Ocean & Coastal Management 107 (2015) 37–45

Contents lists available at ScienceDirect

Ocean & Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Determining the value of the port transport waters: Based on improved TOPSIS model by multiple regression weighting

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ARTICLE INFO

Article history:
Received 7 August 2014
Received in revised form
28 January 2015
Accepted 11 February 2015
Available online 16 February 2015

Index terms:
Index
Sea area for port transport
TOPSIS
Weight

ABSTRACT

The determination of the value of sea area used for port transportation involves the distribution of economic interests between the Chinese government and the users of sea areas. This paper builds an evaluation index system for the value of port transport sea areas. It is the first of its type to introduce the multiple regression weighting TOPSIS method (Technique for Order Preference by Similarity to an Ideal Solution) to study the value of a port transport sea area. This method was applied in the determination and calculation of the value of port transport sea areas in coastal counties (cities, districts) in Zhejiang province.

The results show that various influencing and impact factors significantly affect the value of the sea area. These factors differ in their level of effect; the value and grade of the sea area for port transportation are closely linked with the order of quality relating to the sea area. The multiple regression weighting TOPSIS method has superior advantages with regard to the adaptability of its evaluation method and the accuracy of evaluation results, with calculated results showing growth at different levels compared with the criteria for the sea area use fee.

This research will play a very important role in these three fields: valuation system construction for government marine resources, ocean development and ocean management by the government.

1. Introduction

As China is a maritime country with large sea areas for port transportation and abundant resources and ports along its coastline, it has great potential to accelerate the development of the marine transportation industry. For a long time, free use of port transport sea areas has caused the disorder of marine development activities and aggravated marine pollution. To strengthen the management of seaport transportation, promote the rational development and sustainable use of sea areas, safeguard China's ownership of sea areas and protect the legitimate rights and interests of the users of sea areas, the Chinese government promulgated the "Law of the People's Republic of China on the Administration of the Use of Sea Areas" in 2001. This law clearly defines that "the government executes the regulation for paid use of sea areas; any entities and individuals are requested to pay the fee for use of a sea area to the marine administrative department in accordance with relevant provisions of the State Council". The valuation for use of a port transport sea area is not only the fundamental work of the marine administrative department and government responsible for execution of the rule for paid use of the port transport sea area; it is also an important technical basis for the promotion of the market operation of port transport sea areas (Wang and Zheng, 2013). Under the conditions of the market economy, the value can reflect the value of the port transport sea area. In this regard, scientific theories and appropriate evaluation methods should be developed to ensure its impartiality and fairness.

Currently, the valuation process for the right to use port transport sea areas has become very complicated because the trading market for port transport sea areas is not yet mature in China and because of the mobility and openness of the sea area for port transportation as well as the particularity of the property right. The traditional discounted cash flow method (Wen et al., 2014), a method based on cost-benefit analysis, has brought many prominent problems regarding seriously subjective evaluation results, poor comparability and low creditability, etc. due to reasons such as low effectiveness and reliability or incorrect selection and improper use. To improve accuracy of the valuation of port transport sea areas, the State Oceanic Administration and the Ministry of Finance have jointly formulated the standard and regulation for the

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http://dx.doi.org/10.1016/j.ocecoaman.2015.02.004
0964-5691/

collection of fees for the use of sea areas. To reflect actual differences in the quality and economic benefits of the sea areas, the fee is based on different grades of port transport sea areas and on how the sea area is used (Liu and Zhang, 2007; Wang et al., 2008). The standard also clearly requires that the bidding or auction programs of the government should require that the minimum value of the targeted sea area should not be lower than the standard for compensation for use of a sea area of the same grade as regulated by the governments at both national and provincial levels. Hence, the charge for use of sea areas for port transportation is not only an economic instrument for the protection and rational development of marine resources but is also an effective method for maintaining and increasing the value of state-owned assets (Guangdong Finance Department, 2011).

Fees for the use of port transport sea areas have been executed by the coastal counties (cities, districts) in China, a standard formulated by the State Oceanic Administration and the Ministry of Finance in 2007. The use of an expert scoring method to determine the relevant weighting factors for setting these fees is easily subject to the effects of subjectivity. Furthermore, it has been seven years since this standard was enacted in 2007. There have been significant changes in terms of the scale of development of the marine economy in different areas, development status of regional economies, regional social development levels and conditions of resources and environment, and so on. Additionally, the fee for use of sea areas is same at different costal counties (cities, districts) of the same level. The above reasons make it impossible to reflect accurately the current criteria for fees for the use of sea areas in terms of the specific value differences of sea areas in different coastal areas or the time value for the right to use sea areas. This difficulty, to a certain extent, may restrict the implementation of the rule for paid use of port transport sea areas and affect the market-oriented allocation of marine resources.

