Study on Coordinated Development Degree Between Ports' Economic Level and Ecological Environment

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Abstract Qualitative and quantitative methods are combined to calculate the coordinated development degree. The index system is divided into two sub-index systems- comprehensive economic level and ecological environment. Entropy method and Principle Component Analysis method are used respectively to calculate the weight of those sub- index systems. Further, static coordinated development degree is calculated to reflect the relationship between ports' economic level and ecological environment, dynamic coordinated development degree is calculated to reflect the trend of relationship. At last, Qin- Huang Dao Port is selected as a sample, it's static and dynamic coordinated development degrees are calculated. From this sample, we can find all steps of calculating the coordinated development degree are effective, reasonable and are easy to operate.
Key words Coordinated development degree; Ecological environment; Economic level

1 Introduction

There are 50 years for developed countries to study on the ports' influence to ecological environment. There are two phrases of study: the first phrase is 1960s- 1990s, some scholars began to study on ports' influence of environment, the second phrase is after 1990s, Sustainable of Ports' Development compelled the development of study, lots of quantitative and qualitative study were put forword. There are some representatives of quantitative, such as European Policy on Port Environmental Protection wrote by Goulielmos A M.. There are some representatives of quanlitative,such as Banalcing Port Planning: Demand, Capacity, Land, Cost, Environment and Uncertainty wrote by Headland JR etc.. From 1990s, Chinese scholars began to study. Chinese scholars most use qualitative method to solve that question, and there are few empirical researches. Ports' economic development is always accompanied by wasting energies and pollutes environment. In this paper, qualitative and quantitative methods are combined to solve that question. At last, Qin- Huang Dao Port is selected as a sample, it's static and dynamic coordinated development degrees are calculated.

2 Construction of the Index System

The rules of building index system are pertinence, comprehensive, and comparability, and regionalism, static and dynamic nature. The index system is divided into two sub-index systems—comprehensive economic level and ecological environment.

2.1 Index of comprehensive economic level

The index of comprehensive economic level reflects the economic level of port itself, and port's contribution of total society. The ports comprehensive economic index system which is composed of explicit and implicit items can embody the characteristics of the times. The explicit comprehensive economic indexes mainly embody the development level of the port itself. The implicit comprehensive economic indexes are the internal development factors of ports, and embody the ability of sustainable development. Then, this paper builds an index system which includes four layers: aim layer, criterion layer, sub- criterion layer and index layer [1]. See as table 1.

2.2 Index of ecological environment

Based on the low-carbon theory, the index system of ecological environment is build as Table 2

3 The Weight of Index

For avoiding the shortcomings of subjective empowerment, and making full use of original data, the entropy method is used to calculate the weight of comprehensive economic level. The correlation of ecological environment indexes is low, so Principal Component Analysis is used to calculate the weight of ecological environment indexes.

3.1 Entropy method

Table 1 Index System of Comprehensive Economic Level

Aim Layer	Criterion Layer	Sub- criterion Layer	Index Layer
Comprehensive Economic Level (A1)	Explicit comprehensive economic indexes (B1)	Zone situation(C1)	Land zone (D1)
			Water zone (D2)
		Infrastructure(C2)	Number of berth (D3)
			Number of deepwater berth (D4)
			Water depth of fairway (D5)
			Number of loading and unloading machine (D6)
			Distribution of port district (D7)
		Development level of transport(C3)	Number of transport enterprises (D8)
			Number of ship agents (D9)
			Number of cargo agents (D10)
			Density of international line(D11)
		Production performance(C4)	Throughout (D12)
			Average growth rate of 5 years (D13)
			Ranking of world ports (D14)
		Port Environment (C5)	Clearance efficiency (D15)
			Freedom policy (D16)
			Informationlization (D17)
		Entrepreneurship(C6)	Rate of loading and unloading (D18)
			Costs of reaching port (D19)
			Rate of costs (D20)
		Cargo distribution and transportation system (C7)	Road (D21)
			Railway (D22)
			Waterway (D23)
	Implicit comprehensive economic indexes (B2)	Condition of economics and finance (C8)	City GDP (D24)
			Foreign Trade (D25)
			Foreign direct investments (D26)
		Relevant service industry(C9)	Machinery-producing industry (D27)
			Port-producing industry (D28)
		Technical innovation and Human resources (C10)	Level of technical innovation (D29)
			Rate of college graduates (D30)

Entropy is a measurement which makes use of probability theory to determine the uncertainty of information. Given n objects, m evaluation indexes, and original data matrix $X = (x_{ij})_{n\times m}$.The steps of entropy method are as follows:

(1) Standardization of data

For eliminating the different units of dimension, non-dimensional should be done. The step of isometric method is as follows: Positive index:

$$x_{ij}^{'} = \frac{x_{ij} - x_{i\min}}{x_{i\max} - x_{j\min}} \qquad (i = 1,2,\cdots,n; j = 1,2,\cdots,m)$$

Negative index: $x_{ij}^{'} = \frac{x_{j\max} - x_{ij}}{x_{j\max} - x_{j\min}} \qquad (i = 1,2,\cdots,n; j = 1,2,\cdots,m)$

x_{ij} the j[th] evaluation index of the i[th] sample; $x_{j\min}$ $x_{j\max}$ the maximum value of the j[th] index; the minimum value of the j[th] index.

