda_7+ s_2^-=0.21\theta \\
0.933\lambda_1+1.823\lambda_2+2.406\lambda_3+0.069\lambda_4+1.801\lambda_5+3.261\lambda_6+0.541_7+ s_3^-=2.406\theta \\
0.9\lambda_1+0.344\lambda_2+6.755\lambda_3+1.648\lambda_4+0.492\lambda_5+1.22\lambda_6+0.484\lambda_7+ s_4^-=6.755\theta \\
0.607\lambda_1+1.301\lambda_2+0.532\lambda_3+5.758\lambda_4+1.235\lambda_5+3.547\lambda_6+0.094\lambda_7-s_1^+=0.532 \\
0.445\lambda_1+5.196\lambda_2+0.735\lambda_3+3.43\lambda_4+0.314\lambda_5+0.299\lambda_6+1.826\lambda_7-s_2^+=0.735 \\
\lambda_1,\lambda_2,\lambda_3,\lambda_4,\lambda_5,\lambda_6,\lambda_7>=0 \\
s_1^- ,s_2^-, s_3^-, s_4^-, s_1^+, s_2^+>=0,
\end{cases}
\qquad (4\text{-}11)
$$

In the same way, we can get specific DEA model formula of Yinkou port, Rizhao port, Tangshan port, Qingdao port and Yantai port.

For the solution of the linear programming, we can use special linear programming software, like LINDO,LINGO and so on. This paper used MaxDEA software to calculate C^2R model in DEA series model. MaxDEA software is a specially mathematical software solving series of DEA model, and it is powerful, easy to operate[30]. Inputting the data to MaxDEA software, defining decision making units, input index and output index, and then run it to get final DEA model analysis results in table 4.12

Table 4.12 the final result of DEA model by using MaxDEA analysis and calculate

DMU	θ	∑λ	s_1^-	s_2^-	s_3^-	s_4^-	s_1^+	s_2^+
Dalian	0.869546	0.449592	0.16407	0	0	0.62129	0	1.882488
Qingdao	1	1	0	0	0	0	0	0
Rizhao	1	1	0	0	0	0	0	0
Tangshan	0.679736	0.73213	36.0088	0.75887	0	0	0	3.377779
Tianjin	1	1	0	0	0	0	0	0
Yantai	1	1	0	0	0	0	0	0
Yingkou	1	1	0	0	0	0	0	0

Analysis of calculate results：

(1)DEA validity analysis:

To Qingdao port, Tianjin port, Rizhao port, Yantai port, Yinkou port, θ*=1，$s^-=0$，$s^+=0$，so the decision making units of these port are DEA validity, not only technique validity, but scale validity. To Dalian port, Tangshan port, θ*<1, so the decision making unit of these port are not DEA validity, neither technique validity or scale validity.

(2)The judgment of the return to scale

Set the optimal solution of formula 3-8 DEA model to be θ*，λ*， under the C^2R model, there are the following theorem of the judgment of the production activities of the effectiveness of decision making units

1 if $\frac{1}{\theta *}\sum_{j=1}^{n}\lambda_j * =1$，then return to scale of the decision making units keeps the same;

2 if $\frac{1}{\theta *}\sum_{j=1}^{n}\lambda_j * <1$，then return to scale of the decision making units is ascending;

3 if $\frac{1}{\theta *}\sum_{j=1}^{n}\lambda_j * >1$，then return to scale of the decision making units is descending.

Obviously, to Qingdao port, Tianjin port, Rizhao port, Yinkou port, θ*=1，∑λ=1，=1，so return to scale keeps the same. To Dalian port, $\frac{1}{\theta *}\sum_{j=1}^{n}\lambda_j *$=(1/0.869546)* 0.449592=0.517042<1, so return to scale is ascending. To Tangshan port, $\frac{1}{\theta *}\sum_{j=1}^{n}\lambda_j *$=(1/0.679736)* 0.73213=1.07708>1, so return to scale is descending.

(3)Projection analysis(the structure of transforming invalid decision making units into DEA effective decision unit)

Not all decision making units in the evaluation system are DEA effective, in order to analysis some non DEA efficient decision making units, and points out that the cause of non effective, and on the basis of analysis trying to turn non DEA efficient decision making units into DEA efficient decision making units, therefore, we need to discuss the projection on the relatively effective surface with the decision making units.