The grades of sea areas and fees charged for use of sea areas were formulated by the Ministry of Finance and the State Oceanic Administration, who considered all possible factors that might affect the value of the sea areas, including the special natural and social attributes of sea areas and quantification of the marine economy and environment of sea areas. A rectification of the fee for the use of sea areas based on the above formulation could reflect the value of port transport sea areas along Chinese coastal counties (cities, districts) more accurately. Accordingly, this paper introduces the use of the TOPSIS model and a multiple regression measurement model from a critical perspective to determine the factors that may affect the value of port transport sea areas and the impact index weighting factor. The paper considers the use of the current criteria for charging a fee to use sea areas. It employs the TOPSIS model to calculate the value of port transport sea areas, improves it based on the method of interpolation to rank the quality level of port transport sea areas of China's coastal counties (cities, districts) of the same level and calculates the value of the sea areas accordingly. The paper provides a new approach to valuing resources and sea areas. Based on the research results of this paper, the approach can be directly used as the minimum value by marine administrative departments for transfers in port transport sea areas, thereby minimizing the blindness of market transactions, enhancing the management of China's sea area assets and safeguarding the added-value of resources at sea areas.

2. Methodology

TOPSIS is a common decision analysis tool for finite solution and multi-objective modeling (Hwang and Yoon, 1981). Based on index properties and data collected about alternatives, this method selects a group of the best indicators and data as the virtual positive ideal solution and a group of the worst indicators and data as the virtual negative ideal solution. Accordingly, the comparison of the solutions can dot pitch the Euclidean distance between the positive and negative ideal points. The resulting Euclidean distance then may be used to evaluate whether a solution is good. The only condition needed for the use of the TOPSIS method is that all utility functions should be monotonically increasing or decreasing. As the TOPSIS method is based on a simple working theory and is easily understood and applied, it soon attracted the attention of relevant economic and management departments and has been widely applied. Previous applications include a business model comparison (Zhou et al., 2012), evaluating transportation systems (Awasthi et al., 2011), competition in the tourism industry (Zhang et al., 2011), a product adoption process for the automobile market (Kim et al., 2011) and performance measurement for aviation firms (Aydogan, 2011). However, TOPSIS has not been seen applied in the assessment of the sea value of coastal areas. The traditional TOPSIS method also has some weaknesses (Yang and Li, 2003; Hua and Tan, 2004; Hu, 2002; Yang and Chen, 2011; Li et al., 2011), which mainly appear in the following two aspects.

First, the traditional TOPSIS method is normally intended for use as a subjective method for the design of all evaluation indicators and determination of the weight function, such as expert evaluation method or an analytic hierarchy process (AHP). This type of design of evaluation indicators and weighting methods to some degree can better reflect the experiences and opinions of experts. However, it involves many subjective factors in the designed indicator system and determined weight function, which are more dependent on the subjective judgment of decision-makers, rather than providing quantified evidence for the overall reasonableness of the indicator system and the subjective analysis of the weight function. Because it fails to reflect the actual evaluation indicators, it loses its rationality and fairness.

Second, the only condition needed for the use of the TOPSIS method is that all utility functions should be monotonically increasing or decreasing. Through the determination of the positive ideal solution and negative ideal solution, the positive and negative values of the actual specimens are introduced to the evaluation model to define clearly the relative order of importance and subordination of the targets of multiple specimens. Therefore, it is mainly used in the evaluation of preferred solutions from a variety of alternative solutions; however, it cannot determine the value of each targeted specimen, which, as a result, has limited the scope of application of TOPSIS.

3. Improvement of the TOPSIS algorithm

The value of port transport sea areas varies substantially based on factors influencing the sea areas, including how a sea area is used, its location, natural conditions, quantity of resources, environmental quality status, social and economic conditions in surrounding areas, and so on. China's Ministry of Finance has already passed regulations and rules to guide use of sea areas by different applications and grades. Thus, the main purpose of this paper is to address how to adjust the charge for use of the port transport sea areas of some coastal counties (cities, districts) of the same level but in different regions based on the current value limits within the upper and lower grades.

The determination of the value of the port transport sea area is actually an issue relating to the order of importance and calculation of multi-targeted values; in addition, the values of the sea areas introduced in this paper for determination of the indicators and data are monotonic. Hence, the use of the TOPSIS method in the determination of the value of port transport sea areas is not only applicable and feasible but also is the first in China for research of the topic.

Note that, to reflect the effectiveness of the indicators, the evaluation indicators shall often be given different weights. The multiple regression method is a commonly used objective weighting method, with principles based on algebra matrix and mathematical statistics, for study of the correlations between multiple independent variables and certain dependent variables. The underlying concept is to find the mathematical expressions that best represent the relationship between the independent and dependent variables; in other words, a multiple regression measurement model must be built. Furthermore, based on the regression coefficients of the independent variables and dependent variables, application of a normalized data processing method is suggested to calculate the weight values. The premise for excellent the interpretation ability of the multiple regression weighting method is that the independent variable and dependent variables should have complete data from statistics and observations and the linear correlation between the two must be true rather than formal. Use of independent variables and a dependent variable for statistics of the observation values is suggested as well as performing an R-test for the built mathematical model. If the R-value thus obtained is greater than 0.5, then the regression results of the mathematical model are statistically feasible. This paper intends to apply the multiple regression weighting method to calculate the indicator weight through the use of objective statistical and observational data, which can avoid errors caused by subjective assumptions and can reveal the degree of effect of influencing and impact factors on the value of port transport sea areas.