The value of positive index is bigger, the performance of it is better. The value of positive index is smaller, the performance of it is better. For eliminating the effect of isometric, axes is translated. After translation, $x_{ij}^{'}$ becomes $x_{ij}^{''}$. $x_{ij}^{''} = x_{ij}^{'} + 1$, '1' is the amplitude of translation. Then, standardized

index is as follows: $y_{ij} = x_{ij}^{"} / \sum_{i=1}^{n} x_{ij}^{"}$

Table 2 Index System of Ecological Environment

Aim Layer	Criterion Layer	Sub- criterion Layer	Index Layer
Low- carbon ecological environment (E1)	Consumption and saving (F1)	Energy (G1)	Energy utility management (H1)
			Renewal resources (H2)
			Energy saving of techniques and equipments (H3)
		Water resource (G2)	Water utility management (H4)
			Dispose of waste water (H5)
			Utilization of rain (H6)
			Water saving of techniques and equipments (H7)
		Material resources (G3)	Material resources utility management (H8)
			Material resources saving of techniques and equipments (H9)
	Quality (F2)	Water quality (G4)	Criterion of water quality (H10)
			dispose of oil fouling (H11)
		Air quality (G5)	Criterion of air quality (H12)
			Exhaust gas recirculation (H13)
		Greening (G6)	Criterion of greening (H14)
			Methods of greening (H15)
		Rubbish (G7)	Criterion of dispose of rubbish (H16)
			Methods of dispose of rubbish (H17)

(2) The information entropy of the j[th] index

The information entropy of the j[th] index is e_j: $e_j = -K\sum_{i=1}^{n} y_{ij} \ln y_{ij}$

In the above formula, constant *k* is related to sample n. If a system is complete disordered, the degree of order is 0, the maximum value of entropy is 1, $y_{ij} = 1/n, K = 1/\ln(n)$, $e_j = -\frac{1}{\ln(n)}\sum_{i=1}^{n} y_{ij} \ln y_{ij}$,

$0 \le e_j \le 1$, the information value of the j[th] index is d_j, and d_j=1-e_j.

(3) Calculation of index weight

The weight is calculated by the coefficient of information value. The coefficient of information value is bigger, the contribution of evaluation is bigger. Then, the weight of the j[th] index is as follow:

$$\omega_i = d_j / \sum_{j=1}^{m} d_j$$

(4) Calculation of index of comprehensive economy level:

$$S_i = \sum_{i=1}^{m} \omega_i y_{ij}$$

After standardization of data, the computational result is between 0 and 1. The result is closer to 1, the comprehensive economy level is better.

3.2 Principal Component Analysis

Principal Component Analysis can translate correlated indexes into non- correlated indexes. The steps are as follows:

(1) Standardization of original data

$$y_{ij} = \frac{x_{ij} - \bar{x}_j}{\sigma_j}, \quad \bar{x}_j = \sum_{j=1}^{n} x_{ij}, \sigma_j = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n} (x_{ij} - \bar{x}_j)^2}$$

(2) Calculation of matrix of pairwise correlated indexes

$$R=\begin{bmatrix} 1 & r_{12} & \cdots & r_{1p} \\ r_{21} & 1 & \cdots & r_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ r_{p1} & r_{p2} & \cdots & 1 \end{bmatrix} \quad r_{ij}=r_{ji}$$

(3) Calculation of eigenvector and characteristics root

This step use special programming Jacobi method to calculate. The characteristics root of matrix R is: $\lambda_i \geq \lambda_{i+1} \geq 0 (i=1,2,\ldots,p)$, and the eigenvector is $\alpha_i=(\alpha_{1i},\alpha_{2i},\cdots,\alpha_{pi})$, and i=1,2,…,p.

(4) Calculation of variance contribution ratio β_i and accumulated contribution ratio $\sum_{i=1}^{k}\beta_i$

The variance contribution ratio β_i is the weight of principal component F_i in total variance $\sum Var(F_i)$, i.e. β_i is the weight of the i[th] principal component in total in formations. $\sum_{i=1}^{k}\beta_i$ are the total weights of 1st to k[th] principal components.

(5) Selection of principle component

If $\sum_{i=1}^{k}\beta_i$ is bigger than 0.85×total information, the 1[st] to k[th] principle components reflected primary information of original index, and $F_i=\alpha_i^T Y_i^T \quad (i=1,2,\cdots,m)$

Y_i α_i --- eigenvector of principle component F_i; transversal vector of standardized data.