Setting θ*, λ*, s^-, s^+ are the optimal solution of the decision making units in the linear programming, initialing $X=\theta^* x_0- s^-$,$Y=y_0+ s^+$, and we call (X, Y) the projection which is on the relatively effective surface of the (x0, y0) which decision making unit j_0 stands for. The projection forms a new decision making units. It can prove that the new decision making units (X, Y) is valid relative to the original DEA effective decision unit by using mathematical method.

The projection on a relatively effective surface of the decision making units for Dalian port ：

$X=\theta^* x_0- s^-$=0.869546*（0.381，0.38，0.933，0.9）-（0.16407，0，0，0.62129）=（0.1672 ，0.3304，0.8113，0.1613）

$Y=y_0+ s^+$=（0.607，0.445）+（0，1.882488）=（0.607，2.3275）

The projection on a relatively effective surface of the decision making units for Tangshan port ：

$X=\theta^* x_0- s^-$=0.679736*（53.441，2.234，1.801，0.492）-（36.0088，0.75887，0，0）=（0.3170 ，0.7597，1.2242，0.3344）

$Y=y_0+ s^+$=（1.235， 0.314）+（0，3.377779）=（1.235， 3.6918）

By using projection analysis we can find that the situation of Dalian port and Tangshan port is that they do not make full use of input resources, and the output is limited. If Dalian port make full use of logistic resources, it can get output like current but only have to pay 80% input price. Relative to other effective decision making units, Tangshan port also have serious situation that not making full use of port logistic resources.

The following conclusions can be set based on the analysis of the results：

Under the C^2R model, in the three of the northern bohai sea hub port, Qingdao iron ore port and Tianjin iron ore port logistics efficiency are the highest, they are not only the technology effectively, but also in scale, are effective decision making units. Yingkou, Rizhao, Yantai iron ore port under the current scale of port logistics also have high efficiency, and the logistics efficiency value is 1, they are also the effective decision making units[31]. It means that these ports have made full use of the infrastructure, try best to play and expand the capacity of port logistics. At the same time, the analysis of the return to scale of these ports shows that they are constant. And the scale of the port now has to achieve the best benefit, therefore these ports can appropriately expand the scale of the ports according to actual needs, so as to change the situation of lack of ability in the northern bohai sea iron ore port logistics.

The value of iron ore logistics efficiency of Dalian port overall is less than 1. It means that it is ineffective decision making units, neither technology effectively, nor in scale. As one of the northern Bohai sea hub ports, there are much space to improve iron ore port logistics efficiency. Through the projection analysis, we found that Dalian port infrastructure failed to make full use of the resources. There is a certain amount of waste. But in return to scale analysis, Dalian port is increasing in return to scale. Therefore, on the one hand Dalian port needs to integrate existing production resources and make full use of the facilities, to let it exert its maximum effect and change the status quo of DEA invalid; Dalian port, on the other hand is increasing in return to scale. It means that in the future the development space is very big. The Dalian port investors can take positive measures to appropriately expand the scale of the ports, then economies of scale will have bigger promotion, to achieve the best condition of economies of scale. For example in the case of making full use of existing production resources, to increase the number of the coal berth and all kinds facilities and improve the railway transportation system and attract investment, etc. It can make the port operation and service efficiency to improve greatly.

The iron ore port of Tangshan logistics efficiency value is less than 1. So it is ineffective decision making units, neither technology effectively, also not effective scale. Through the projection analysis, we found that there is a serious resources in Tangshan port relative to other DEA effective decision making units. It wastes a lot of the resources. Tangshan port iron ore logistics efficiency is lower because the infrastructure is not harmonious and infrastructure resources did not play a biggest role[32]. What is more, Tangshan port iron ore logistics scale decline. Even continue to increase the port infrastructure, to improve the capacity of iron ore logistics, port efficiency is difficult to have a lot of ascension, so the urgent task in the Tangshan port now is to carefully examine and verify the rectification in each process of iron ore logistics , to find the problems existing in the each process, such as whether berth capacity and transportation ability are harmonious, or yard storage capacity meets the need, or ore storage period is too long, or the mechanical type is complete, whether the mechanical quantity is the best combination, etc.