The building of an indicator system to determine the value of a port transport sea area should be based on full consideration of the marine economy, social and environmental factors, etc. of the coastal counties (cities, districts). It should focus on analysis and reflection of the development, utilization and trends of the current sea areas, the system's effect on the future grading and classification of the sea areas and analysis of the factors that have control of and leading roles in the value of the sea areas. These factors have been already covered by large numbers of studies (Chen and He, 2002; Luan and Li, 2007). This paper intends to design a generalized method to adjust the fee for use of port transport sea areas of the same grade; design work relating to an indicator system for determining port transport sea areas will not be the focus of discussion in this paper, which therefore will be described in the empirical section. The specific introduction of the execution of the determination process is hereby given as follows.

3.1. Build the sea value matrix of the port

To determine the value of the port transport sea area, assume that the number of the coastal counties (cities, districts) is *m* and the lowest level of the indicator system consists of a number of evaluation indicators represented by *n*. x_{ij} means No. j indicator of No. i coastal county (city, district); $(x_{i1}, x_{i2}, \ldots, x_{in})$ and $(x_{1j}, x_{2j}, \ldots, x_{mj})^T$ represent the attribute value of the specimen county (city, district) located at the port transport sea area and the attribute value of the determined indicator, respectively. The above indicators are constructed as the value-determination matrix X:

$$X = (x_{ij})_{m\times n} = \begin{pmatrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{pmatrix} = [B_1, B_2, \cdots, B_n] = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{pmatrix} \tag{1}$$

3.2. Data unidirectional and dimensionless processing

To avoid possible calculation errors of the indicators due to the differences of the dimensions, order of magnitudes of direction of effect on the value of sea area, it is required to have unidirectional dimensionless processing for the value determination matrix X to build a standardized value matrix $Y = (y_{ij})_{m\times n}$. To reduce the complexity for calculation of the TOPSIS model, this paper applies the Range Method for its processing.

$$y_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}} \tag{2}$$

where $1 \le j \le n$ and $\min x_{ij}$ and $\max x_{ij}$ represent the minimum and maximum value of evaluation indexes, respectively.

3.3. Assign weight by using multiple regression econometric model

Build the multiple regression measurement model. Take the use value of port transport sea areas of m coastal counties (cities, districts) (integral of the area of port transport sea area and the fee for use of sea area per unit) as the dependent variable. Take all four influencing factors, including the level of development of the marine economy, regional economic development status, regional social development level and resource environment, as the independent variables. Use statistical software to calculate the regression coefficients.

$$y = \sum_{t=1}^{l} \beta_t X_t \tag{3}$$

Build the multiple regression measurement model. Take all four influencing factors, including the level of development of marine economy, regional economic development status, regional social development level and resource environment as the dependent variables. Take the correlation factor indicators relating to all four influencing factors as the independent variables. Use statistical software to calculate the regression coefficients.

$$y = \sum_{j=1}^{n''} \beta_j X_j \tag{4}$$

Use the multiple regression measurement model to test empirically the degree of effect of the influencing and impact factors on the fee for use of a sea area. Considered the result acceptable if the correlation coefficient is greater than 0.5. With the regression coefficient obtained, apply the normalized data processing method to calculate the impact weighting of all four influencing factors on the fee for use of a port transport sea area and the impact weighting of the correlation impact factors on the four influencing factor indicators. Then, based on the calculated results, calculate the comprehensive weight of the correlation impact factors.

$$W_j = \frac{R_t}{\sum_{t=1}^{l} R_t} \times \frac{r_j}{\sum_{j=1}^{n'} r_j} \tag{5}$$

where W_j is the comprehensive weight of No. j impact factor, l is the numbers of the influencing factors, and n' is the number of correlation impact factors of all influencing factors; R_t is the regression coefficient of No. t influencing factor, and r_j is the regression coefficient of the No. j correlation impact factor.

3.4. Building a weighted standardized matrix of sea areas of different grades

Put the comprehensive weight vector obtained from above calculations $\omega = (\omega_1, \omega_2, \cdots, \omega_n)$ into the decision matrix, and then calculate the weighted standardized matrix of sea areas of different grades Z.

$$Z = (z_{ij})_{m' \times n} = \begin{pmatrix} \omega_1 y_{11} & \omega_2 y_{12} & \cdots & \omega_n y_{1n} \\ \omega_1 y_{21} & \omega_2 y_{22} & \cdots & \omega_n y_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \omega_1 y_{m'1} & \omega_2 y_{m'2} & \cdots & \omega_n y_{m'n} \end{pmatrix} \quad (6)$$

where m' represents the numbers of coastal counties (cities, districts) at each grade.