(6) Calculation of comprehensive value

β_i $F=\sum_{i}^{k}\beta_i F_i$, variance contribution ratio of F_i

4 Model of Coordinated Development Degree and Discriminated Criterion

4.1 Model of coordinate degree

The coordinate degree between port and ecological environment is a quantitative index which measures the coordinate status between port and ecological environment. The method of discrete coefficient is used to calculate coordinate degree[2]:

C coordinate degree between port and ecological environment, 0≤C≤1;
P exponent of comprehensive economy;
E exponent of ecological environment;
k adjustment coefficient

$$C=\left\{\frac{P\times E}{(\frac{P+E}{2})^2}\right\}^K$$

4.2 Model of coordinated development degree

The model of coordinate degree can reflect the synchronous coordinate status between port and ecological environment, but it cannot reflect the coordinated development level. The coordinated development level emphasizes the holistic, synthetic and interiority. Not only the coordinate degree, but also the coordinated development level can be reflected by the model of coordinated development degree. In this paper, static coordinated development degree is calculated to reflect the coordinate status between port and ecological environment, dynamic coordinated development degree is calculated to reflect the development trend.

(1) Static coordinated development degree

$$D_s=\sqrt{C\times I}, \quad I=\alpha P+\beta E$$

D_s is the static coordinated development degree; C is coordinate degree; I is comprehensive evaluation index of port and ecological environment, it reflects the total benefit of port and ecological environment; α and β are undetermined indexes, separately reflects the important degree of port and ecological environment, α and β can be given different value by different region and times.

(2) Dynamic coordinated development degree

Static coordinated development degree $D_s(t)$ reflects the coordinate degree between port and ecological environment when time is t, but it cannot reflect the dynamic development trend of

coordinate development. Thus, dynamic coordinated development degree D_d is introduced in coordinate degree. Given static coordinated development degree $D_s(t-1)$ and $D_s(t)$, then

$$D_d = D_s(t) / D_s(t-1)$$

D_d>1, reflects the trend of coordinated development is increasing; D_d=1, reflects the trend of coordinated development is stable; D_d<1, reflects the trend of coordinated development is decaying.

If $D_s \in [0,0.4)$, the coordinated development degree is low, ecological environment should be the prerequisite of the improvement of port comprehensive economy level. If $D_s \in [0.4,1]$, the coordinated development degree is suitable, economy level and ecological environment were improved synchronously[3].

5 Empirical Research

We select Qin- Huang Dao Port as a sample, and collect data from Tangshan Statistical Yearbook and Chinese Ports Statistical Yearbook, calculate the weight of comprehensive economic level by Principal Component Analysis Method, and calculate the weight of ecological environment by Entropy Method. Then, we acquire data of weight as Table 3.

Table 3 The Weight of Index

Index	Weight	Index	Weight	Index	Weight	Index	Weight	Index	Weight	Index	Weight
D1	0.0312	D2	0.0324	D3	0.0327	D4	0.0342	D5	0.0338	D6	0.0337
D7	0.0334	D8	0.0341	D9	0.0335	D10	0.0336	D11	0.0339	D12	0.0331
D13	0.0325	D14	0.0336	D15	0.0341	D16	0.0336	D17	0.0329	D18	0.0335
D19	0.0356	D20	0.0328	D21	0.0332	D22	0.0334	D23	0.0342	D24	0.0328
D25	0.0322	D26	0.0336	D27	0.0336	D28	0.0325	D29	0.0331	D30	0.0332
H1	0.0586	H2	0.0576	H3	0.0588	H4	0.0630	H5	0.0589	H6	0.0591
H7	0.0589	H8	0.0593	H9	0.0589	H10	0.0611	H11	0.0633	H12	0.0626
H13	0.0561	H14	0.0491	H15	0.0579	H16	0.0579	H17	0.0589		

Let $\alpha = \beta$=0.5, K=2, then static coordinated development degree D_S and dynamic coordinated development degree D_d are calculated as Table 4.

Table 4 Static and Dynamic Coordinated development Degree

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
D_S	0.253	0.285	0.298	0.301	0.323	0.436	0.465	0.402	0.456	0.461
D_d	0.998	1.002	1.031	1.025	1.032	1.065	1.056	1.028	1.076	1.065

From table4, we find D_S of 5 years (2000-2004) are smaller than 0.4, D_S of 5 years (2005-2009) is higher than 0.4. It means that the comprehensive economic level and ecological environment are not coordinated in 5 years(2000-2004), and is coordinated in 5 years (2005- 2009). We find D_d is bigger than 1 in 9 years(2001-2009), it means the level of coordinated development is increasing, the trend is good.

6 Conclusions

As an important industry, port wastes lots of energies and pollutes environment. The coordinated development degree is important for ports, according to the degree, the ports can adjust mode of production and enhanced control measure. In this paper, the index system is divided into two sub-index systems—comprehensive economic level and ecological environment. Entropy method and Principle Component Analysis method are used respectively to calculate the weight of those sub- index systems. Further, static coordinated development degree is calculated to reflect the relationship between ports' economic level and ecological environment, dynamic coordinated development degree is calculated to reflect the trend of relationship. At last, Qin- Huang Dao Port is selected as a sample, it's static and dynamic coordinated development degrees are calculated. From this sample, we can find all steps of calculating the coordinated development degree are effective, reasonable and are easy to operate.

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