5. Summary and Scope

5.1 Summary

Through the discussion of the above chapters, the specific research train of thought can be summarized in this paper as follows: first, analyze the demand for iron ore and transportation background in our country, and the present situation of port iron ore terminal in our country, and analysis the iron ore discharge capacity of the three major ports group along the coast of China, decide to study the northern bohai sea port iron ore logistics. Then according to the concept of port logistics and port logistics efficiency, I put forward the concept of iron ore port logistics and iron ore port logistics efficiency, and analyses the factors which can affect the iron ore logistics efficiency. Then the paper summarizes the traditional evaluation methods both at home and abroad, next use the data envelopment analysis method as the port logistics efficiency evaluation model, and select of principal component analysis (pca) as an aid in the method of data envelopment analysis (dea) method, to improve the limitations of data envelopment analysis (dea) method. What is more, according to the factors that influence efficiency of iron ore port logistics and the principles, index system of the iron ore logistics efficiency evaluation index system is established. Finally, through to the introduction of iron ore port in the northern bohai sea, treat the port in 2011 iron ore production data as the evaluation sample, using principal component analysis (pca) respectively for the input and output index of raw data to extract the principal component, then extract the principal component data as the initial data in analysis DEA model. Use data envelopment analysis (dea) model to evaluate logistics efficiency of each iron ore port, then determine the relative effectiveness in each port logistics efficiency to provide theoretical basis to improve their operation and management efficiency.

This paper first analyzes the concept of port logistics and port logistics efficiency, and then puts forward the concept of iron ore port logistics and iron ore port logistics efficiency, and analyzes the influence factors of the efficiency of the logistics of iron ore port, to establish a comprehensive port iron ore logistics efficiency evaluation system. Through comparison and analysis of port logistics efficiency evaluation methods, and combine with their own advantages and disadvantages, finally select data envelopment analysis to evaluate the northern bohai sea main iron ore port logistics efficiency. And then introduces the principle of data envelopment method and mathematical derivation. It also introduces the principle of principal component analysis. Because in this paper, it is not directly by using the method of data envelopment to the evaluation index system of input and output data when analysis, and it selects the principal component analysis (pca) as an aid in the model of data envelopment analysis by using pca dimension reduction, as the first to reduce the number of the original evaluation system index. Through calculation and analysis, I can extract four input and two output indicators which can summarize evaluation index, and the index number after reduced can meet the requirements of the DEA model for input and output indicators. So that DEA model can more accurately evaluate the effectiveness of decision making units, increasing the accuracy of each iron ore port logistics efficiency evaluation. Finally treat bohai sea mainly iron ore port 2011 data as sample, by solving the C^2R model in DEA, then calculate each decision making unit output respectively in the C2R model, to determine the relative effectiveness of each port logistics efficiency. At the end, provide theoretical basis to improve their operation and management efficiency.

5.2 Scope

In 2011, China's imports of iron ore are 0.686 billion tons, and the total discharge capacity of coastal ports which iron ore berth discharge capacity is beyond 0.1 million tons is about 551 million tons. But it still can't meet the demand of the increasing imports of iron ore in China. At the speed of fast and steady, the economic in China developed in 2012, and the domestic potential demand is huge, such as steel, cement, shipbuilding and other heavy industry products. They are the first one ranked in the world. There is more than 50% of the total urbanization in our country. So the large amount of urban housing construction, iron and steel production will continue to increase, and demand for iron ore will also increase. Ore terminal in our country, therefore, still need to speed up in the construction, so as to adapt to our country’s request. According to the requirement of the "transportation twelfth five-year development plan", in the period of "twelfth five-year", in our country we will speed up in the construction of the Bohai sea region and the Yangtze river area to build iron ore port for foreign trade. According to the coastal large-scale iron and steel base, support the construction of iron ore terminal, to improve the discharge ability of large iron ore port.

In the northern bohai sea region, due to the location of the Anshan iron and steel, Shougang iron and steel, Hebei iron and steel and other large iron and steel enterprises, the total tons of iron ore imports will continue to grow in this region. Look at Beijing and Shandong province, the total imported iron ore there are more than 200 million tons. At the same time, the iron ore port through capacity in this region is far less than the actual throughput. Therefore, we need to try to speed up the construction of new iron ore terminal, in order to meet the growing needs. Such as the construction of Nanjiang area of Tianjin port and the construction of west area of Yantai port. The new ports will ease the current situation that our country's iron ore discharge capacity is insufficient.

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