3.5. Positive ideal solution and negative ideal solution for determination of grading of sea areas

The TOPSIS model algorithm requires determining the positive ideal solution Z^+ and negative ideal solution Z^- of the grading of each sea area separately, with consideration for the different types of the indicators. The specific method is to use the maximum value and minimum value of each indicator in the sea area-grading weighted standardization decision matrix $Z = (Z_{ij})_{m' \times n}$, which separately represents the positive ideal solution vector $(Z_{ij}^+)_{m'' \times n}$ and the negative ideal solution vector $(Z_{ij}^-)_{m'' \times n}$.

$$Z^+ = \{\max(Z_{i1}), \max(Z_{i2}), \cdots, \max(Z_{in})\}, \quad 1 \le i \le m'' \quad (7)$$

$$Z^- = \{\min(Z_{i1}), \min(Z_{i2}), \cdots, \min(Z_{in})\}, \quad 1 \le i \le m'' \quad (8)$$

3.6. Building a theoretical model to calculate the value of the port transport sea area

The fee for use of a sea area of the same grade as stipulated in the criterion for charging for use of a sea area is considered the minimum value of the equivalent sea area, and the fee for use of a sea area of the upper grade is considered the maximum value of the equivalent sea area. Based on the Chinese standard for charging for use of a sea area, this paper intends to design an extreme value range of the sea areas and use the positive and negative ideal solutions to reflect the value of the sea areas to build a theoretical model to interpolate the value of a port transport sea area.

$$C_i = C^- + \frac{Z_i - Z^-}{Z^+ - Z^-} \times \left(C^+ - C^-\right) \quad (9)$$

where C_i represents the value of the sea area of No. i coastal county (city, district); C^- represents the fee for use of the sea area of the current grade of No. i coastal county (city, district); C^+ represents the fee for use of the sea area of the upper grade of No. i coastal county (city, district); and Z_i represents the vector value of No. i coastal county (city, district).

4. Case study

4.1. General description of the cases

As a major marine province in China, Zhejiang ranks first in terms of its sea area and length of coastline, which are 260,000 square km and 6696 km, respectively; the province has a superior combination of advantages due to its abundance of sea ports, fisheries, tourism, oil and gas, beaches, islands and ocean energy, etc. According to "Regulation for management and use of sea area in Zhejiang Province", the right to use the sea area for development of industries, commerce, transportation, tourism, entertainment and other profit-oriented projects and the right to use the same sea area by more than two potential users should only be obtained through a public bidding and auction process. The marine administration department of the province shall determine the transfer value for the use of the sea area located within the province in accordance with the location of the sea area, purpose of use and functions, etc. The transfer value for a use-right of the sea area shall not be lower than the fee stipulated in the national and provincial regulations for a similar sea area and similar purpose.

Currently, the Ministry of Finance and the State Oceanic Administration have already issued regulations and laws relating to the classification, grading and guide value for the use of sea areas in coastal counties (cities, districts) in Zhejiang province. To explain better the effectiveness of the determination process for the value of the port transport sea area based on multiple regression weighting TOPSIS model, this paper will conduct an empirical analysis with data from 19 coastal counties (cities, districts) in Zhejiang Province used as the specimen to calculate the value of port transport sea areas. The criteria for the grading and fee for the use of port transport sea areas in 19 coastal counties (cities, districts) in Zhejiang Province promulgated by the Ministry of Finance and the Oceanic Administration of the People's Republic of China are shown in Table 1.

The sea areas of these 19 coastal counties (cities, districts) are distributed in eastern Zhejiang Province, mainly in Ningbo City, Zhoushan City, Jiaxing City, Taizhou City and Wenzhou City. Spatial distribution of these 19 coastal areas (cities, districts) in Zhejiang Province is illustrated in Fig. 1.

4.2. Building an indicator system for valuing port transport sea areas

4.2.1. Indicator system

The ocean is an extremely rich natural resource with duality for both use and ecological service. Similarly, the sea area for port transport also has a dual nature. First, it has use value, as the sea area is a means of production involved in the production processes of the marine industry. That value is represented as the space use value of the sea area. Second, the sea area can provide free resources and services such as climate regulation, rainfall and environmental purification and survival of marine lives. These resources and services have ecological service value represented by the compensation for the marine ecological environment. The former are closely related to the development scale of the marine industry, location of sea area and social and economic conditions at surrounding areas, etc. The latter are subject to impact from the quality of seawater and the quantity of resources etc.

The life cycle of the sea area at ports begins with the development and utilization of coastlines and ends when the coastline is damaged and the sea area loses its service function as an ecosystem. The cycle's duration depends on whether human and the sea could coexistence in harmony. There is considerable evidence that human pressures are responsible for the degradation of the marine environment. 'Management' of marine ecosystems therefore largely depends upon lifting human pressures (Morris et al., 2014). Thus, protective development of marine resources is of great benefit for prolonging the life cycle of the sea.

The valuation indicator system for the sea area at a seaport should be based on the Theory of Resource Economics and theories relating to the evaluation of ecological value and land value. It is important to conduct a comprehensive analysis of factors that may

Table 1
Criteria for the grading and fee for use of port transport sea area in 19 coastal counties (cities, districts).

Grade of the sea area	Sample areas	Criterion for fee of use (Yuan/Hm^2)	Increase of charge rate in adjacent grades	Charging methods
First-grade Sea		2100	17%	Annual charging
Second- grade Sea	Longwan District, Wenzhou City; Haishu District, Ningbo City.	1800	50%	
Third- grade Sea	Dinghai District, Zhoushan City; Jiaojiang District, Taizhou City.	1200	33%	
Fourth- grade Sea	Yueqing City; Pinghu City; Putuo District,Zhoushan City; Shengsi District,Zhoushan City; Wenling City; Yuhuan District.	900	50%	
Fifth- grade Sea	Ninghai District; Xiangshan District; Ruian City; Dongtou District; Daishan District; Linhai City; Sanmen District.	600	100%	
Sixth- grade Sea	Pingyang County; Cangnan County.	300		

affect the value of the sea area from the dual perspectives of the value of the port transport sea area, with consideration for the relationship that may affect the factor index, value of the sea area and availability and historical characteristics of the indicator data, etc. These factors include nature, economy, society and ecology. Thus, the indicator system for calculating the value of the port transport sea area may be built in a scientific and reasonable manner.

This paper is developed with consideration for the relationships between the value attribute of the resources at the port transport sea area and the influencing factor indicator system. First, this paper employs the expert consultation method and applicable principles for selection of calculation factors needed for the value determination of a sea area, including the leading factor principle, difference principle, quantification principle and timeliness principle to select major factors that significantly affect the quality and value of the sea areas in coastal counties (cities, districts) in Zhejiang Province. The selected factors are not only typical and representative to reflect the differences of the sea areas in terms of nature, resources, environment, social economy and location but also feature wide coverage, easy acquisition of the index value and a range of variation. A framework for a value calculation indicator system for a port transport sea area is thus constructed. The framework comprises four influencing factors: development scale of the marine economy, development status of the regional economy, level of regional social development and conditions of the resource environment. Other correlation impact factors include gross ocean production and resources along the coastline. Second, this paper employs SPSS (Statistical Package for the Social Sciences) for validation tests of the indicators. Finally, based on the analytical results of SPSS statistical software and on comments and advice from experts, some of the impact factor indicators are removed, and ultimately a calculation indicator system for the value of the port transport sea area is thus built (see Table 2).

4.2.2. Data sources

The research team has successfully acquired the required data relating to four influencing factors of 19 coastal counties (cities, districts) in Zhejiang Province, including the development scale of the marine economy and 19 other impact factor index values, including the comprehensive index for marine economic output. Sources include all available documentation and files in all counties (cities, districts), including 2013 Statistical Yearbook, 2013 National Economic and Social Development Bulletin, 2013 Report of Marine Biological Quality Monitoring, 2010–2013 Statistical Report for Marine Economy prepared by the Oceanic Administration and through field surveys and other means.

4.3. Calculation of the value of sea areas at ports

4.3.1. Weight calculation and statistical test

Formulas (1) and (2) are applied for dimensionless processing of the indexes, to calculate the standard data value and to construct the standardized decision matrix for determining the value of the

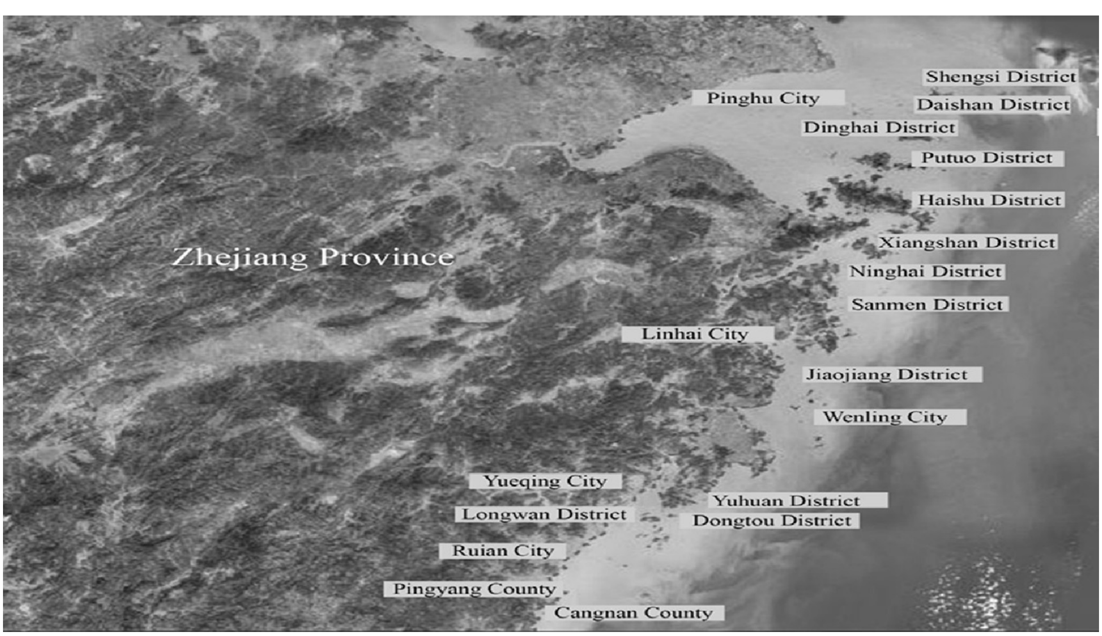

Fig. 1. Distribution of sea areas of these 19 coastal counties (cities, districts).

port transport sea area.

Using formulas (3) and (4), this paper uses SPSS to perform regression testing between the target layer and influencing factors data layer and between the influencing factors data layer and the impact factors layer, with the calculated correlation coefficient of the influencing factors and impact factor up to 0.6 or greater. These figures indicate a high level of correlation of the indexes between the target layer and the influencing factors layer as well as between the influencing factors layer and impact factors layer. The data results obtained from regression tests have statistical significance (see Table 3).

Then, apply formula (5) to calculate the comprehensive weight of the factor index. Table 4 presents the calculation results.

4.3.2. Construction of weighted decision matrix

Use formula (6) to build the weighted standardized decision matrix according to different grades of the sea area.

4.3.3. Use of the TOPSIS model for determination of the value of a sea area

Formulas (7) and (8) are used for this purpose. Based on the above analysis, we can obtain the comprehensive indexes vector value and the positive ideal solution and negative ideal solution of the sea areas of different grades in 19 coastal counties (cities, districts) in Zhejiang Province. Then, formula (9) may be used for calculating and determining the values of the port transport sea area in 19 coastal counties (cities, districts) in Zhejiang Province separately. Table 5 presents the relevant calculation results.

The “rate of increase” as indicated in Table 5 represents the percentage of value increase of the port transport sea area compared with the original charge for the use of said sea area.

4.4. Analysis of the results

i. From Table 4, the value of a sea area used for port transportation is subject to influence by four influencing factors including the development scale of the marine economy and 19 other impact factor indexes, including the rate of increase of the marine economy output. The quality index of the seawater quality negatively affects the value of the sea area; however, the other 18 impact factor indexes and four influencing factor indexes positively affect the value of the sea area. All influencing factors and impact factor indexes show different effects on the value of the port transport sea area.

With regard to the influencing factor weight (see Table 4), the weights are arranged in descending order of resource: environmental condition > developmental scale of the marine economy > level of regional social development > regional economic development status. This arrangement is consistent with the basic principle for value estimation of the sea area, namely, “the condition of the sea area and the development scale of the marine economy directly impact the value of the sea area”.

With regard to the impact factor comprehensive weight (see Table 4), the top two factors with positive influence are length of coastline, one of the factors included in the resources and environmental conditions, and rate of increase of the marine economy output, one of the factors included in the development scale of the marine economy. The length of coastline is the dominant factor influencing the capacity of cargo ships in the port transport sea area. This factor has a relatively higher weighting factor in the resource and environmental condition. Furthermore, the resource and environmental condition has the highest weighting factors among all four influencing factors; therefore, the comprehensive weights of this factor ranks first. The weighting of the influencing factor of the development scale of the marine economy is lower than that of the resource and environmental condition. However, due to the “strong marine province” strategy implemented and promoted in Zhejiang Province, the development speeds of the marine economy and marine economy output of all coastal counties (cities, districts) are continuously increasing with significant correlation. This strategy results in the dominant position of the weight of rate of increase of the marine economy output as the influencing factor of the development scale of the marine economy. Therefore, the comprehensive weight of the rate of increase of the marine economy output surpasses that of the number of berths, which ranks second.

A factor that may negatively influence the comprehensive weight is the index of seawater quality, one of the factors included in the resource and environmental conditions. This is because the index of seawater quality only reflects the extent of marine pollution. The results from a regression test of the historical data and the factor index of resources and environmental condition show a negative correlation.

ii. Comparing the value of the sea areas in coastal counties (cities, districts) as indicated in Table 5, we can find that Haishu District of Ningbo City and Longwan District of Wenzhou City have the highest values for sea areas classified as grade 2, and Cangnan County and Pingyang County have the lowest value for sea areas classified as grade 6. According to the current criteria, the fee for use of a sea area decreases from grade 2 to grade 6 (as shown in Table 1). Furthermore, the value of the sea area determined based on the multiple regression weighting TOPSIS method introduced in this paper is calculated through adjusting the fee for use of a sea area within the range of upper and lower grades based on the fee for use of a sea area of the current grade. Therefore, the values for the sea areas also decrease from grade 2 to grade 6. However, sea areas of the same grade with a good resource environment and high levels of development of the marine economy, regional economy and regional society as well as a

Table 2
Calculation indicator system for the value of the port transport sea area.

Target layer	Influencing factors (Data layer)	Impact factors (Data layer)
Value of the port transport sea area	Development scale of the marine economy (Development index of marine economy)	Growth rate of the total output value of marine economy; Coastline unit output value; Port throughput; Marine economic added value accounting for the local GDP (Gross Domestic Product) ratio.
	Development status of regional economy (Index of gross domestic product)	Gross domestic product; local fiscal revenue; investment in fixed assets of the whole society; Total retail sales of social consumer goods; Foreign trade export
	The level of regional social development (Industrial agglomeration degree)	Infrastructure improvement degree; Traffic conditions developed degree; regional employment rate; density of population; External radiation capability index; Average infrastructure construction of unit area
	Resources and environment conditions (Sea resources index)	Water quality index; number of berths; length of coastline; Marine biodiversity index

Table 3
Statistical test results.

Target layer	Influencing factors data layer	Level 1 correlation coefficient[a] (R)	Level 1 regression coefficient[b]	Impact factors data layer	Level 2 correlation coefficient[c](r)	Level 2 regression coefficient[d]
Value of the port transport sea area	Development index of marine economy	0.713	0.26	Growth rate of the total output value of marine economy;	0.86	0.64
				Coastline unit output value;		0.05
				Port throughput;		0.08
				Marine economic added value accounting for the local GDP ratio.		0.22
	Index of gross domestic product		0.17	Gross domestic product;	0.72	0.23
				Local fiscal revenue;		0.3
				Investment in fixed assets of the whole society;		0.08
				Total retail sales of social consumer goods;		0.25
				Foreign trade export;		0.04
	Industrial agglomeration degree		0.2	Infrastructure improvement degree;	0.62	0.15
				Traffic conditions developed degree;		0.28
				The regional employment rate;		0.12
				Density of population;		0.04
				External radiation capability index;		0.13
				Average infrastructure construction of unit area		0.53
	Sea resources index		0.47	Water quality index;	0.87	−0.14
				Number of berths;		0.35
				Length of coastline;		0.42
				Marine biodiversity index;		0.16

[a] Correlation coefficient of the target layer and Influencing factors data layer.
[b] Regression coefficient of the target layer and Influencing factors data layer.
[c] Correlation coefficient of the influencing factors data layer and impact factors data layer.
[d] Regression coefficient of the influencing factors data layer and impact factors data layer.

higher vector value have a relatively high value for sea areas of corresponding grades. Examples include Haishu District, with a sea area of grade 2, and Cangnan County, with a sea area of grade 6. This signifies that the multiple regression weighting TOPSIS method introduced in this paper employs a basic principle for value determination according to quality ranking of sea areas within the same grade of some counties (cities, districts).

iii. Table 5 also indicates that, through comparison of the values of the sea areas in all counties (cities, districts), the fee for use of sea areas of the same grade shows a different rate of increase.

As shown in Table 5, the value for the port transport sea area calculated using this method has witnessed an increase of more than 30% for three coastal counties (cities, districts). Ten of the coastal counties (cities, districts) have seen a value increase of 10%–30%. The value increase for all other coastal counties (cities, districts) is within 10%, with an average increase rate of 19.5%. This reflects the rule of fluctuation of the value for use of sea areas within the range of current grade and the upper grade.

5. Discussion

i. The empirical analysis shows that the advantages for the use of this method for evaluating the value for use of port transport sea areas are mainly reflected in the applicability of the evaluation method and the accuracy of the evaluation results.

First, the multiple regression weighting TOPSIS method can ensure that the calculated value will fluctuate within the range of fees for use of sea areas of upper and lower grades, and the current criteria for charging for use of sea areas have been executed for many years in 217 coastal counties (cities, districts) throughout the country. Therefore, the value evaluated by this method complies with relevant provisions for grading of relevant sea areas that were issued by the Ministry of Finance and State Oceanic Administration and can be accepted by the market. Zhejiang Provincial Oceanic Administration approved and adopted the research results of this paper in 2013 and formulated provisions relating to the value of the sea areas at ports of its seven counties (cities, districts), putting them into effect thereafter.

Second, the multiple regression weighting TOPSIS method has a solid mathematical foundation and a sophisticated calculation process. It avoids the weakness of the original subjective empowerment method, i.e., largely influenced by personal reasons, and the value calculated by this method is reliable and accurate.

ii. This research will play a very important role in three fields, as discussed below: government marine resources valuation system construction, ocean development and management, and activities of sea areas valuation.

Government marine resources valuation system construction. To accurately grasp the effects of economic and social development changes on the value of port transport sea areas, the Chinese Oceanic Administration and the Ministry of Finance could organize experts and scholars in marine management, value estimation of sea areas, economic management and so on throughout the country to revise the criteria for setting the sea area use fee in 217 coastal counties (cities, districts) every three years based on the research results of this paper. They might recalculate the criteria for setting fees for use of sea areas of the same grade in coastal counties (cities, districts) to reflect actual differences in the value of port transport sea areas and the time value of the right for using sea areas. This calculation would provide the evaluated minimum value for the marine administrative departments in 217 counties (cities, districts) when such activities as public bidding, auction and

Table 4
Weighted calculation results.

Confirmed indexes	Influencing factors weight	Impact factors weight	Comprehensive weights	Comprehensive weight ranking
Growth rate of the total output value of marine economy;	0.23	0.65	0.1495	2
Coastline unit output value;		0.05	0.0115	16
Port throughput;		0.08	0.0184	13
Marine economic added value accounting for the local GDP ratio;		0.23	0.0529	6
Gross domestic product;	0.16	0.26	0.0416	9
Local fiscal revenue;		0.33	0.0528	7
Investment in fixed assets of the whole society;		0.09	0.0144	15
Total retail sales of social consumer goods;		0.28	0.0448	8
Foreign trade exports;		0.04	0.0064	17
Infrastructure improvement degree;	0.18	0.12	0.0216	11
Traffic conditions developed degree;		0.23	0.0414	10
Regional employment rate;		0.09	0.0162	14
Density of population;		0.03	0.0054	18
External radiation capability index;		0.11	0.0198	12
Average infrastructure construction of unit area;		0.42	0.0756	4
Water quality index;	0.43	−0.13	−0.0559	Negative impact
Number of berths;		0.33	0.1419	3
Length of coastline;		0.4	0.172	1
Marine biodiversity index;		0.14	0.0602	5

transfer of the sea areas are being processed. According to the revised criteria for use fees, it is predicted that the overall sum for use of sea areas in China will increase by approximately 15%–20%.

Ocean development and management by the government. Marine environmental conditions and economic development levels greatly influence seaport value. Thus, coastal counties (cities, districts) should strengthen their environmental impact assessment systems for construction projects at coastal areas and sea areas near the ports to efficiently control pollution, strengthen restoration of shorelines, further improve the environmental conditions at port transport sea areas in coastal counties (cities, districts) and improve the sustainable contribution and use value of port transport sea areas. They should also increase their investment in research and development of the ocean so that the linkage between marine science and the marine industry will be improved, the quality of marine economic development will be enhanced and the use value of the sea areas at harbors will be promoted.

Activities of sea areas valuation. With the current evaluation practices, human factors are still overly affecting the choice of valuation indicators as well as weight determination. If the sea valuation agencies use the methods we provide in this article, those subjective factors will be avoided and assessment results will be more reliable.

6. Conclusions

Evaluating the price for using a sea area is not only a fundamental requirement for the execution of the rule for paid use of sea areas but is also an important technical basis for the promotion of the market operation of the sea area. Under the conditions of the market economy, the price can reflect the value of the sea area. In this regard, scientific theories and appropriate evaluation methods should be employed to ensure impartiality and fairness. The price evaluation process for the right to use a sea area has become very complicated because of the mobility and openness of the sea as well as the specificity of the property right. Using the multiple regression weighting model in this article, we have defined a valuation indicator system for the sea area while avoiding excessive interference from subjective factors. This system, combined with the TOPSIS technology, is engineered to support multiple objective decisions to determine the price by using the interpolation calculation model through supposing the positive ideal solution, the

Table 5
Calculation results for the values of port transport sea areas in Zhejiang Province.

Grade of the sea area	Sample areas	Value (Yuan/Hm^2)	Value increase rate	Vector value	Positive ideal solution	Negative ideal solution
Second-grade Sea	Longwan District, Wenzhou City	1950	8.30%	0.1859	0.2725	0.0965
	Haishu District, Ningbo City	2010	11.70%	0.217		
Third-grade Sea	Dinghai District, Zhoushan City	1575	31.30%	0.3861	0.5051	0.1901
	Jiaojiang District, Taizhou City	1425	18.80%	0.3091		
Fourth- grade Sea	Yueqing City	960	6.70%	0.2425	0.8314	0.0929
	Putuo District, Zhoushan City	1095	21.70%	0.5747		
	Shengsi District,Zhoushan City	1020	13.30%	0.3924		
	Yuhuan District	975	8.30%	0.2618		
	Wenling City	960	6.70%	0.2368		
	Pinghu City	975	8.30%	0.2784		
Fifth-grade Sea	Ruian City	660	10%	0.1585	0.5447	0.0478
	Dongtou District	720	20%	0.2514		
	Daishan District	825	37.50%	0.4089		
	Xiangshan District	765	27.50%	0.3181		
	Ninghai District	705	17.50%	0.2134		
	Sanmen District	645	7.50%	0.1276		
	Linhai City	690	15%	0.1853		
Sixth-grade Sea	Cangnan County	570	90%	0.1628	0.1731	0.0751
	Pingyang County	330	10%	0.0834		

negative ideal solution and the extreme interval of price. Additionally, we tested the method of valuation with empirical cases, which were significantly effective.

It is obvious that this method could provide minimum prices for oceanic administration when sea areas need transferring. It also can provide technology support for a financial department when a sea valuation system needs reconstructing as well as guidance for the oceanic administration when the policy for marine development and management needs re-enacting. Finally, this method can serve as a systematic and objective tool for sea valuation agencies. However, as investigation of the theory and research on price evaluation for use of sea areas started rather late, there are many issues to be solved, necessitating that our marine experts and scholars work together to ensure that the sea areas market operates in ways that continuously promote stable and coordinated development of the marine economy.

Acknowledgments

The authors thank the anonymous reviewers for their constructive feedback.

This work was supported by the following two funds: (1) Management and Use of Sea and Island of Zhejiang Province Ocean and Fisheries Bureau (Project No.: [2013]149) and (2) Major project of “marine science” of Zhejiang Ocean University (Project No.: 20130114).

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ocecoaman.2015.02.004.

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